



Identification and Safety Effects of Road User Related Measures

Deliverable 4.2



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Work package 4, Deliverable 4.2

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Executive summary



Safety CaUsation, Benefits and Efficiency (SafetyCube) is a European Commission supported Horizon 2020 project with the objective of developing an innovative road safety Decision Support System (DSS). The DSS will enable policy-makers and stakeholders to select and implement the most appropriate strategies, measures, and cost-effective approaches to reduce casualties of all road user types and all severities.

This document is the second deliverable (4.2) of work package 4, which is dedicated to identifying and assessing road safety measures related to road users in terms of their effectiveness. The focus of deliverable 4.2 is on the identification and assessment of countermeasures and describes the corresponding operational procedure and outcomes. Measures which intend to increase road safety of all kind of road user groups have been considered.

The following steps have been carried out:

- Identification of human related road safety measures– creation of a taxonomy
- Consultation of relevant stakeholders and outcomes of previous related projects for identification of most important human related measures
- Systematic literature search and selection of relevant studies on identified key measures
- Coding of evaluation studies
- Analysis of key measures on basis of coded studies
- Synopses of key measures

The core output of this task are synopses on road safety measures, which will also be available through the DSS. Within the synopses, each countermeasure (or group of measures) was analysed systematically on basis of scientific studies and is further assigned to one of four levels of effectiveness (marked with a colour code). Essential information of around 240 included studies was coded and will also be available in the database of the DSS.

Furthermore, the synopses contain theoretical background on the measures and are prepared in different sections with different levels of detail for an academic as well as a non-academic audience. These sections can be read independently.

It is important to note that quantifying the relationship between road user related countermeasures and road safety is a difficult task. Corresponding evaluation studies are not always assessing the impact of a countermeasure on the accident occurrence or severity but rather on alternative factors which, however, are proven or considered as relevant for road safety. The descriptive and qualitative context provided in the measures synopses is therefore important to be considered.

The analysed countermeasures were assessed as 'Green' (effective), 'Light green' (probably effective), 'Grey' (unclear results) or 'Red' (ineffective or counterproductive).

Effective	Probably effective	Unclear results	Ineffective or counterproductive
<ul style="list-style-type: none"> • Law and enforcement – General police enforcement, speeding • Law and enforcement – DUI checkpoints, selective and random breath testing • Law and enforcement – Laws and enforcement for seatbelt wearing • Fitness to drive assessment and rehabilitation – Alcohol interlock • Fitness to drive assessment and rehabilitation – Rehabilitation • Awareness raising and campaigns – Seatbelt • Law and enforcement – License suspension 	<ul style="list-style-type: none"> • Law and enforcement – BAC limits, BAC limits for novice drivers • Driver training and Licensing – Formal pre-license training, graduated driver licensing and probation • Education and voluntary trainings and programmes – Child pedestrians • Awareness raising and campaigns – Aggressive and inconsiderate behaviour • Awareness raising and campaigns – Campaigns in general • Awareness raising and campaigns – Child restraint • Awareness raising and campaigns – Speeding and inappropriate speed • Awareness raising and campaigns – Driving under the influence • Law and enforcement – Increasing traffic fines • Law and enforcement – Hours of service regulations for commercial drivers • Law and enforcement – Demerit point systems • Law and enforcement – Red light cameras • Fitness to drive assessment and rehabilitation – Medical referrals 	<ul style="list-style-type: none"> • Law and enforcement – Laws and enforcement for mobile phone use (handheld, hands-free) • Education – None statutory training for novice drivers 	<ul style="list-style-type: none"> • Fitness to drive assessment and rehabilitation – Age-based screening of elderly drivers

1 Introduction



1.1 SAFETYCUBE

Safety CaUsation, Benefits and Efficiency (SafetyCube) is a European Commission supported Horizon 2020 project with the objective of developing an innovative road safety Decision Support System (DSS) that will enable policy-makers and stakeholders to select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties of all road user types and all severities.

SafetyCube aims to:

1. develop new analysis methods for (a) Priority setting, (b) Evaluating the effectiveness of measures (c) Monitoring serious injuries and assessing their socio-economic costs (d) Cost-benefit analysis taking account of human and material costs
2. apply these methods to safety data to identify the key accident causation mechanisms, risk factors and the most cost-effective measures for fatally and seriously injured casualties
3. develop an operational framework to ensure the project facilities can be accessed and updated beyond the completion of SafetyCube
4. enhance the European Road Safety Observatory and work with road safety stakeholders to ensure the results of the project can be implemented as widely as possible

The core of the project is a comprehensive analysis of accident risks and the effectiveness and cost-benefit of safety measures focusing on road users, infrastructure, vehicles and injuries framed within a systems approach with road safety stakeholders at the national level, EU and beyond having involvement at all stages.

Work Package 4

The objective of work package 4 is to analyse data, implement developed methodologies (WP3) concerning accident risk factors and road safety measures related to the road users. It examines accident risks and safety measures concerning all types of road users including Vulnerable Road Users (VRU). Personal as well as commercial transportation aspects are taken into account. Therefore, various data sources (macroscopic and in-depth accident data) and knowledge bases (e.g. existing studies) will be exploited in order to:

- identify and rank risk factors related to the road use
- identify road user related measures which address the most important risk factors
- assess the effect of measures

The work on human related risks and measures in road traffic is done according to the methodologies and guidelines developed in WP3 (Martensen et al., 2017) and uniform and in parallel with the work packages dealing with infrastructure (WP5) and vehicle (WP6) related risks and measures. Furthermore, the latter process is monitored and steered by WP8.

All main results of WP4 will be integrated into the DSS and linked with each other (risk factors and measures) and with outcomes of other work packages (WPs 5, 6, and 7¹).

¹ WP7 is dealing with serious injuries.

1.2 PURPOSE OF THIS DELIVERABLE

This deliverable reports on the work in task 4.2, which aims at identifying key road safety measures focusing on road users – in contrast to measures targeting road infrastructure or vehicles. A further aim of this task was to evaluate these measures in terms of their safety effects based on scientific evidence.

All considered measures seek to change human risk behaviour (or attitudes etc.) or mitigate personal risk factors. Therefore, an overview of the most relevant psychological models and theories on human behaviour and its potential for modification is given as a preface. Furthermore, this deliverable functions as a documentation of all steps taken in process of identifying and assessing the road safety measures which are listed in chapter 5. This process comprises the following steps, taken in order to achieve the common purpose of SafetyCube:

- Identification of human related road safety measures and creation of a corresponding taxonomy
- Consultation of relevant stakeholders for 'hot topic' identification
- Systematic literature search and selection of relevant studies on identified measures
- Coding of studies
- Analysis of safety effects of measures on basis of coded studies
- Synopses of safety effects of measures

The main result of deliverable 4.2 is a variety of systematically analysed road safety measures, which focus on road users, documented in 'synopses'. Information from coded studies as well as synopses will be incorporated into and made available through Safety Cube's Decision Support System (DSS): <http://www.roadsafety-dss.eu/>. As the synopses are very comprehensive documents, they form individual documents and are also appended to this deliverable.

It is crucial to note that the overall approach of SafetyCube – to quantify risk factors and assess measures quantitatively – is challenging to apply when human decision making and behaviour come into play and has to be interpreted within provided context.

The presence or absence of some risk factors such as fatigue is not absolute but rather a (temporary) state on a continuum. Then again, some risk factors are not directly observable (e.g. personality) and can never be completely and objectively determined.

The effectiveness of road user measures in terms of crash reduction is difficult to ascertain since there are many intermediary factors, which have to be controlled for. Thus, many studies evaluating the safety effects of measures use alternative outcome variable, which are known or assumed to be linked to safe behaviour or accident occurrence, respectively, such as attitudes, psychological diagnostic tests or performance in a driving simulator. Furthermore, road safety measures are not always implemented separately but in a set of measures. This further complicates the assessment of the question to which extent a change can be attributed to a single measure component.

Taking all this into account makes it vital to provide qualitative information for each risk factor or road safety measure alongside the quantitative assessment.

2 How road safety measures affect behaviour

Most road user related measures aim at establishing and influencing behaviour towards safe behaviour in road traffic. As human behaviour is complex and a multitude of factors and interactions shape behaviour, theories can help to understand specific actions of road users. Psychological theories and models describe which factors should be considered, explain relationships between the single factors and give an indication about how behaviour can be modified. Models can be used both to generate countermeasures and for evaluating measures (Shinar, 2007).

"A valid theory or model of human behaviour enables us not only to understand why we behave on road the way we do, but also to predict driver's reaction to many potential safety measures" (Shinar, 2007, 54). Depending on the focus of a measure, specific models can be applied, explaining among others perceptual, attentional, cognitive, social, motivational and emotional determinants of road user behaviour. In the following paragraphs, some of the most common theories and models, which are used for explaining road user behaviour and are applied for generating human related road safety measures, are presented.

The **Theory of Planned Behaviour (TPB)** (Ajzen, 1988) is one of the leading theories used for explaining risky behaviour or violations in traffic and is also applied frequently to designing campaigns and educational measures. This theory focuses on decision making to carry out a certain behaviour considering e.g. the social context. According to the TPB, the intention for a behaviour is based on the combination of three factors: attitudes toward the behaviour, subjective norms and perceived behavioural control. The intention then again is the strongest predictor of the actual behaviour. An example for a favourable road safety attitude can be: "Helmets can protect me in case of an accident". Subjective norms represent the assumed expectations of others towards the intended behaviour and motivation to behave respectively e.g., "others wear helmets and it's trendy". The perceived behavioural control can be described as the individual perception of one's ability to perform the intended behaviour e.g. "I have a helmet which fits and I know how to use it correctly." Over time, the TPB was extended with several factors including habit, motions, and descriptive norms.

Rehabilitation measures such as driver improvement courses are often based on the **Transtheoretical Model of Change (TMC)** (Prochaska, 2007). This model explains the process of behavioural modifications. If a new behaviour should be adapted by an individual, five different stages have to be passed: pre-contemplation, contemplation, preparation, action and maintenance. In the pre-contemplation phase, the person has no intention to change the behaviour. If a person starts to think about the problem (e.g. inspired by relevant information) and is willing to change something, the next stage is entered. After that, concrete possibilities for change are considered and tried out. In the phase of action, relevant new behaviours are practiced, but the risk is still high to return to previous behavioural patterns. If the new acquired actions turn into a habit, the stage of maintenance is reached. The strength of this model is that interventions can be set according to the phase an individual is situated in.

Schlag et al. (2012) address the question why and in which situation rules are violated and summarises psychological theories and findings in a **Model of traffic rule compliance**. The authors distinguish between internal and external motivation for rule compliance. If individuals are internally motivated they are convinced about the meaningfulness of a rule like *not drinking while driving* and behave according to the rule even if the situation does not have favourable conditions for obeying it.

In contrast, external motivation relies on perceived consequences of non-compliance and correct behaviour is shown to avoid penalties and fines. If the subjective feeling of being caught is low, the rule compliance decreases. Furthermore, if an offence is committed several times without negative consequence (e.g. fines) habits of non-compliance can be established like driving over the speed limit. Changes in informal social norms can support internally motivated rule compliance (e.g. zero tolerance of drink-driving).

Learning theories and risk models can be used for designing driver training since driving skills, knowledge and raising awareness of risks are taught. The model of Hatakka et al. (2002) known as the Gadget-Matrix, divides the driving task and behaviour into four hierarchical levels and important elements for driving education are identified. The highest level concerns general life goals e.g. the relevance of driving and the vehicle for the driver. Goals and the context of the drive such as planning the journey or social environment form the next level. The other levels are linked to the adaption to specific driving situation like choosing appropriate speed for the situation and the skills for handling the vehicle.

Enforcement can be based on the **Deterrence theory** and **classical learning theories** on conditioning and reinforcement. According to the deterrence theory individuals will avoid offending behaviour if they fear the perceived consequences. Furthermore, the likelihood of apprehension and the severity and the swiftness of the penalty influences behaviour. If the risk of apprehension is high and the penalty sufficiently severe then the effect of deterrence will be high (SWOV, 2013). In addition, learning theories show that the more consistent and intense enforcement is, the greater the rate of compliance. Immediate feedback to the behaviour has more effect than one delayed in time (Shinar, 2007).

3 Identification and prioritisation of measures



3.1 CREATING A TAXONOMY OF HUMAN RELATED ROAD SAFETY MEASURES

Analogous to task 4.1, as a first step road safety measures focusing on road users had to be collected and systematised in a taxonomy in order to further determine 'key measures' alongside various criteria such as previously identified risk factors or stakeholders' priorities.

The initial approach to generate a comprehensive list of road user measures was to collect measures for each of the considered risk factors and continuously expand this list – based on the expertise of the consortium. For further completion, the starting point (risk factors in the first place) was altered to measures per road user group and per type of measure such as 'law and enforcement' or 'rehabilitation'. As Vulnerable Road Users (VRU) are of special interest to the SafetyCube project, all different kinds of road user groups were considered as the taxonomy was created. Dependent on the measure type VRU are included on different levels of the taxonomy or in the corresponding synopses, respectively.

While different approaches were tested, it was decided to structure the taxonomy based on measure types, which resulted in five global categories, similar to the categorisation used in the project 'Supreme' (van Schagen & Machata, 2010):

1. Law and enforcement
2. Education and voluntary training
3. Driver training and licensing
4. Fitness to drive assessment and rehabilitation
5. Awareness raising and campaigns

A more detailed description of each of these measure categories is provided subsequently. The full taxonomy can be found in appendix A. It has to be noted that the taxonomy is not exhaustive. Some of the road safety measures are not distinctly relatable to any of the three SafetyCube topics: human, infrastructure and vehicle. For example, at first glance alcohol ignition locks can be associated with the vehicle, but, as a rehabilitation measure, it is not built-in by the manufacturer in the first place but installed later and used only for the specific time of the measure.

3.1.1 Law and enforcement

Within a safe system approach, traffic law enforcement is one of the instruments to secure or improve traffic law compliance. 'Traffic law enforcement' covers the entire penal procedure designed to persuade road users to behave safely and to obey traffic laws and regulations: i.e. surveillance, the process of law and the imposition of penalties. The narrower concept of 'Police enforcement' refers to the actual work of detecting a traffic law violation, apprehending the offender, and securing the evidence needed for his prosecution. In general, police enforcement can only be effective if it operates in a supportive physical and social environment of road design, laws, regulations, safe traffic culture, and a sensitive penal system. Consequently, the effectiveness of police enforcement cannot be seen in isolation from how the enforcement actions are supported by road characteristics, communication with road users, fair and effective penalties, and from how the

police collaborate with the other parties in the traffic law enforcement chain (road authority, courts).

Basically, in line with the definition above the three basic building blocks of traffic law enforcement are:

1. The introduction of new laws, or revision of existing laws, to set up a system of incentives/disincentives able to induce a safer traffic behaviour
2. The actual enforcement of the laws or rules by man-made checks or by automatic control (e.g. enforcement cameras)
3. The punishment of offenders by different types of sanctions

In developing a taxonomy for studies on traffic law enforcement, the emphasis was on finding research within the three basic categories that are the basic building blocks of traffic law enforcement, namely 1. Laws, 2. Enforcement, 3. Sanctions. Based on both expert opinion, earlier reviews, and on preliminary literature searches it was found that for each of these three categories/components there were a number of topics that generated international research interest and that should be included for further review and analysis in the SafetyCube WP 4 framework.

For the component 'Laws' the most studied research topics included the following: Laws regulating the use of protective equipment (seat belt, helmet, child restraints, protective clothing), laws regulating different types of impaired driving (lowering BAC limits, BAC limits for specific groups) and laws for professional drivers (e.g. hours of service laws for professional drivers). For the component of 'Police enforcement' (actions and methods) most of the enforcement studies centred on the enforcement of eight specific violations namely drinking and driving, drugged driving, aggressive driving, speeding, red light running, distracted driving, not wearing seat belts, and mobile phone use while driving. For the category 'Sanctions' there were two specific research topics, the effects of increasing traffic fines/penalties and the effects of introducing demerit point systems, also labelled as 'non-monetary sanctions'. Thus the more than 20 specific countermeasures reviewed within the SafetyCube WP 4 framework pertain to the three main links in the total chain of traffic law enforcement, covering: Law (BAC limits, seat belt laws, child restraints laws, helmet wearing laws, mobile phone use laws), enforcement actions and method (red light cameras, enforcement of speeding, enforcement of the seatbelt use, DUI checkpoints, drugged driving enforcement, mobile phone use enforcement, aggressive driving enforcement) and sanctions (demerit point systems, increased penalties). To be noted that the synopsis helmet wearing laws will be included in the DSS at a later date.

3.1.2 Education and voluntary training

Education and Voluntary Training (EVT) refers to any education program or training scheme that aims to increase safe road user behaviour. This can take a wide variety of forms including: practical real world training, training in a simulator or simulated environment, and classroom based education. The aim of this topic was to examine whether gaining knowledge and learning/practicing new skills can change behaviour and ultimately reduce collisions. The links between knowledge, attitudes and behaviour are complex (also see chapter 2) and the best quality studies are those, which assess actual behaviour rather than self-reported. The majority of studies falling under this topic examine behaviour change not road traffic collisions; so, it is even more difficult to assess how behaviour change influences the likelihood of being involved in a collision.

This topic has overlaps with both 'Driver training and licencing' and 'Awareness raising and campaigns'. If the training is optional then it belongs to the EVT- topic – if it is a mandatory part of initial licencing or graduate driver programmes then it falls into 'Driver training and licencing'. The overlap with 'Awareness raising and campaigns' is most apparent in more general educational schemes aimed to be delivered within schools or those that employ techniques such providing

information leaflets. Generally speaking, if the education/training was school based then it falls into the EVT-topic but if the only educational content was producing items such as leaflets or other educational materials then the study falls into the topic of 'Awareness raising and campaigns'.

The EVT topic is divided by road user age and experience and then further subdivided by individual transport mode (see appendix A). The term 'general road safety' was used as a catch all when studies did not fit into individual categories. This is a very broad topic and many potential studies were identified. Two synopses have been produced for EVT focusing on child pedestrian skills (primarily school based) and training for novice/young drivers. Studies have also been coded relating to child/adolescent cycling skills training and trainings for elderly and will appear in the first public release of the DSS but the synopses will be written at a later date. Papers on the topics general road safety education programmes aimed at adolescents and hazard perception will be coded and synopses are planned. Additional synopses that are not included in this report and the associated studies will appear in the final release version(s) of the DSS.

3.1.3 Driver training and licencing

Young drivers are disproportionately represented in motor vehicle collisions. Graduated driver licencing (GDL) programs and probationary license were progressively introduced in several countries worldwide since the early 1970s in order to reduce fatal crashes and high-risk behaviour of teen drivers. Most formal pre-license training (FPLT) focuses on teaching procedural skills related to vehicle control. They cover many formats, including professional driving instruction and school-based driver education. The graduated driver licencing (GDL) is a licencing system designed to provide learners with driving experience and skills gradually over time in low-risk environments by restricting night-time driving, carrying passengers, expressway, and unsupervised driving during initial stages. Reasonable amounts of studies were found on graduated driver licencing and on formal pre-license trainings, which were mostly from the United States and some from Europe and Oceania. The effect of GDL on road safety is usually measured as a change between before and after the GDL implementation in crash rate, crash involvement, or crash incidence. Regarding the effect of FPLT, it can be measured as a difference in driving performance between drivers who did not complete the same training.

Health requirements for the initial registration of the driving license are often not defined and the current health status of a candidate for the initial application for a driver's license is mostly not examined. The most frequent health requirement is a vision test of which there are various types of tests in place in different countries. Many studies describe the influence of certain diseases (e.g. Alzheimer's, diabetes, cognitive impairment) on fitness to drive, however these are often age related diseases and thus are not relevant for a candidate for the initial application for a driver's license. Furthermore, the studies often result into variation of personal performance such as reaction times or perceptual speed; however, the effect on road safety and on crash frequency is not available in literature.

When it comes to the required age for the initial registration most studies investigate the effect of graduated licencing and not many studies address the matter of required age for licencing in isolation and how changes to this age affect the accident and fatality rates. Studies on young teen-age drivers reveal that the characteristics and causes of accidents with young drivers are different from those of older drivers. There are findings in the scientific literature suggesting that 16-year-olds are more likely than older teenagers to be in single-vehicle crashes, to speed, to have many passengers (especially other teenagers) in their vehicles, and to be responsible for their crash.

Studies have shown that one of the largest contributing factors to the crash risk of novice drivers is the lack of experience manifesting itself in a shift of attention from the traffic environment to the primary driving tasks (e.g. how to change gears). Here the programs of accompanied/supervised driving prove beneficial by the fact that the learner can gain experience under mandatory

supervision by an experienced driver (often parents) for a certain period before driving alone. Accompanied driving is often a part of graduated driver licensing applied together with other aspects for beginner drivers such as restricted driving time (e.g., night-time driving restrictions) or passenger restrictions allowing only one teenage passenger. Some studies analysing the sole effect of accompanied driving indicate that accompanied driving has a significant effect on crash risk reduction on young novice drivers. To be noted that the synopses health requirements and required age for the initial registration and will be included in the DSS at a later date.

3.1.4 Fitness to drive assessment and rehabilitation

Fitness to drive assessment differs from the assessment of driving abilities in the sense that its subject is not so much the procedural and theoretical knowledge that is necessary to participate in traffic (i.e. conducting a vehicle, knowing traffic rules) but the general suitability of a person to apply this knowledge in a continuous and responsible way. The implementation of diagnostic tools to test the fitness to drive is a precondition for taking appropriate measures if this fitness is impaired.

Two major groups of reasons why a person's fitness to drive can be doubted were addressed: because of their health condition and because of earlier offenses (in particular drunk driving). In the case of medical conditions, the focus was on diagnostic tools to establish the fitness to drive. Two practices can be differentiated here: diagnostic of medical referrals and age-based screening. Medical referrals are drivers with a medical condition, which give rise to doubts whether they can still drive safely. In the synopsis "Fitness to drive diagnostic of medical referrals", it is described how the assessment should be tailored to the medical condition that caused the concern for their fitness to drive. Furthermore, the main diagnostic tools and their evaluation in terms of sensitivity (detecting unfitness to drive if this is the case) and specificity (not causing "false alarms" for persons who are really fit to drive) are described.

A group of particular concern for fitness to drive assessment are elderly drivers, as old-age is often accompanied by a certain decline of cognitive and motoric functions that are considered important or even vital for driving (e.g. perception, reaction time in decision making, flexible movements of the head, etc.). Moreover, older persons are more often subject to medical conditions that bear a risk for driving (e.g. dementia, Parkinson's disease, diabetes). Based on these observations, in many countries drivers are routinely screened for fitness to drive from a particular age on (independent of their health status). The pros and cons of this practice as well as the results of evaluation studies will be discussed in the synopsis "Age based fitness to drive assessment".

For the group of offenders, the focus was on drink driving offenders and on rehabilitation measures. The most important rehabilitation measures for drink-driving offenders are alcohol interlock and rehabilitation courses as alternative punishment. The synopsis "Rehabilitation courses as alternative punishment for drink-driving offenders" gives an overview of purpose and types of rehabilitation courses as well as an evaluation of the effectiveness of such courses to prevent recidivism (i.e. being caught drink-driving again). The synopsis "Alcohol interlock" contains two parts. The first is a technical part that evaluates alcohol interlocks as a vehicle measure and the second focuses on the behaviour of the road user. Alcohol interlocks as a vehicle measure focuses on the ability to prevent a driver under the influence to start his/her car, and the behavioural part focuses on the prevention effect of alcohol interlocks and evaluates their capability of preventing drink-driving in two periods: a.) while the interlock is installed and b.) after the interlock has been removed.

3.1.5 Awareness raising and campaigns

Road safety communication campaigns aim at informing, persuading and motivating people to change attitudes, beliefs and behaviour and, eventually, at improving road safety. Campaigns are –

as recommended – often implemented jointly with other road safety measures like enhanced enforcement or to support another introduced road safety measure, e.g. to promote changes in legislation. Boundaries are also often overlapping with education programmes. Whether or not campaigns as a stand-alone measure is yielding effects or only with (or as) a supporting measure is subject of ongoing discussions.

While designing campaigns for the purpose of informing road users is straightforward, modifying actual problem behaviour is more challenging and less immediate. In many cases, risk awareness is insufficient to shape behaviour as human acts are not always a result of reason and conscious decision-making. However, campaigns can shape the “mediators” in cognition, in particular knowledge, awareness, attitudes, beliefs, values and perceived norm (see also chapter 2).

Some road safety measures produce immediate effects on behaviour, such as police patrolling. By contrast, campaigns are designed to have an effect after one is exposed to it several times ('constant dripping wears the stone'). Since there is no simple stimulus response mechanism for campaigns and multi-layered impact factors are involved, it is challenging to validly and reliably measure its effectiveness. Furthermore, it is hard to attribute directly a change in accident occurrence to a campaign. Consequently, it is all the more important to define clearly the aim and target group of a campaign and to apply a sophisticated evaluation design before implementing awareness raising measures. A major opportunity for road safety campaigns, however, is to change the narrative of road users in the long run by e.g. focusing on positive, model behaviour to beneficially change the perceived norm towards a stronger road safety culture. What is widely missing is research on the medium- and long-term effects of various awareness raising measures and campaigns.

For the measures category 'awareness raising and campaigns' it was decided to create six single synopses: one very general on the effectiveness and five for the specific topics of speeding, driving under the influence, aggressive behaviour, child restraint and seat belt use. This approach is a result of the number of studies identified for individual topics. For some themes, such as distraction, not enough campaign evaluations are currently available.

3.2 HOT TOPICS AND PRIORITIES IN ROAD SAFETY

Since a fully exhaustive list of evaluated human related countermeasures cannot be provided, certain topics had to be prioritised over others. For one thing, it is important to provide information on the effectiveness of measures, which are tackling risk factors identified in the previous step - independently from the origin of the risk factor (human, infrastructure or vehicle). However, the vast majority of human related measures also addresses human related risk factors. Secondly, it had to be ensured that measures that future DSS users are interested in are considered and presented in the DSS.

3.2.1 Processing of stakeholders' input and policy and research outcomes

For the purpose of presenting mid-term results and receiving additional input, a further SafetyCube stakeholder workshop was held in September 2016 in Brussels (a list of participants can be found in the appendix D). This occasion was used to consult the various participants on their priorities with respect to road safety measures that target the road users. Stakeholders were asked to complete a questionnaire (see appendix B) where they could indicate the most important human related road safety measures in their view for the risk factors speeding, DUI, fatigue, distraction, cognitive impairments, aggression, non-use of safety devices such as helmets. The measure categories provided were 'law and enforcement', 'education, training, licensing, diagnostics and rehabilitation', 'awareness raising' and 'others'. In total, information from 14 surveys was analysed in a simple count mode of statements.

Overall, the most nominations were made for awareness raising and law and enforcement measures. However, the answers were more concrete for the latter (e.g. stricter laws for recidivists, salary linked fines or more dense police controls). For awareness raising, the input from stakeholders was rather global and vague such as 'campaigns in general' or 'focus on social norms'. By trend, this was also the case for measures related to education, training, licensing, diagnostics and rehabilitation, where surveyed stakeholders indicated e.g. 'education in schools' or 'feedback on driving behaviour'. The most suggestions for measures were made for the risk factors speeding and drink-driving. Almost a fifth of all nominations are not human related measures but are referring to the vehicle or infrastructure categories (e.g. ISA, section control).

The list of measures collected was then used to check whether the taxonomy covers the stakeholders' needs regarding human centred road safety measures. All statements from surveyed workshop participants can be found in appendix C.

3.2.2 Vulnerable road users

In the process of first literature searches and establishing a taxonomy of measures, vulnerable road users were considered within each of the five global measures categories. Dependent on the availability and number of evaluation studies, the road user or age group is included in the measure labels on the second or third level of the taxonomy as appropriate. However, it was not useful for all types of measures to differentiate explicitly by each road user group.

4 Study selection and coding



4.1 LITERATURE SEARCH AND STUDY SELECTION

The aim was to collect information on studies dealing with the effectiveness of road safety measures in a uniform manner (as far as possible). Therefore, a standard methodology was developed by WP3 that has already been applied to task 4.1 which dealt with the effect of risk factors. This included a literature search strategy, a coding scheme to record key data and metadata from individual studies and guidelines for summarising the findings per countermeasure. Copies of these documents and the associated instructions and guidelines can be found in Martensen et al. (2017). While focusing on measures the methodology was slightly adapted and supplemented in order to suit the measure topics.

4.2 LITERATURE SEARCH

For each of the identified and selected measure topics a standardised literature search was conducted in order to identify relevant studies to be included in the DSS and to form a basis for a concluding summary (synopsis) and further analyses. A standardised procedure was developed in WP3 and applied for each examined measure in SafetyCube (within WPs 4, 5, 6, 7). The closer look at each countermeasure in terms of literature search resulted in the need for adaptations of the corresponding taxonomy, especially on the second and third, more detailed levels. The literature search was documented according to the Guidelines of WP3 in a standard template to make the gradual reduction of relevant studies transparent. This documentation of each search is included in the corresponding supporting documents of the synopses (see Appendix E). The databases used for literature search in WP4 were the following:

- Scopus
- TRID
- Web of Science
- Science Direct
- Dok Dat²
- PubMed
- Google Scholar

4.3 STUDY SELECTION

Accident counts versus Safety Performance Indicators as Outcome

The initial aim was to find studies that provided an estimate of the effectiveness of road user measures in terms of accident reduction – since this is the primary aim of road safety work. These kind of evaluation studies are, however, rarely available since there are many factors influencing accident occurrence that often cannot be controlled for in evaluation designs. This is especially the case for measures, which target the road users in contrast to infrastructure or the vehicle. Thus, studies investigating the effect of measures on alternative outcomes, which are proven or assumed to have a safety effect, are also considered, coded and made available via the Road Safety DSS. These outcomes can be:

- Self-reported accident history

² Internal database of Austrian Road Safety Board

- Risk behaviours such as speeding or drink-driving (observed, self-reported, official records)
- Driving performance (observed, experiment)
- Results of psychological diagnostic tests
- Intended behaviour
- Attitudes, beliefs, perceived norm

Psychological constructs such as attitudes and intentions can be used given that a link between attitudes and behaviour has been established by psychological theory (see also chapter 2). These indicators (intentions, attitudes, etc.) are often used to test the impacts of, for example, campaigns (e.g. their effect on safe behaviour). When considering road user related risks and related measures, it is especially important to have also a look at studies that report on constructs as self-reported behaviour or cognitive diagnostic measures. This is because the presence of a human related risk factor in an accident is far less easy to determine than the presence or absence of a safety feature in a vehicle or the presence or absence of an infrastructural element. However, if the effect of a measure is determined by these mediated factors it should be noted that this is an indirect measurement.

Studies have been considered which either assess the effect of a road safety measure on accidents (fatal, injured, material damage) or on one or several alternative road safety indicators.

4.4 STUDY CODING

With the aim of creating a database of estimates of risk factors and safety effects of road safety measures, a template was developed (WP3) that determined what information per study should be provided and offered the opportunity to report this information uniformly across topics and WPs. Guidelines were also made available for the task of coding with detailed instructions on how to use the template. The design of the coding template accommodates the variety and complexity of different study designs.

The following information is provided per study and will also be retrievable in the DSS:

- Road system element (road user, infrastructure, vehicle) and level of taxonomy so that users of the DSS will be able to find information on topics they are interested in
- Basic information on the study (title, author, year, source, origin, abstract etc.)
- Road user group examined
- Study design
- Variable(s) of exposure to the countermeasure
- Outcome variable (e.g. number of injury crashes)
- Type of effects
- Effects (including corresponding measures such as confidence intervals)
- Biases
- Summary

For the full list of information provided per study, see Martensen et al. (2017). Completed coding files were uploaded to the web-based DSS. In total, around 240 studies on human related road safety measures have been coded within WP4.

Quality control for coding and analyses

An internal review process has been established within WP8 in order to assure quality of the study coding and summarizing effects in synopses. This procedure, which is uniform across operative WPs (road users, vehicle, infrastructure and serious injuries), is explained in the methodology description in the DSS.

5 Analysis and summary



This chapter describes how the information from the coded studies and additional in-depth crash data was analysed and summarised. For many countermeasures, this analysis and summary will be available through the DSS in the form of a measure 'synopsis'. The audience of the synopses will be varied – both academic and non-academic stakeholders e.g. policy makers. Thus, synopses are structured in different sections, for different target groups, that can be read independently.

The DSS will provide information for all coded studies (see above) for various road safety risk factors and measures. The synthesis of these studies will also be available, in terms of a 'synopsis' indicating the main findings for a particular measure derived from meta-analyses or another type of comprehensive synthesis of the results (e.g. vote-count table).

Synopses were created for key measures on different levels of the taxonomy, thus, for different levels of detail. Whether a synopsis was created for the first, second, or third level of the taxonomy was decided during the task of searching literature by the responsible partner, mainly dependent on the availability of studies for a certain topic. Moreover, the synopses contain context information for each measure from literature that could not be coded (e.g. literature reviews or qualitative studies). On the other hand, not all the coded studies that will populate the DSS are included in the analysis documented in the synopses. Synopses, which were available by June 2017, can be found in appendix E.

The synopses aim to facilitate different end users: decision-makers looking for global estimates vs. scientific users interested in result and methodological details. Therefore, the synopses contain sections for different end user groups that can be read independently. Moreover, the structure of the synopses is differentiated into three distinct parts:

- a. **Summary:** A two-page document reporting the key aspects of the topic, the main results, and transferability conditions. This part addresses users, who need a short overview of the topic and the main results, such as policy makers.
- b. **Scientific overview:** A four to five page document including a short synthesis of the literature, an overview of the available studies, a description of the analysis methods, and an analysis of the effects. This section aims to describe the way the reported effects have been estimated, with a full analysis of the methods and results, in order to give the user all the necessary information to understand the results and assess their validity.
- c. **Supporting document:** This section describes the literature search, compares the available studies in detail (optional) etc. It aims to provide the most detailed information for the scientific reader and interested user (no initial page limit).

A colour code was assigned to each synopsis. The colours (green, light green, grey and red) indicate how effective the countermeasure is concerning road safety (see also chapter 6.1).

5.1 LAW AND ENFORCEMENT

5.1.1 General police enforcement, speeding

Colour code: **Green**

The effects of speed enforcement are mostly positive in reducing crash frequency, mean vehicle speed and the proportion of drivers exceeding the speed limit. Furthermore, the coded studies encompass several topics and have good levels of quality and consistency. For the reasons mentioned above, the overall impact of speed enforcement is characterized as green (effective).

Abstract

Speed enforcement aims to prevent drivers exceeding the speed limit by penalizing those who do. Therefore, speed enforcement affects the level of road safety, causing a reduction in crash frequency, in mean vehicle speed and in the number of vehicles travelling over the posted speed limit. Seven high quality studies involving various speed enforcement measures were coded. On the basis of both studies and effect numbers, it can be argued that speed enforcement creates positive impacts on road safety. However, there were isolated cases that reported different results.

5.1.2 DUI checkpoints/Selective & Random Breath testing

Colour code: **Green**

The effects of introducing or increasing alcohol-related enforcement actions are mostly positive in reducing crash frequency in general, and alcohol-related fatal accidents in particular. Enforcement, together with laws limiting alcohol concentration, has a deterrent power, discouraging offences. Furthermore, the coded studies exhibit high levels of quality and consistency. For the reasons mentioned above, the overall impact of driving under the influence (DUI) checkpoints and random breath tests is characterized as green (effective).

Abstract

DUI checkpoints and random breath tests are enforcement measures implemented in order to discourage people from driving after drinking. Drivers are tested in order to investigate whether their blood alcohol concentration (BAC) is higher than the legal limit. The implementation of these measures affects the level of road safety, causing a reduction in the number of crashes. Five high quality studies focusing on sobriety checkpoints were coded. On the basis of both study and effect numbers, it can be argued that implementing DUI checkpoints and random breath tests have positive impacts on road safety.

5.1.3 Seatbelt wearing

Colour code: **Green**

On the basis of the existing literature, the law mandating the use of seatbelts, and related enforcement activities, produce positive effects on road safety. In combination, they are particularly effective. In general, it can be observed that an increase in seatbelt use reduces/mitigates road safety risk, and reduces the number of fatalities and severe injuries.

Abstract

Seat belt legislation aims at establishing a system of incentives/ disincentives for road vehicle users, to induce safer traffic behaviour as a result of using this type of protective equipment. The discipline is heterogeneous, as countries or states can address user categories differently (e.g. front seat occupants, rear seat occupants). Law enforcement dictates the way to secure or improve traffic law compliance and it refers both to the surveillance activity and the imposition of penalties. In the

United States (examined by most of the studies) the distinction between Primary and Secondary Enforcement Law is significant. The secondary measures allow police to punish the omitted seatbelt use “per se”, without requiring the coexistence of other types of violations, and thus produces the best road safety results. The existence of seatbelt legislation, sustained by the enforcement activities, induces a significant safety improvement in the behaviour of road users. This improvement can be seen in terms of seatbelt usage, which is also linked to a decrease in the number of fatalities and a mitigation of injury severity.

5.1.4 BAC limits/BAC limits for novice drivers

Colour code: **Light Green**

The effects of laws introducing BAC limits are mostly positive in reducing crash frequency and reducing especially the number of mainly alcohol-related fatal/injury accidents. The per-se law, together with enforcement and other DWI laws, has a deterrent power that discourages offences. Furthermore, the coded studies have some good levels of quality and consistency. On the other hand, many studies showed no effect on road safety and two studies indicated an increase of fatal crashes. For the reasons mentioned above, the overall impact of BAC laws is characterized as light green (effective).

Abstract

Laws limiting blood alcohol concentration have been introduced worldwide in order to diminish the frequency of alcohol-related fatal/injury crashes. These laws (and their implementation) aim to discourage drivers from drinking and driving. Zero tolerance laws were introduced for young drivers, in order to address the issue of driving while impaired among inexperienced drivers. The implementation of these laws, either alone or combined with other DWI laws and enforcement, affects the level of road safety and causes a reduction in the number of crashes. Ten high quality studies involving lowering BAC limits were coded. On the basis of both study and effect numbers, it can be argued that limiting BAC for drivers create positive impacts on road safety. However, some scarce cases reported opposite results, indicating increases in total crashes.

5.1.5 Mobile phone use (handheld/hands-free)

Colour code: **Grey**

The effects of implementing laws and increasing enforcement against mobile phone use while driving are mixed. To date, studies have shown positive, positive without statistical evaluation, non-significant and even negative effects. Currently, as there is only some indication of effectiveness the overall impact of laws and enforcement is characterized as grey.

Abstract

Laws and enforcement against mobile phone use while driving are widely used as safety measures to prevent drivers from talking, texting or dialling while driving. In that context, fifteen high quality studies were coded. In general, there is some indication that laws and enforcement have a positive impact on road safety and most specifically on self-reported and observed mobile phone use while driving. However, in a number of studies, statistical evaluation is absent and some other studies indicate non-significant and even negative effects. Meta-analyses showed a negative effect of laws on drivers' mobile phone use and furthermore, there is no evidence of a reduction in crashes or fatalities. Consequently, on a basis of both study and effect numbers, it can be argued that the evidence for a road safety effect of laws and enforcement against mobile phone use is far from conclusive. This topic needs further investigation and statistical evaluation.

5.1.6 Increasing traffic fines

Colour code: **Light Green**

There is evidence that higher fines are associated with less traffic violations, but effects may be limited in time and place. Therefore, this measure is considered as probably effective (light green).

Abstract

Penalties for traffic violations, e.g. in the form of fines, are part of the traffic law enforcement chain. According to deterrence theory, a sufficiently high chance of detection of a violation and a sufficiently high penalty will deter road users from committing traffic violations. This synopsis describes the effects of fine increase on several road safety indicators. Studies on fines and road safety have linked the increase in fines to changes in traffic violations, changes in recidivism (re-offending), and changes in crashes. A 2016 meta-analysis indicated that fine increases between 50 and 100% are associated with a 15% decrease in violations; that fine increases of up to 50% do not influence violations, and that fine increases over 100% are associated with a 4% increase in violations and thus tended to be counterproductive. The effects of fine increase on recidivism are mixed, but the more severe and frequent offenders do not seem to be influenced by fine increases. An increase of fines was associated with a 5-10% reduction in all crashes, and a 1-12% reduction in fatal crashes. In general, studies had insufficiently controlled for confounding factors and results should be interpreted cautiously. Moreover, most studies looked at the effect immediately after a change in fines and at places with high enforcement levels. Therefore, the possibility that the reported effects are limited in time and place cannot be excluded.

5.1.7 Driving hours and rest time / hours of service regulations for commercial drivers

Colour code: **Light Green**

Some but not all studies indicate that regulations concerning driving times and rest time or hours of service have reduced commercial driver fatigue and fatigue-related accidents. The impact of hours of service regulations on fatigue and accident risk depends upon multiple factors, including enforcement and monitoring, economic market pressure, and types of affected driver schedules.

Abstract

'Driving hour and rest time' or 'hours of service' (HOS) regulations are regulations that limit when and for how long drivers of commercial motor goods or passenger vehicles are allowed to drive and/or work during a particular period. The purpose of these regulations is to reduce driver fatigue and to reduce fatigue-related accidents. The levels of enforcement of these regulations were found to vary and to be low in many countries. Both in Europe and in USA high violation levels of the regulations have been noted. In Europe there is no direct evidence that HOS regulations have reduced average driving times, driver fatigue, or accidents. In the USA the evidence of the safety effectiveness of HOS regulations is mixed. Both positive and negative findings have been reported, in terms of change in driving and rest time, sleep, and accidents. There is evidence that increased or improved monitoring or enforcement of HOS regulations leads to higher compliance and more safety.

5.1.8 Demerit Point Systems

Colour code: **Light Green**

There is some indication that the countermeasure can reduce road safety risk, however in practice the effects wear off rather quickly.

Abstract

With a demerit point system, demerit points are meted out to traffic offenders in addition to the normal penalty. Generally, more demerit points are meted out when the offence is more serious. If a defined points' limit is exceeded, suspension of the licence follows. In most cases the traffic offender needs to prove that he is capable of driving safely by following a driving course or by some other measure. A 2012 worldwide meta-analysis indicated that point systems had a positive effect in reducing the number of traffic violations as well as the number of accidents, fatalities and injuries. However, the effects wore off in less than 18 months. This is probably due to low / decreasing levels of enforcement resulting in a small chance that traffic offences are detected. It can be expected that point systems achieve longer lasting safety effects when enforcement levels are sufficiently high and sustained over time. In addition, a demerit point system can be expected to be more effective when the system includes a broad scope of major dangerous traffic violations (speed, alcohol, red light, use of seat belts/helmet/child restraints, dangerous overtaking, priority rules, headway distance), when intermediate measures (such as warning letters and educational measures) are targeted at specific groups of offenders, and when the point system, including its communication and administration, is simple, transparent and fair.

5.1.9 Red light cameras

Colour code: **Light Green**

Studies indicate that red light cameras decrease right-angle crashes but at the same time increase rear-end and other types of crashes. Since rear-end crashes are often associated with less severe injury than right-angle crashes, it may be assumed that the net effect on road safety is positive. Therefore, this measure is probably effective (light green code).

Abstract

Red light cameras (RLCs) are one of several possible countermeasures against red light running. Red light running is a risky traffic violation since it is associated with very serious, high injury crashes. Besides red light cameras, other countermeasures may include improving the driver's view of the intersection, converting intersection to roundabout, producing a raised intersection or improving the traffic signal phasing. A 2013 meta-analysis indicated that RLCs decrease right-angle injury collisions by 33%, but at the same time increase injury rear-end collisions by 19%. Several North-American studies after the meta-analysis, one European study and one Korean study, have confirmed that RLCs reduce right-angle crashes, but at the same time increase rear-end crashes and other types of crashes. Since rear-end crashes are often associated with less severe injury than right-angle crashes, it may be assumed that the net effect on road safety is positive. RLCs have been found to achieve larger road safety effects when red light violations are deliberate, when intersections have high proportion of right-angle crashes and lower proportion of rear-end crashes, when cameras are signposted, and when cameras are in continuous operation, rather than rotational

5.1.10 Driver Licence suspension

Colour code: **Green**

Studies indicate that licence suspension (or licence revocation) is an effective measure for reducing violations and crashes of (repeat) offenders. It should be added that for drink- drivers, other sanction measures, in particular alcohol-interlock programs, will likely produce greater road safety benefits than licence suspension. Also, licence suspension in combination with other measures will likely perform better in reducing recidivism than licence suspension in isolation.

Abstract

In most countries, a licence suspension means a temporary withdrawal of the privilege to drive a motorised vehicle. Most often after a fixed period of time and after fulfilling certain conditions (e.g. paying a fee, and/or participating in a rehabilitation program), the driving privileges will be restored. There are two basic ways in which licence suspension may improve road safety. First, the threat of licence suspension may motivate drivers to improve their traffic behaviour and to abstain from risky driving. Second, licence suspension temporarily removes risky drivers from traffic. Studies indicate that licence suspension (and also licence revocation) is effective in reducing crashes and violations of repeat offenders. A 2004 meta-analysis has estimated that licence suspension or revocation measures reduced crashes and violations of suspended offenders by 17% and 21% respectively. A 2009 meta-analysis indicated that administrative licence suspension laws reduced all fatal accidents by 4%. It should be added that for specific groups of offenders, such as drink-drivers, other sanction measures, in particular the alcohol-interlock measure, will likely produce larger road safety benefits than licence suspension. Also, the combination of licence suspension and other measures, such as rehabilitation programs, or vehicle impoundment, will likely perform better than licence suspension as a single measure.

5.2 EDUCATION AND TRAINING

5.2.1 Pedestrian skills training for children

Colour code: **Light Green**

There is some evidence, including a meta-analysis, that behaviour based education/training for children in pedestrian skills can improve the skills that children require to cross the road. However, some studies had mixed results and those with follow up results suggested that the benefit of training may reduce over time.

Abstract

There is some evidence, including a meta-analysis, that behaviour based education/training for children in pedestrian skills can improve the skills that children require to cross the road. However, it is not clear how sustained this improvement is over time and the age of the children undertaking training may have an impact on its success. There may also be an increased risk when skills are beginning to be learned until children fully master them. Education/training has been linked to reduced numbers of accidents involving child pedestrians however this has not been studied recently and therefore link between education/training and accidents is unclear for more recent studies.

5.2.2 Education – none statutory training for novice drivers

Colour code: **Grey**

The 5 selected studies report a mixture of significant and none significant results and differences in methodologies prevent the comparison of results. There was not enough evidence in the selected studies to establish a link between education and voluntary training aimed at novice drivers and skills improvement or risky behaviour reduction.

Abstract

The crash risk of young (aged <25 years old) and novice drivers is greater than that of the general driving population. Five studies focusing on education and voluntary training for young/novice drivers were examined. Their focus was on skills improvement (cognitive and vehicle handling) and on reducing risky behaviour such as speeding and driving under the influence of alcohol. Training was a mixture of on road and simulator training as well as classroom based training.

Skills/behaviour/attitudes were assessed using on-road or simulated driving tests or questionnaires. Not all results were compared with an independent control group and self-assessed behaviour/attitudes may not represent actual behaviour. Results showed a mixture of significant and non-significant findings for both driving skills and reducing risky behaviour. There was insufficient evidence to establish a link between the education/training reported here and improved skills and reduced risky behaviour.

5.3 DRIVER TRAINING AND LICENCING

5.3.1 Formal pre-license training/ Graduated driver licensing and probation

Colour code: **Light Green**

Graduated driver licensing (GDL) seems to be effective in improving road safety for 16 and 17 year old drivers but the results are more inconsistent for those aged 18 to 20 years. In the majority of the coded studies, the implementation of a strict GDL results in a reduction of the crash rate (overall, fatal, or injury-related). However, in a few studies, the effect is not significant, and sometimes is the opposite. Regarding the formal pre-license training, where only a few number of studies have been coded, it seems that completing a mandatory specific training or a computer-based training improved road safety and simulated driving performances. However, it has also been shown that an intensive driving course and time-discount were detrimental for novice drivers' road safety.

Abstract

Young drivers are disproportionately represented in motor vehicle collisions. Graduated driver licensing (GDL) programs and probationary licenses were progressively introduced in several countries worldwide since the early 1970s in order to reduce fatal crashes and high-risk behaviours in teen drivers. The 34 reviewed studies focused on the effect of the GDL and formal pre-license training (FPLT) on learner and novice drivers' road safety (four meta-analyses and thirty original papers). Before-after studies or time series analyses (21), cohort studies (4), longitudinal or observational studies (2), and quasi-experimental or experimental studies (3) were used to investigate the effect of GDL and FPLT on crash rate (overall, fatal, leading to severe injury, occurring during the night, or in presence of passengers) and traffic violations. Most of the studies were conducted on car drivers from the United States (n = 21). The results tend to indicate that GDL and FPLT have a global positive effect on road safety, but some inconsistent results were noted regarding drivers aged 18 and above. More specifically, GDL and FPLT appear to reduce crash rates and, to a small extent, improve driving behaviour. However, these effects are sometimes reversed for older drivers (>18 years).

5.4 FITNESS TO DRIVE ASSESSMENT, SCREENING AND MEDICAL REFERRAL

5.4.1 Alcohol interlock

Colour code: **Green**

The results of the research on the effectiveness of the alcohol interlock are positive in terms of reducing recidivism. However, once the device is uninstalled, the recidivism rates become comparable to those in the control group. Therefore, the effect on road safety is positive but only while the device is installed and remains installed.

Abstract

For many years, drink driving has posed a serious threat to road safety. That threat can be countered most efficiently by preventing drunk drivers from driving. An alcohol interlock can verify whether or not a driver's Blood Alcohol Concentration (BAC) is lower than the maximum threshold set by the legislator. If the driver's BAC exceeds that threshold, the vehicle will not start and as a result

prevents driving. In relevant studies, the recidivism rates are typically compared between offenders who had an alcohol interlock installed (experimental group) and those who did not (control group). Such a comparison can be carried out during the period while the device is installed and/or during a follow-up period after the device is removed. The results from a recent meta-analysis show that installing an alcohol interlock reduces recidivism risk by 75%. However, in a follow-up period after the alcohol interlock is removed, recidivism risk is only decreased by 7% compared to the control group. That difference is not statistically different from those who had not installed an alcohol interlock. A similar pattern of results also emerges from most recent studies. Alcohol interlocks do what they promise to do: while installed they reduce the risk on drink driving, however, once removed the recidivism rates increases towards their initial level.

5.4.2 Rehabilitation

Colour code: **Green**

Rehabilitation courses – if properly performed – can reduce the likelihood of recidivism. Important characteristics of a course are a focus on behavioural change (i.e. concrete plan of what to do when a relapse is imminent) rather than simply providing information. Furthermore, it should be spread over at least several weeks.

Abstract

The main purpose of rehabilitation courses is to reduce recidivism with respect to drink driving offences. Such a course is educational or psychologically oriented, and typically organised in small groups. Recent studies were analysed. The main outcome variable in all of these studies was recidivism for 'driving under the influence of alcohol' (DUI) in the 2 to 3 years following the course. Participants were compared to non-participants (as e.g. DUI-offenders who were charged with a more traditional sentence such as a prison sentence). The results show that rehabilitation courses for DUI-offenders can reduce recidivism and thus have a positive effect on road safety. Studies comparing the percentage of recidivists in the participant group with the percentage of recidivists in the control group show a decrease in recidivism of up to 36%. A meta-analysis of the studies, which use a logistic regression or cox regression, showed that rehabilitation courses can reduce recidivism by 40%. A weakness of almost all studies in this area is that the analysis of recidivism is based on participants who completed the course. The percentage of completers is variable and is not routinely evaluated as an aspect of course-quality. There is also the problem of matching variables between the experimental group and the control group. Unseen confounding factors could have biased the results.

5.4.3 Age-based screening of elderly drivers

Colour code: **Red**

Although studied by a number of good quality studies, age based screening of all elderly drivers for fitness to drive has not been found to reduce fatalities. At the same time, there are indications that it might increase fatalities among elderly pedestrians and the average risk per licensed (elderly) driver.

Abstract

Due to the increased numbers and mobility of elderly drivers in most industrialised countries, there has been a growing concern to assure the fitness of elderly drivers. Therefore, many countries have introduced additional re-licensing requirements like vision tests, medical check-ups, or on-road driving tests for all drivers from a certain age on (most often 70 years). From a scientific point of view there is no indication that age-based screening of elderly drivers improves road safety. Although a good number of studies from Europe, Canada, and Australia have investigated this effect in the last decade, no effect of increased safety was found. On the contrary, there are implications that the

measure might have two unwanted side-effects: (1) increased accident risk per licensed driver, and (2) increase of pedestrian fatality rate. However, studies from the United States indicate that obliging drivers to appear in person for licence renewal, rather than allowing re-licensing on-line or per mail has a beneficial effect on the number of fatal crashes involving elderly drivers.

5.4.4 Medical referrals

Colour code: **Light Green**

A number of the evaluated off-road tests appear to have some potential for predicting driving performance, and for identifying drivers who do not require an “on-road fitness to drive” assessment. These require further research. Most of the studied tests are not sufficiently accurate to predict on-road performance as a replacement for on-road assessment.

Abstract

The overall aim of fitness to drive assessment is to determine whether a driver with functional impairments will be able to drive a car, and where limitations are detected, determine how these can be compensated for. This overview reviews studies evaluating whether off-road assessment tools can replace on-road testing (at least partly) in this process. None of the evaluated tests (N=14) perfectly predicts driving performance. Thus, none would be able to fully replace on-road driving assessment. Drive-Safe/DriveAware and SMC Tests have the highest reported sensitivity and specificity. These have the potential to eliminate the need for on-road testing for a substantial proportion of the tested drivers. However, replication studies are required, particularly because the results depend on the composition of the tested group.

5.5 AWARENESS RAISING AND CAMPAIGNS

5.5.1 Campaigns, general (no specific risk factor or combined)

Colour code: **Light Green**

There is some indication that campaigns are beneficial for road safety on various levels. Meta-analyses show an association with accident reduction, increased safe behaviours and risk awareness. However, for other outcome variables such as drink-driving or safety relevant attitudes, no such effect was found. Furthermore, meta-analysed studies vary strongly, mainly regarding the design of the evaluated campaigns.

Abstract

Road safety communication campaigns aim at informing, persuading and motivating people to change attitudes and behaviour and ultimately at improving road safety. Two meta-analyses on campaigns with various road safety themes showed an association with a reduction of accident occurrence (9%) as well as a favourable change in (observed and self-reported) seat belt use (+25%), yielding behaviour (+37%), speeding behaviour (-16%) and risk comprehension (+16%). No significant changes are indicated, however, for drink-driving behaviour, favourable road safety attitudes and knowledge. Often, when road safety campaigns are implemented, they are accompanied by increased enforcement. Accounting for this factor, a decrease in accidents can still be found in a meta-analysis due to campaigns solely, however, a smaller one (10% vs. 13% for campaigns combined with enforcement).

5.5.2 Seatbelts

Colour code: **Green**

Results consistently show that seatbelt campaigns increase seatbelt use. As seatbelt use reduces injury severity significantly, this countermeasure has a positive impact on road safety.

Abstract

The main purpose of seatbelt campaigns is to encourage car occupants to use seatbelts. Meta-analyses evaluating mainly studies from the 1980s or early 1990s showed a significant positive average effect on road safety (+15%-25%). Studies, conducted in recent years, indicate a minor increase of general observed seatbelt usage (+1.8%-6.4%). This can be attributed to an already high baseline rate. Furthermore, it should be noted that all analysed seatbelt campaigns were accompanied by strong enforcement activities or law changes. Therefore, it is not clear to what extent the effects are attributable to the campaign itself. Moreover, transferability to European countries might not be possible as most coded studies were carried out in the USA.

5.5.3 Child restraint

Colour code: **Light Green**

Results show that child restraint campaigns have significant positive effects on child restraint use. However, most campaigns do not indicate long-term effects. Furthermore, only a few studies on evaluations of child restraints could be found and the quality of some studies was not satisfactory.

Abstract

The main purpose of child restraint campaigns is to promote the safety of children in vehicles by using child restraints. Results provide some indication that campaigns on child restraint usage have positive effects on road safety. Studies which measure observed child restraint use show a significant increase between 12% and 28%. Self-reported child restraint use increases between 23% and 30%. No clear statement can be drawn on influencing knowledge and attitudes as studies use different theoretical approaches and measurements. However, there are some indication that knowledge and some attitudes can be improved by campaigns. Results should be considered carefully, as the methodology of some studies is quite poor. Furthermore, the identification of long term effects has not been adequately studied.

5.5.4 Driving under the influence

Colour code: **Light Green**

There is some indication that drink-driving campaigns have a positive impact on attitudes towards drink-driving and even related accident occurrence. There is less evidence of the effectiveness of designated driver programmes.

Abstract

The main purpose of DUI (Driving Under the Influence) campaigns is to raise awareness regarding impaired driving as well as to promote sober driving. Results provide some indication that drink-driving campaigns can have positive effects on road safety. One out of two meta-analyses showed an association with crash reduction. A further meta-analysis and other individual studies with indirect outcome measures showed mixed results. While self-reported drink-driving behaviour did not considerably change, attitudes towards drink-driving were favourably influenced to some extent. Designated driver programmes seem to have lower potential to prevent drink-driving. However, most of the coded individual studies focus on young drivers and to some extent on passengers aged up to 34 years. Thus, conclusions can only be drawn regarding this age group.

Furthermore, it should be noted that some analysed DUI campaigns were accompanied by enforcement activities. Therefore, it is not clear to what extent the effects are attributable to the campaign itself.

5.5.5 Speeding

Colour code: **Light Green**

Results show that anti-speeding campaigns can have significant positive effects on road safety (behaviour). However, some campaigns are combined with enforcement activities, while others do not indicate long-term effects or do not take other indirect effects, like changes in traffic, into account.

Abstract

The main purpose of speeding campaigns is to raise awareness regarding speeding and inappropriate speed, that is speed not adapted to the prevailing traffic, road or weather conditions. Results provide some indication that speeding campaigns have a positive effect on road safety. A meta-analysis showed a significant 16% reduction in speeding. While one individual study reported a 30-45% decrease of fatalities and significant changes in attitudes and behaviour, some other studies did not find any significant changes either in actual behaviour, or in attitudes. Further, it should be noted that some analysed speeding campaigns were accompanied by enforcement activities. Therefore, it is not clear to what extent the effects are attributable to the campaign itself.

5.5.6 Aggressive and Inconsiderate Behaviour

Colour code: **Light Green**

There is some indication that campaigns addressing aggressive, unsafe or inconsiderate behaviour in road traffic have a positive impact on accident occurrence and self-reported (un)safe and (in)considerate behaviour.

Abstract

The main purpose of campaigns addressing aggressive, unsafe or inconsiderate behaviour in road traffic is to raise awareness as well as to promote considerate behaviour towards all other road users. Results provide some indications that campaigns targeting aggressive or inconsiderate behaviour can have positive effects on road safety. Some studies indicate an association with the number of killed and injured car passengers, non-fatal and severe injuries or at fault accidents. However, campaign evaluations with indirect outcome measures showed rather mixed results (significant reduction in speeding, non-significant change in unsafe behaviour and rule violations). Furthermore, it should be noted that the studies considered are quite different regarding the exposure variable(s) (different aims and resources of campaigns) and outcome measures and have at least minor limitations: combining a campaign with other road safety measures is often seen and a detailed documentation of evaluation methods is missing in some cases.

6 Conclusions



6.1 DISCUSSION OF RESULTS

As shown in Table 1, out of the 23 measures synopses presented here, seven were assigned the colour code 'Green' (effective) indicating that studies consistently show that the measure has a positive effect on road safety and thus lead to an improvement of road safety. These measures are mainly related to law and enforcement but also to fitness to drive assessment and rehabilitation. A further 13 measures concluded that there is some evidence that the measure(s) has some effectiveness on road safety but there are some problems in terms of mixed results, study design, or number of studies available. This category mainly consists of awareness raising campaigns and law and enforcement measures, but also includes driver training/licensing and education/voluntary training. Especially with campaigns, it is not always straightforward to conclude that a link exists between accident reduction and campaigns. Therefore, due to the weak association the 'Light green' colour code was assigned to these measures. Two synopses were assigned the code 'Grey' indicating that there was not enough evidence to draw valid conclusions about its effect on road safety. For instance, studies examining laws and enforcement for restricting mobile phone use while driving showed that that the subject area is well researched but the studies produced mixed and contradictory findings as the results were a mixture of positive, negative and non-significant effects. One synopsis (Age-based screening of elderly drivers) was assigned the colour code 'Red' (Ineffective or counterproductive) due to the fact that this specific measure had contradictory results and there were also cases where fatalities were increased.

Table 1: Human Behaviour related measures synopses by colour code.

Effective	Probably effective	Unclear results	Ineffective or counterproductive
<ul style="list-style-type: none"> • Law and enforcement – General police enforcement, speeding • Law and enforcement – DUI checkpoints, selective and random breath testing • Law and enforcement – Laws and enforcement for seatbelt wearing • Fitness to drive assessment and rehabilitation – Alcohol interlock • Fitness to drive assessment and rehabilitation – Rehabilitation • Awareness raising and campaigns – Seatbelt 	<ul style="list-style-type: none"> • Law and enforcement – BAC limits, BAC limits for novice drivers • Driver training and Licensing – Formal pre-license training, graduated driver licensing and probation • Education and voluntary trainings and programmes – Child pedestrians • Awareness raising and campaigns – Aggressive and inconsiderate behaviour • Awareness raising and campaigns – Campaigns in general • Awareness raising and campaigns – Child restraint 	<ul style="list-style-type: none"> • Law and enforcement – Laws and enforcement for mobile phone use (handheld, hands-free) • Education – None statutory training for novice drivers 	<ul style="list-style-type: none"> • Fitness to drive assessment and rehabilitation – Age-based screening of elderly drivers

Effective	Probably effective	Unclear results	Ineffective or counterproductive
<ul style="list-style-type: none"> • Law and enforcement – License suspension 	<ul style="list-style-type: none"> • Awareness raising and campaigns – Speeding and inappropriate speed • Awareness raising and campaigns – Driving under the influence • Law and enforcement – Increasing traffic fines • Law and enforcement – Hours of service regulations for commercial drivers • Law and enforcement – Demerit point systems • Law and enforcement – Red light cameras • Fitness to drive assessment and rehabilitation – Medical referrals 		

Limitations

As previously discussed evaluating the relationship between road safety and road user related measures is a difficult task, especially when campaigns are considered. More specifically, since the most important outcome measure is a reduction in crashes and fatalities, it is not straightforward to link these reductions to a campaign while controlling for all other possible contributing factors. Consequently, the defined outcome measures to account for campaign effects are often ‘indirect’ like intended behaviour or attitudes etc. Even though there is evidence concerning the influence of these constructs on actual behaviour, there are always also other determining factors (e.g. situational factors) that cannot be accounted for. Similarly, other measures such as laws and enforcement have been found to focus on behavioural measures, which are used as indirect road safety indicators (e.g. speed reduction, reduced mobile phone use while driving etc.). Therefore, the effect on crashes and fatalities cannot be easily estimated.

6.2 CONCLUSIONS AND NEXT STEPS

The next task of SafetyCube is to begin the priority setting between road safety related countermeasures; in this case those that relate to road user behaviour. This will be mainly done through Cost-Benefit Analyses (CBA) on selected measures, through the SafetyCube Calculator. Methodological guidance has been provided for this task:

Economic efficiency analysis will be included in the SafetyCube Decision Support System (DSS) by means of a CBA calculator. The main focus of the DSS is therefore to give the best available knowledge on each countermeasure and on risk factors that they can help to neutralize. Consequently, rather than assessing the efficiency of programs, the CBA calculator will be directed to assess the efficiency of the implementation of a single unit of a counter measure. This Cost Benefit Analysis calculator will combine information on countermeasures from the analysis work packages (4, 5, 6) and information from WP3 about the crash costs, the relative

frequency of crashes/casualties of different severities (i.e. how many severely injured are there for any fatality?), and about the discount rate. This information will be available for each country or as a European mean. For each countermeasure, the writer of the synopsis will fill the CBA calculator with default values (e.g. the crash-costs from the country in which the measure costs have been established). The user of the DSS can then replace the default values with his or her own values.

(Martensen et al., 2016)

The next steps will be to select measures (with a known effect on crash and/or fatality reduction) and apply cost-benefit analysis through the SafetyCube calculator. The objective of a CBA is welfare maximisation and the main result of a cost-benefit analysis is a monetary estimate of the benefits and costs of a road safety measure. A measure is cost-effective if its benefits are greater than its costs. In this way, a measure with the largest net present value (i.e., surplus of benefits to costs) will be the first choice to implement.

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List of Abbreviations



AADT	Annual Average Daily Traffic
ANOVA	Analysis of Variance
ARC	Awareness Raising and Campaigns
BAC	Blood Alcohol Concentration
CaDaS	Common Accident Data Set
CARE	Community database on Accidents on the Roads in Europe
GDL	Graduated Driver Licensing
CMF	Crash Modification Factor
DSS	Decision Support System
DUI	Driving Under the Influence
DWI	Driving With Influence
EVT	Education and Voluntary Training
ETSC	European Transport Safety Council
HGV	Heavy Goods Vehicle
ISA	Intelligent Speed Adaption
IVIS	In-Vehicle Information System
MANCOVA	Multivariate Analysis of Covariance
OECD	Organisation for Economic Cooperation and Development
RLC	Red Light Camera
SPI	Safety Performance Indicator
TPB	Theory of Planned Behavior
VRU	Vulnerable Road User(s)
WP	Work Package

Appendix A: Taxonomy of human related road safety measures

This table represents the taxonomy of human related road safety measures in SafetyCube.

1 st level Type of measure	2 nd level Road user, risk factor, combination	3 rd level Specific measure
Law and enforcement	Speeding	Police enforcement, speeding
	Drink-driving or riding	Random breath testing
		DUI checkpoints, selective breath testing
		Lowering BAC limits
		BAC limits for specific groups (novice or professional drivers)
	Drugged driving or riding (illegal)	Police enforcement, drugged driving or riding
	Aggressive and unsafe driving or riding	Police enforcement, aggressive driving
	Fatigue, professional drivers	Hours of service regulation
	Distraction	Laws restricting mobile phone use (handheld)
		Laws restricting mobile phone use (hands-free)
		Police enforcement, mobile phone use
	Seatbelt	Seat belt law and safety effects
		Police enforcement, seatbelt use
	Child restraint	Child restraint law and safety effects
	Protective clothing	Protective clothing
	Helmet, cyclists	Helmet wearing law
		Law on helmet standards
		Safety effect of helmets
	Helmet, PTW	Helmet wearing law
		Law on helmet standards
Safety effect of helmets		
Red light running	Safety cameras, red light cameras	
	Police enforcement, red light running	
Fines, demerit point system and general patrolling	Fines and penalties	
	Demerit point system	
	General police enforcement and patrolling	
Education and voluntary trainings or programmes	Children, pre-school and primary school	Pedestrians
		Cycling
		General road safety
	Adolescents, secondary school	Pedestrians
		Cycling
		General road safety
	Young, novice drivers and riders	Driving
		PTW riding
		General road safety
	Elderly	Pedestrians
		Cycling

		Driving
		PTW riding
		General road safety
	General population	Usage and fitting of child restraint
		Pedestrians
		Cycling
		PTW riding
		Driving
		Hazard perception
		Adverse conditions (weather, light)
		Unsafe or risky behaviour
		Rewarding programmes
	General road safety	
	Professional drivers	Truck
Bus, coach		
Car, van		
General road safety		
Driver training and licensing	Formal pre-licence training	Duration of driver training
		Content of driver training
		Driving test
	Graduated driver licensing and probation	Overall effect of graduated driver licensing
		Speed restriction
		Night-time driving restriction
		Passenger restriction
	Health requirements for initial registration	Other driving restriction
Private vehicles (car, PTW)		
Required age for initial registration	Commercial vehicles (truck, bus, taxi)	
	Required age for initial registration	
Accompanied driving or riding	Accompanied driving or riding	
Fitness to drive assessment and rehabilitation	Offenders	Fitness to drive assessment
		Rehabilitation
		Alcohol interlock
	Young offenders	Fitness to drive assessment
		Rehabilitation
	Medical referrals	Dementia
		Medical referral, other
Elderly drivers	Fitness to drive assessment, screening	
Professional drivers	Fitness to drive assessment, screening	
Awareness raising and campaigns	Speeding and inappropriate speed	Speeding and inappropriate speed
	Distraction	Distraction
	Driving under the influence of alcohol or drugs	Driving under the influence of alcohol or drugs
	Fatigue	Fatigue
	Seatbelt use	Seatbelt use
	Child restraint use	Child restraint use
	Helmet, protective clothing and visibility	Helmet, protective clothing and visibility
	Aggressive, inconsiderate and unsafe behaviour	Aggressive, inconsiderate and unsafe behaviour
	Road safety campaigns, general	Road safety campaigns, general

Appendix B: Stakeholder questionnaire

Most important human-related Road Safety Measures

Road Safety Workshop, Brussels, Sept. 27th 2016



Dear Road Safety Expert,

to ensure we are covering the most important and pressing issues in SafetyCube|and set the right priorities, your expertise is very needed. Safety Cube is currently collecting human related road safety measures within the areas

- Law and Enforcement
- Education, Training, Licensing, Diagnostics, & Rehabilitation
- Awareness Raising

On the back side you will find a list of behaviour related risk factors (left column), which have been identified as the most pressing ones. **Please think of the most important and promising countermeasures** tackling these risks and write them down – if possible assigned to one of the three categories of measures! Not all cells have to be filled in, only the most important measures **from your point of view** are required. Please insert three measures per cell at most!

If an important human related measure cannot be assigned to one of the specified risk factors, please note it in the last two rows.

Thank you very much for your valuable input!



Most important human-related Road Safety Measures **from my Point of View**

Road Safety Workshop, Brussels, Sept. 27th 2016



Measure > Risk v	Law and Enforcement	Education, Training, Licensing, Diagnostics, Rehabilitation	Awareness Raising	Others
Speeding				
Drunk driving				
Drugged driving				
Fatigue				
Distraction				
Cognitive impairments				
Emotions (Aggression)				
Non-use of safety devices (seat belt, child restraint, helmet)				
Other, insert here				
Other, insert here				

Appendix C: Outcomes of stakeholder questionnaire

The table shows all nominations of stakeholders' subjectively most important human-related road safety measures for certain risk factors. Multiple mentions are indicated in the column next to the measure. Coloured items (purple) indicate measures that are dealt with in another WP (vehicle or infrastructure related).

Measure > Risk v	Law and Enforcement	Education, Training, Licensing, Diagnostics, Rehabilitation	Awareness Raising	Others				
Speeding	Law against recidivists	2	Education in schools	1	Campaigns in general (live campaigns, consequences, posters, leaflets, radio and TV spots)	4	ISA	4
	Police controls	2	Demerit points licence	1	Campaign: fear appeal, hard campaigns with children victims	2	Speed limiters	1
	Salary linked fines	1	Education on risk, consequences	1	Campaign: enforcing good behaviour	1	Automated vehicles	1
	Higher fees	1	Education before licensing, secondary school	1	Target-specific campaigns	1	Right speed limit for the right road	1
	Cross border enforcement	1	Feedback based on video images	1	Evaluate why are certain campaigns working and others not	1		
	Section control, trajectory control	6	Demonstrations 30km/h vs 50km/h	1	Focus on social norms in peer groups	1		
	Speed cameras	4	Make aware consequences (also legal consequences in cases of crashes), with real cases	1				
	ISA	3	Database of repeat offenders (also for minor but very regular offences)	1				
	Radar	2	Awareness courses for repeat offenders	1				
	Traffic calming systems, infrastructure based	1						
Black box	1							
Drunk driving	Alcohol interlock	6	Education in schools	1	Campaigns in general (poster, leaflets, radio, TV)	4	Mandatory alcohol interlock in HGVs and LGVs	1

	Law against recidivists	1	Education before licensing, secondary school	1	Campaign: enforcing good behaviour	1	
	Police controls, presence, random stops	5	Demerit points licence	1	Campaign: fear appeal	1	
	Zero tolerance	2	Make aware the consequences on the driver and third parties – make it alive with real cases	1	Peer pressure	1	
	Alcohol interlocks for repeat offenders	1	Rehabilitation measures	1	Evaluate why are certain campaigns working and others not	1	
	Black boxes, particular with repeat offenders	1	Database of repeat offenders (also for minor but very regular offences)	1	Trial with 'drunk glasses'	1	
	Mandatory alcolock for repeat offenders	1	Awareness courses for repeat offenders	1	Bob campaign twice a year (summer and winter)	1	
	Quick pre-tests	1			Target-specific campaigns	1	
	Enlarge definition of recidivism	1			Focus on social norms in peer groups	1	
	Increased enforcement on places/moments when risk is highest	1					
	Investigating alcohol use in each injury accident (also in fatalities)	1					
Drugged driving	Police controls, on adequate level, more, frequent, random stops	4	Education in schools	1	Campaigns in general (posters, leaflets, radio and TV spots)	3	
	Quick pre-tests, salvia test	2	Demerit points license	1	Awareness/info medical sector, campaigns to doctors (legal drugs)	2	
	Drug testing controls	1	Make aware the consequences on the driver and third parties – make it alive with real cases	1	Campaign: enforcing good behaviour	1	
	Law against recidivists	1	Rehabilitation measures	1	Campaign: fear appeal	1	
	Simple check-list	1	Database of repeat offenders (also for minor but very regular offences)	1	Evaluate why are certain campaigns working and others not	1	
	Increased enforcement on places/moments when risk is highest (salvia testing)	1	Awareness courses for repeat offenders	1	Target-specific campaigns	1	
	Investigating drug use in each injury accident (also in fatalities)	1			Focus on social norms in peer groups	1	

Fatigue	Professional: rest-drive-time	1	Feedback on driving behaviour, experienced based approach	2	Campaigns in general (poster, leaflets, radio, TV, live campaigns about consequences.)	5	Sensors in vehicle	1
			School/work programs	1	Campaign: enforcing good behaviour	1	Advanced technology	1
			Train how to check your own fatigue	1	Campaign: fear appeal	1	Mandatory in-car fatigue warning system in all new vehicles	1
			Regular breaks	1	Actions in companies	1		
			Educational programs for high risk groups (night shift workers etc.)	1	Target-specific campaigns	1		
			experience-based approach		Focus on social norms in peer groups	1		
					Info about facts	1		
					Sensitisation on the danger of driving at night	1		
					Evaluate why are certain campaigns working and others not	1		
Distraction	Law, enforcement against the use of mobile phone while driving	1	Use technology to show the driver his real activities (eye-tracking), experience based approach (VR, simulator.)	2	Campaigns in general (sensitisation, posters, leaflets, radio, TV, live campaigns on consequences.)	5	Vehicle design	1
	Salary linked fines	1	Driver education	1	Campaign: enforcing good behaviour	1	Advanced technology	1
	Mobile phone check using camera pictures (like speed camera)	1	Demonstration/simulation: ask driver to text while driving	1	Campaign: fear appeal	1	Handsfree devices obligatory	1
	Increased overall enforcement	1	Should be a part of training and testing for licenses. Particularly with new in-vehicle devices	1	Funny campaigns	1	Technology to ban smartphone use while driving	1
	Investigating smartphone use in each serious injury accident (also fatalities)	1	Educate the consequences	1	Evaluate why are certain campaigns working and others not	1		
			Don't FB and drive, all the education of (young) phone users on the importance of not being distracted while driving	1	Target-specific campaigns	1		
			Educational programs for high risk groups (young drivers etc.)	1	Focus on social norms in peer groups	1		
	Consistent legal criteria	1	Evaluation fitness to drive	1	Info of medical staff	1	Reduce the number of traffic signs	1

Cognitive impairments			Staged screening and assessment system	1	Self-assessment tools	1		
			Medical instructions licensing	1	Personal training	1		
			Training elderly road users	2				
			Training of skills	1				
			Specific tests	1				
			Training of novice drivers	1				
Emotions (Aggression)	Police checks	1	Legal drugs	1	Campaign: enforcing good behaviour	1		
			Include knowledge of other road users in training of drivers, e.g. CPC training for lorry drivers on a bike to experience being overtaken by LGV/HGV	1	Campaign: fear appeal	1		
			Personal training, soft skill training	2	About social rules, "road safety culture"	1		
			Specific tests	1	Sensitisation on the danger of driving after having a dispute	1		
			Rehabilitation courses, educational programs for offenders	2	Raise awareness in driving schools	1		
					Target-specific campaigns	1		
					Focus on social norms in peer groups	1		
Non-use of safety devices	Police controls	2	Education in schools	1	Campaigns in general	2	Disable vehicle	1
	Car lock systems? Car is blocked until all seat belts are put	1	Education on the risk	1	Campaign: enforcing good behaviour	1	Mandatory seat-belt reminders	1
	Automatic detection systems for seat belt	1	Pre-licensing, secondary school	1	Campaign: fear appeal	1		
	Obligated helmet use for speed pedelecs (>4000W + > 45km/h)	1	Better instructions on using child restraint systems	1	Make aware of positive effects (and negative consequences)	1		
	Increased enforcement on places/moments when risk is highest	1	Educational programs for offenders	1	Kids training in early age	1		
	Investigating safety device use in each injury accident (also fatalities)	1	Seat belt reminder in all seats	1	Kids training (grand)parents	1		
	Camera enforcement	1			Crash test or roll-over simulation	1		
					Target-specific campaigns	1		

				Focus on social norms in peer groups	1	
Red Light Running	Camera enforcement	1				
High risk takers	Police checks on critical spots, newly maintained roads	1	Educate ways to compensate on a safe way (training, spots)	1		
			Show the consequences	1		
			Personal training, 'Nachschulung'	1		
Missing driving skills	Camera enforcement	1	Training	1	Let them try. Even when people buy a car	1
			Regular skill testing (every 2 years)	1	Info, factsheets, what is new, what has changed	1

Appendix D: Stakeholder workshop – list of registered stakeholders

September 2016, Brussels

First Name	Last Name
Adina	Marciano
Juliette	Anselot
Ceri	Woolsgrove
Graziella	Jost
Kallistratos	Dionelis
Luana	Bidasca
Niels	Janssen
Jeannot	Mersch
Veneta	Vassileva
Stephen	Stacey
Veerle	Schoutteet
William	Bird
Marcus	Wisch
Wouter	Muesen
Xavier	Cocu
Griet	Van Belleghem
Stijn	Daniels
George	Yannis
Robert	Thomson
Wouter	Van den Berghe
Eleonora	Papadimitriou
Pete	Thomas
Walter	Niewöhner
Klaus	Machata
Alice	Magrin
Rune	Elvik
Maura	van Strijp
Stijn	Dhondt
Ashleigh	Fitness
Heike	Martensen
Wendy	Weijermars
Eva	Aigner-Breuss
Susanne	Kaiser

Appendix E: Synopses on Road User Related Measures, version 1.0

This appendix includes all the synopses on road user measures that were available in July 2017. They will be available through the DSS when it is launched in late 2017. The synopses are intended to be periodically updated to reflect new research or in some cases to expand their scope. Future updates or additions to the synopses will be available in DSS: www.roadsafety-dss.eu

Speeding: general police enforcement, speeding



Giulia Botteghi, Athanasios Theofilatos, Giacomo Macaluso
NTUA, May 2017

1 Summary

1.1 COLOUR CODE

Green

The effects of speed enforcement are mostly positive in reducing crash frequency, mean vehicle speed and the proportion of drivers exceeding the speed limit. Furthermore, the coded studies encompass several topics and have good levels of quality and consistency. For the reasons mentioned above, the overall impact of speed enforcement is characterized as green (effective).

1.2 KEY WORDS

Fixed penalties; deterrence; road safety; enforcement; accident; systematic review; traffic violations; efficiency; speed; enforcement performance indicators.

1.3 ABSTRACT

Speed enforcement aims to prevent drivers exceeding the speed limit by penalizing those who do. Therefore, speed enforcement affects the level of road safety, causing a reduction in crash frequency, in mean vehicle speed and in the number of vehicles travelling over the posted speed limit. Seven high quality studies involving various speed enforcement measures were coded. On the basis of both studies and effect numbers, it can be argued that speed enforcement creates positive impacts on road safety. However, there were isolated cases that reported different results.

1.4 BACKGROUND

Definition of speed enforcement

Speed limit enforcement is the action taken by appropriately empowered authorities to check that road vehicles are complying with the speed limit in force. This not only affects the speed violators who get caught (specific deterrence), but also those who see or hear that others get caught (general deterrence). There are various tools and methods available for speed enforcement. Police enforcement can be a very effective measure, even though the effects are limited both in time and place.

How does speed enforcement affect road safety?

Police enforcement is based on the principle that people try to avoid penalty. Most important is that people have the impression that there is a high chance that they will be penalized when violating a rule. The subjective chance of apprehension is primarily affected by the actual level of enforcement. In addition, it is affected by how much people see or hear about police enforcement. Therefore, the subjective chance of apprehension can be increased by applying both visible and hidden enforcement activities, by publicising specific enforcement activities (e.g. in national or regional media), and by feedback on the results of enforcement activities (e.g. in national or regional media). Findings from the studies demonstrate that the presence of speed enforcement, or the increase in the amount of speed enforcement, leads to a reduction in crash frequency and speed, and to an increase in speed compliance.

Which safety outcomes are affected by speed enforcement?

The reviewed studies focus on various outcomes. In some studies, the main focus is estimating the reduction of the number of crashes due to the speed enforcement with different methods (e.g. before-after comparison, calculation of crash modification factors, etc.). In addition to this, other studies

investigate the effects of speed enforcement on speed reduction and on the number of vehicles travelling over the speed limit.

How is the effect of speed enforcement on road safety studied?

The international literature has examined a variety of different approaches and ways to study the effect of speed enforcement on road safety. Often this measure is examined alongside others (e.g. seat belt enforcement, etc.) and not by itself, and its examination is adjusted to the models selected to capture the entire situation for the given case.

1.5 OVERVIEW OF RESULTS

The effects of police enforcement on road safety tend to increase the level of road safety. Usually the various study findings link police enforcement to decreased crash frequency. In particular, one study shows that as the number of enforced sites and issued tickets increased, and the average check length decreased, a reduction of speed-related collisions was observed.

With regard to mean vehicle speed, the majority of studies show a significant reduction, with a beneficial effect on road safety. Positive effects were also found on the number of vehicles exceeding the speed limit. Conversely, one study reports a non-significant effect of the increase of fixed penalties for speeding on the speed compliance.

Transferability

The coded studies are based on data from several countries, including Norway, Netherlands, Canada and the United Kingdom. In addition, two meta-analyses were performed and results from different countries (Australia, United states, European Union countries, South Korea, Israel, etc.) were collected. Although this is a good sample for general trends in developed countries, there is a lack of studies representing less motorized countries. Moreover, the totality of studies examines all motor vehicles, without differentiating between different road users.

Notes on analysis methods

The methodology applied for capturing the impact of police enforcement on road safety varies considerably between studies. This variation is mainly in terms of the mathematical models utilised, but also in the outcomes evaluated as dependent variables. There is also a certain margin for investigating different road user categories and/or other geographical regions. All the above make the results for police enforcement generally transferable, though relative caution is always required.

2 Scientific overview

2.1 ANALYSIS OF STUDY DESIGNS AND METHODS

After appropriate use of various search tools and databases, five (5) high quality studies and two (2) meta-analyses (Elvik, 2007; Eke et al., 2009) were selected and coded to evaluate the effectiveness of the speed enforcement on road safety. Five studies (Elvik, 2007; Elvik et al., 2012; Goldenbeld et al., 2005; Li et al., 2017; Eke et al., 2009) investigated the effects of speed enforcement on the number of accidents; Goldenbeld et al. (2005) also analysed the mean speed and the percentage of vehicles travelling over the posted speed limit. Furthermore, two other studies (Elvik et al., 2007; Walter et al., 2011) focused on the number of drivers exceeding the speed limit and Walter et al. (2011) also analysed the drivers' speed.

In order to examine the relationship between the various exposures and outcome indicators, the majority of the studies used multivariate statistical models or univariate parameter significance testing (e.g. generalized linear model with Poisson distribution, multiple linear regression model, F-test, etc.). Moreover, two studies (Elvik, 2007; Eke et al., 2009) combined data from multiple studies through a meta-analysis. Two other studies (Elvik et al., 2012, Walter et al., 2011) did not mention any statistical analysis, but comparisons before and after the speed enforcement were conducted.

Regarding the number of accidents, all the examined studies show a reduction of crash frequency. The meta-analysis carried out by Elvik (2007) showed a positive relationship between the amount of enforcement and the effects on accidents. Similarly, Elvik et al. (2012) reports a reduction of the number of fatalities with the increase in the amount of speed enforcement. Additionally, Goldenbeld et al. (2005) shows a decrease in the number of injury accidents and serious traffic casualties, while Li et al. (2017) asserts that as the number of enforced sites and issued tickets increase, the number of speed-related collisions decreases and, as the average check length decreases, a greater reduction of speed related collisions is observed. The last study concerning the crash frequency is a meta-analysis conducted by Eke et al. (2009), which shows a significant reduction of crash frequency for all severities, due to different measures, such as implementation of speed enforcement, increase of the amount and change type of speed enforcement.

When examining speed enforcement, another popular outcome is the number of drivers exceeding the speed limit. The first study (Elvik et al., 2007) shows a non-significant effect of the increase of fixed penalties for speeding, on the number of vehicles travelling over the posted speed limit. Conversely, Goldenbeld et al. (2005) shows a significant decrease in the percentage of offenders during the enforcement program. In the same way, Walter et al. (2011) reports a reduction in the proportion of speeding drivers and 'extreme' speeding drivers (15mph or more above the speed limit), due to the increase in the level of enforcement.

With regard to mean speed, Goldenbeld et al. (2005) reports a significant reduction during the enforcement program. Similarly, findings from Walter et al. (2011) show a decrease in 85th percentile speed and mean speed, but without any statistical evidence.

An overview of the main features of the coded studies (sample, method, outcome and results) is illustrated on Table 1.

Table 1 Description of coded studies.

Number	Author(s); Year; Country;	Sampling frame for law and enforcement investigation	Method for law and enforcement investigation	Outcome indicator	Main Result
1	Elvik R., Christensen P.; 2007; Norway	The aim of the study is to evaluate the effects of increases in the fixed penalties for seat belt wearing and for speeding. Data from counting stations and speed camera sites were obtained for the years 1995 to 2003, from 33 sites.	Multiple linear regression model	Speeding compliance [percent change];	Increased fixed penalties for not wearing seat belts appear to be effective in increasing compliance, whereas increased fixed penalties for speeding do not appear to be effective.
2	Elvik, R.; 2011; various	An accident modification function for speed enforcement was developed, relating the size of the effect on accidents to the level of enforcement introduced. 13 studies of the effects of speed enforcement were retrieved. 2 cross-sectional studies were omitted, while 11 before-after studies containing 63 data points (then reduced to 15) remained. Only the best models were coded.	Meta-analysis (Inverse function fitted to non-weighted data points & logarithmic function fitted to weighted data points)	Number of accidents [crash modification factor]	A positive relationship between the amount of enforcement (the size of the dose) and the effect on accidents was expected. When studies were pooled and data points aggregated, to reduce the contribution of random variation in estimates of effect, a dose–response pattern emerged.
3	Elvik R., Soggy C. V., Lager L., Amundsen F. H., Plasmin L. T., Kallsen R., Fossil K.; 2012; Norway	The study examines a number of measures (speed, drinking-driving and seat-belt enforcement) in relation to their costs and effects on safety. Data were collected from 2004 to 2006.	Inverse function fitted to non-weighted data points & logarithmic function fitted to weighted data points	Number of fatalities [percent change]	Increasing enforcement could have a large effect on safety and is cost-effective. As an example, a ten-fold increase in speed enforcement was estimated to reduce fatalities by about 11.5%, which is half the fatality risk attributable to speeding.
4	Eke A., Goldenbeld C., Vaa T.; 2009; Netherlands	The report investigates the effectiveness of speed enforcement based on the results of 47 studies. The studies are categorized according to many moderator variables: visibility, signposting, randomization, accompanying publicity, change of type or amount of enforcement, increase of the amount of enforcement, country, accident severity, study methodology, study design.	Fixed and random effects step-by-step Meta-analysis (log-odds method) & Trim and fill analysis	Number of accidents [percent accident reduction]	The overall result is a significant reduction of the number of accidents and there is no indication of publication bias according to the result from the trim and fill analysis.
5	Goldenbeld C., Van Schengen, I.; 2005; Netherlands	The study estimated the effects of 5 years (1998-2002) of a regional speed enforcement program on single carriageway rural roads in the Dutch province of Friesland. 12 road sections (length 60 km) and 28 rural road sections (length 116 km) were considered to evaluate the effects on speed and road accidents respectively.	Repeated measures analysis & before/after comparison [F-test]	Mean speed [R-squared]; Percentage of offenders [R-squared]; Injury accidents [odds ratio]; Serious traffic casualties [odds ratio]	Both the mean speed and the percentage of speed limit violators decreased during the targeted enforcement program. The number of road accidents and casualties decreased more at the enforced than at the comparison roads. Based on the available data, the best possible estimate of the traffic safety effect of the enforcement program is a 21% reduction of both serious casualties and injury accidents.
6	Li R., El- Bassoon K., Kim A., Targum S.; 2017; Canada	In this study, the number of enforced sites, average check length, and number of issued tickets were selected as three important enforcement performance indicators, and their impacts on safety were investigated. In total, 96 monthly observations were used in the model estimation.	Generalized linear model (Poisson distribution)	Monthly Number of Speed-Related Collisions [slope]	The results show that as the number of enforced sites and issued tickets increased, the number of speed-related collisions decreased. Also, as the average check length decreased, a greater reduction of speed related collisions was observed.

Number	Author(s); Year; Country;	Sampling frame for law and enforcement investigation	Method for law and enforcement investigation	Outcome indicator	Main Result
7	Walter L., Broughton J., Knowles, J.; 2011; United Kingdom	Operation Radar was a four-week campaign mounted by the Metropolitan Police in which the level of police enforcement of traffic laws was increased along a six-mile route in London (A23). the study. The operation was carried out five days per week between 6th and 30th May 2008, except for the Bank (public) holidays.	Comparisons between before and after and between before and during the operation	Speed of drivers [absolute difference]; drivers exceeding the speed limit [percent change];	Analysis of the speed data showed that 85th percentile and mean speeds reduced systematically during the operation at sites where static speed enforcement was targeted. The proportion of speeding drivers and 'extreme' speeding drivers (15mph or more above the speed limit) reduced substantially during the operation.

Limitations

There are a couple of limitations in the current literature examining the effects of speed enforcement on road safety. The first is that the totality of studies comes from developed countries, and consequently there is a lack of information concerning the impact of speed enforcement in less motorized countries, such as South America or Africa. The impact of speed enforcement in these environments should be captured from similar studies for a more collective approach.

Secondly, Walter et al. (2011) uses speed as a measure of effectiveness, which is a secondary parameter and does not directly provide a clear image regarding the number of crashes.

2.2 RESULTS FOR SPEED ENFORCEMENT

Introduction

The effects of speed enforcement on road safety can be summarized as follows:

- 4 studies with a significant reduction in the number of accidents;
- 1 study with a decrease in crash frequency, but without any statistical data;
- 1 study with a non-significant effect on speed compliance;
- 1 study with a significant positive effect on the number of vehicles travelling over the posted speed limit;
- 1 study with a reduction in the number of drivers exceeding the speed limit, but no statistical analyses were performed;
- 1 study with a significant reduction in mean speed;
- 1 study with a reduction in speed, but without any statistical analyses.

The complete detailed results from the coded studies appear in Table 2, which is presented in the supporting document.

After the results were reviewed together, in possible consideration of a meta-analysis, the following points were observed:

- a) There is an adequate number of studies. However,
- b) Those studies have used different models for analysis.
- c) There are different indicators, and even when they coincide they are not measured in the same way.
- d) The sampling frames were different.

Description of analysis carried out

Review-type analysis

After considering the previous points, it was decided that a meta-analysis could not be carried out in order to find the overall impact of speed enforcement on road safety. Despite the suitable number of studies, the sampling frames, outcome variables and statistical analyses are all too different for the meta-analyses to be unified. Most importantly, two meta-analyses are included in the coded studies, and since the results have different weights, the only analysis that can be performed is a qualitative one.

Taking the above into consideration, it was decided that both the meta-analysis and the vote count analysis are inappropriate, and thus the review type analysis was selected.

The positive effects of crash reduction appear to occur in several locations, for different severities (fatal, injury, all severities) and also on urban, suburban and rural study sites. Positive effects were also found for the mean speed on rural roads, both for riders and for drivers.

Regarding speed compliance, one study reports a non-significant effect of speed enforcement on road safety. However, the majority of the studies show a significant positive effect for different road types and users.

Overall estimate for road safety

On the basis of the coded studies, it can be asserted that the implementation of speed enforcement, or an increase in the amount of it, has an overall positive effect on road safety. However, there are cases when its impact is inconclusive, but these are in the minority and occur due to unexpected circumstances. The fact that the results are mostly consistent and show a decrease in the number of accidents, in mean speed and in the number of drivers exceeding the speed limit, leads to the assignment of the green colour code for speed enforcement. The variation between indicators, models, framing and general details between studies made the circumstances for conducting a meta-analysis inappropriate.

Conclusion

The review-type analysis carried out show that speed enforcement is usually associated with a reduction in crash frequency and mean speed. In addition, the presence or increase of speed enforcement encourages drivers to keep the speed limits.

3 Supporting document

3.1 IDENTIFYING RELEVANT STUDIES

Literature search strategy

The search strategy aimed at identifying recent studies regarding the implementation of Laws and Enforcement for speeding. The main database that was consulted was Scopus. In general, only recent (after 1990) journal studies were considered. However, high quality conference papers and reports were also considered. Moreover, reference lists of individual studies is also examined.

Limitations/ Exclusions:

- Search field: TITLE-ABS-KEY
- Published: 1990 to current
- Document Type: "Review" and "Article"
- Language: "English"
- Source Type: "Journal"
- Only Transport Journals were considered
- Subject Area: "Engineering and Psychology"

Database: Scopus

Date: 28th March 2017

search no.	search terms / operators / combined queries	Hits
#1	(„law“ OR „enforcement“)	522,120
#2	(„speed“ OR „speeding“)	4,412
#3	#1 AND #2	1,013

Results of Literature research

Database	Hits
Scopus	1013
Total number of studies to screen title	1013

3.2 SCREENING

The abstracts of relevant studies from the initial literature search results were examined to narrow the scope and to detect studies that would be more appropriate at a first stage. Those abstracts give hints as to whether the full text warrants close examination for coding and inclusion in the project.

Total number of studies to screen title	1013
Number of articles remaining after screening of the title = Total number of studies to screen abstract	458
Remaining studies after abstract screening	389
Total number of studies to screen full text	389

3.3 ELIGIBILITY

Total number of studies to screen full-text	389
Full-text could be obtained	389
Reference list examined Y/N	Yes
Eligible papers prioritized	7

3.4 PRIORITIZING CODING

- Prioritizing Step A (existing meta-analyses)
- Prioritizing Step B (most recent studies)
- Prioritizing Step C (Journals over conferences and reports)
- Prioritizing Step D (Prestigious journals over other journals and conference papers)
- Prioritizing Step E (Studies from Europe)

3.5 SUPPORTING QUANTITATIVE TABLE

Below follows Table 2, which includes all quantitative effects from the coded studies for the measures of speed enforcement.

Table 1: Quantitative results of coded studies for speed enforcement impacts on road safety.

Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative Estimate		Effect on road safety
1	Elvik R., Christensen P.; 2007; Norway	Speeding compliance [percent change]	Increasing speeding penalty by NOK 600 (90 US dollars)	Speed camera sites	Per.Ch.: SC=0%, CI [95%] = [0;0]; a=0.05	-
				Permanent counting stations	Per.Ch.: SC=0%, CI [95%] = [-0.1;0]; a=0.05	-
2	Elvik, R.; 2011; Norway	Number of accidents [crash modification factor]	Relative Level of enforcement	weighted data points	CMF: N=-0.248, p=0.00, a=0.05	↓
				non-weighted data points	CMF: N=0.352, p=0.001, a=0.05	↓
3	Elvik R., Soggy C. V., Lager L., Amundsen F. H., Pasnin L. T., Karlsen R., Fosli K.; 2012; Norway	Number of fatalities [percent change]	Speed enforcement	Increase by 50%	Per.Ch.: N= -4.4%	↓*
				Double current level	Per.Ch.: N= -6.5%	↓*
				Three times current level	Per.Ch.: N= -8.6%	↓*
				Three and a half times current level	Per.Ch.: N= -9.1%	↓*
				Four times current level	Per.Ch.: N= -9.6%	↓*
				Four and a half times current level	Per.Ch.: N= -9.9%	↓*
				Five times current level	Per.Ch.: N= -10.1%	↓*
				Six times current level	Per.Ch.: N= -10.6%	↓*
Ten times current level	Per.Ch.: N= -11.4%	↓*				
4	Erke A., Goldenbeld	Number of accidents	All severities	Stationary manual	Per.Acc.Red.: N=-11%, CI [95%] = [-22;1]	↓

Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative Estimate		Effect on road safety		
	C., Vaa T.; 2009; Netherlands	[percent accident reduction]	Implementation of speed enforcement	Patrolling	Per.Acc.Red.: N=-6%, CI [95%] = [-16;4]	↓		
					Radar laser	Per.Acc.Red.: N=0%, CI [95%] = [-3;4]	-	
					Composite other	Per.Acc.Red.: N=-18%, CI [95%] = [-33;1]	↓	
				Injury	Stationary manual	Per.Acc.Red.: N=-12%, CI [95%] = [-26;5]	↓	
					Patrolling	Per.Acc.Red.: N=-6%, CI [95%] = [-20;10]	↓	
					Radar laser	Per.Acc.Red.: N=2%, CI [95%] = [-3;8]	-	
					Composite other	Per.Acc.Red.: N=-18%, CI [95%] = [-30; -4]	↓	
				Fatal	Stationary manual	Per.Acc.Red.: N=-27%, CI [95%] = [-44; -2]	↓	
					Patrolling	Per.Acc.Red.: N=-12%, CI [95%] = [-35;18]	↓	
					Radar laser	Per.Acc.Red.: N=-21%, CI [95%] = [-42;7]	↓	
				Increase of the amount of enforcement	All severities	overall	Per.Acc.Red.: N=-14%, CI [95%] = [-20;-6]	↓
						increase<200%	Per.Acc.Red.: N=-3%, CI [95%] = [-9;4]	↓
			increase>200%			Per.Acc.Red.: N=-11%, CI [95%] = [-21; -1]	↓	
			Injury		overall	Per.Acc.Red.: N=-14%, CI [95%] = [-20; -8]	↓	
					increase<200%	Per.Acc.Red.: N=-4%, CI [95%] = [-11;3]	↓	
					increase>200%	Per.Acc.Red.: N=-7%, CI [95%] = [-20;9]	↓	
			Fatal		overall	Per.Acc.Red.: N=-23%, CI [95%] = [-34; -10]	↓	
					increase<200%	Per.Acc.Red.: N=-12%, CI [95%] = [-27;8]	↓	
			Change of type of enforcement		All severities	Per.Acc.Red.: N=-21%, CI [95%] = [-29; -13]	↓	
					Injury	Per.Acc.Red.: N=-16%, CI [95%] = [-30;1]	↓	
				Fatal	Per.Acc.Red.: N=-35%, CI [95%] = [-38; -32]	↓		
All measures	All severities	Per.Acc.Red.: N=-18%, CI [95%] = [-23; -13]	↓					
5	Goldenbeld C., Van Schagen, I.; 2005; Netherlands	Mean speed [R-squared]	Speed enforcement*T	R-squared: MS=0.09, F (5,125) = 2.4, p=0.038, a=0.05		↓		
		Percentage of offenders [R-squared]		R-squared: PO=0.07, F (5,125) = 1.9, p=0.096, a=0.10		↓		
		Injury accidents [odds ratio]	Speed enforcement	Odds ratio: IA=-0.79, CI [95%] = [0.66;0.95]		↓		
		Serious traffic casualties [odds ratio]		Odds ratio: C=-0.79, CI [95%] = [0.63;0.99]		↓		

Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative Estimate			Effect on road safety
6	Li R., El-Basyouny K., Kim A., Gargoum S.; 2017; Canada	Monthly Number of Speed-Related Collisions [slope]	Increase of Number of Enforced Sites	Slope: N=-0.032, SE= 0.0059, a=0.01			↓
			Increase of Average Check Length	Slope: N=0.0507, SE= 0.0166, a=0.01			↑
			Increase of Number of Issued Tickets	Slope: N=-0.0946, SE= 0.0083, a=0.01			↓
7	Walter L., Broughton J., Knowles, J.; 2011; United Kingdom	Speed of drivers [absolute difference]	Increase of the level of enforcement	before-after	A23 targeted	Abs. Diff.: S=-1.9 mph	↓*
					other A23 sites	Abs. Diff.: S=-1.0 mph	↓*
				before-during	other A23 sites	Abs. Diff.: S=-0.6 mph	↓*
		before-during		A23 targeted	Per. Ch.: D=-9%	↓*	
				close off-route sites	Per. Ch.: D=-4%	↓*	
				other A23 sites	Per. Ch.: D=-7%	↓*	
↓	denotes positive road safety effects			-	denotes unclear or marginal road safety effects		
	↑			denotes negative road safety effects			*

3.5 REFERENCES

List of coded studies

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Law and enforcement: Random breath tests and DUI checkpoints



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NTUA, May 2017

1 Summary

1.1 COLOUR CODE

Green: The effects of introducing or increasing alcohol-related enforcement actions are mostly positive in reducing crash frequency in general, and alcohol-related fatal accidents in particular. Enforcement, together with laws limiting alcohol concentration, has a deterrent power, discouraging offences. Furthermore, the coded studies exhibit high levels of quality and consistency. For the reasons mentioned above, the overall impact of driving under the influence (DUI) checkpoints and random breath tests is characterized as green (effective).

1.2 KEYWORDS

Random breath tests; DUI checkpoints; crash reduction; road safety; safety countermeasures; young drivers; DWI drivers; fatal crashes

1.3 ABSTRACT

DUI checkpoints and random breath tests are enforcement measures implemented in order to discourage people from driving after drinking. Drivers are tested in order to investigate whether their blood alcohol concentration (BAC) is higher than the legal limit. The implementation of these measures affects the level of road safety, causing a reduction in the number of crashes. Five high quality studies focusing on sobriety checkpoints were coded. On the basis of both study and effect numbers, it can be argued that implementing DUI checkpoints and random breath tests have positive impacts on road safety.

1.4 BACKGROUND

Definition of DUI checkpoints and random breath tests

Driving while impaired checkpoints, and random breath tests, are enforcement measures whereby law enforcement officials stop vehicles on a public roadway and investigate the possibility that the driver might be too impaired to drive due to alcohol. Their blood alcohol concentration is tested and compared with the legal limit. DUI checkpoints are those where every driver who is selected at a checkpoint is tested; random breath tests are those where drivers are tested depending on officials' suspicion. Procedures may vary among countries. Their deterrent effect is linked to laws limiting blood alcohol concentrations: people avoid committing an offence because of the perceived risk of detection and the perceived certainty, severity and swiftness of the punishment following detection.

How do sobriety checkpoints affect road safety?

The implementation of sobriety checkpoints has a deterrent effect on driving after drinking: fines and civil/penal responsibility have an impact on drivers' alcohol habits, resulting in a positive effect on road safety. People who have been detected and punished avoid repeating the behaviour as a consequence. Results show that the implementation of these measures, together with BAC limiting laws, leads to a reduction in the number of alcohol-related accidents.

Which safety outcomes are affected by sobriety checkpoints?

The reviewed studies focus mainly on crashes. In some studies, the main focus is estimating the reduction of the number of crashes due to sobriety checkpoints, either with an absolute difference between before and after the installation, or with the calculation of a model. Some of these studies consider just alcohol-related crashes. One study analyses self-reported drunk drivers.

How is the effect of sobriety checkpoints on road safety studied?

This measure is often examined alongside other measures (i.e. BAC laws, seat belt laws, improved enforcement) and not by itself, since it is difficult to isolate each effect. Models are developed to compensate for other measures and for time trends. The most common approach to test the effectiveness of sobriety checkpoints is a comparison before and after the implementation or increase of the measure, or between exposed and non-exposed sites.

1.5 OVERVIEW OF RESULTS

Overall sobriety checkpoint tests improve the level of road safety: the studies coded report a decrease of crash frequency. Both DUI checkpoints and random breath tests proved effective in reducing fatal alcohol-related crashes and crashes in general. In one study the ratio of alcohol-related fatal crashes among young drivers decreases with the increase of the frequency of DUI checkpoints. Finally, one study shows a reduction of self-reported drunk drivers due to the implementation of random breath tests.

Transferability

The coded studies are based on data from several countries, with most of them being from the United States and Australia. Also studies from Canada, France and Sweden are present in the meta-analyses. Although this is a good sample for general trends in developed countries, there is a lack of studies representing less motorized countries. The effects of these measures are evaluated both among all drivers and young drivers, but the studies do not take into account specific categories (e.g. professional drivers).

Procedures vary among countries which makes them difficult to compare.

Notes on analysis methods

The methodology applied for capturing the impact of sobriety checkpoints on road safety varies between studies. This variation is mainly in terms of the mathematical models. There is also a certain margin for investigating different road user categories and/or other geographical regions. All of the above make the results for DUI checkpoints and random breath tests generally transferable, although relative caution is always required.

2 Scientific overview

2.1 ANALYSIS OF STUDY DESIGNS AND METHODS

After appropriate use of various search tools and databases, five (5) high quality studies were selected and coded to evaluate the effectiveness of DUI checkpoints and random breath tests in diminishing crashes: four studies (Elvik et al. 2009, Erke et al. 2009, Ferris et al. 2013, Romano et al. 2015) examined crashes (fatal, alcohol-related, all types, among young drivers); Cestac et al. (2016) investigated self-reported drunk drivers.

In order to examine the relationship between the exposure and outcome indicators, different models were used: multilevel modelling and regression models (join-point and log-linear); Elvik et al. (2009) and Erke et al. (2009) performed meta-analyses controlling for publication bias through trim and fill analysis.

The relationship between self-reported drunk drivers and roadside breath tests (RBT) found by Cestac et al. (2016) is statistically significant but the estimated effect is small if compared to other variables investigated in the study (cultural and social influences on drunk driving).

The five studies meta-analysed by Elvik et al. (2009) estimated a reduction of fatal crashes that prove to be statistically non-significant. Conversely in the meta-analysis by Erke et al. (2009) 40 studies were combined in order to evaluate the effect of checkpoints on fatal crashes: different measures were examined (new type of enforcement, increased enforcement, DUI checkpoints and random breath tests), with the overall effect being a statistically significant reduction of crashes (all types). The study reports the effects estimated when controlling for publication bias (if possible), and also when not taking it into account. Both approaches show a reduction of fatal crashes, higher in the latter case.

Ferris et al. (2013) developed a linear-log model in order to evaluate the relationship between the increase of random breath tests and alcohol related crashes, per hundred thousand of licensed drivers in Australia. The two jurisdictions investigated have different RBT policies: in Queensland, the ratio of RBT to licensed drivers is maintained close to one, whereas in Western Australia it is close to one third. The correlation found is inverse. The last study coded (Romano et al. 2015) used a structural equation model in order to estimate the direct and indirect effects of 20 underage drinking laws and three general driving safety laws, on alcohol-related crashes involving teens, taking into account the data of 51 US jurisdictions. The frequency with which checkpoints were conducted was coded as "0" if checkpoints were either illegal or otherwise not conducted, "1" if they were conducted infrequently (e.g., only during holidays), and "2" if they were conducted frequently (e.g. on a monthly or weekly basis). The positive correlation obtained in the study is statistically significant.

An overview of the main features of the coded studies (sample, method, outcome and results) is illustrated on Table 1. The studies are marked with [R] or [D] to denote whether they refer to random breath test or to the DUI checkpoint group.

Table 1 Description of coded studies.

Number	Author(s); Year; Country;	Sampling frame for DUI checkpoints investigation	Method for DUI checkpoints investigation	Outcome indicator	Main Result
1 (R)	Cestac J., Kraïem S., Assailly J.P; 2016; France	Questionnaires of 10,023 car drivers from 15 European countries regarding alcohol consumption and driving behaviours were collected;	Multilevel modelling	Self-reported drunk drivers [slope]	The number of breath tests is negatively linked to drunk driving, showing that this measure is efficient in preventing drunk driving. However, the effect is

		the number of roadside alcohol breath tests in 2008 were recorded by the European Transport Safety Council (ETSC, 2010)			small in comparison with cultural and individual-level factors.
2 (R)	Elvik R., Høye A., Vaa T., Sørensen M.; 2009; Norway	5 studies were meta-analysed to examine the effects of introducing random breath test laws on fatal crashes in America.	Meta-analysis; before after	Fatal accidents [percent accident reduction]	The results show a non-significant reduction. No difference has been found between the effects on fatal accidents involving alcohol and on the total number of fatal accidents
3 (RD)	Erke A., Goldenbeld C., Vaa T.; 2009; Norway	40 studies were combined in a meta-analysis to estimate the effectiveness of DUI checkpoints in reducing all type of crashes. The countries analysed are: USA, Canada, Australia, France, Sweden, UK, New Zealand. 116 effect estimates has been obtained or computed from these studies.	Log-odds method; meta-analysis (random effects); test of heterogeneity; trim and fill analysis	Alcohol related accidents [percent accident reduction]	The result of the study is that overall we have a reduction of total crashes due to DUI checkpoints: the reduction is lower if the publication bias is considered.
4 (R)	Ferris J., Mazerolle L., King M., Bates L., Bennett S., Devaney M.; 2013; Australia	The dataset of breath tests is provided by the Traffic Analysis Unit of the states of Queensland and Western Australia state for approximately 10 years. Crash data consist of police attended accidents (July 2004-June 2009)	Join-point regression model; linear-log OLS regression	Alcohol related crashes [absolute difference]	Results show an inverse correlation between alcohol related (RBT) crashes and random breath tests: an increase in the number of RBT leads to a decrease in alcohol related crashes.
5 (D)	Romano E., Scherer M., Fell J., Taylor E.; 2015; USA	Annual fatal crashes from 1982 to 2010 are provided by NHTSA's Fatality Analysis Reporting system (NHTSA, 2013b) for all 51 jurisdictions in the USA.	Structural equation modelling (SEM) techniques with Analysis of Moment-Based Structures (AMOS)	Ratio of the number of alcohol-related fatal crashes among drivers aged 15 to 20 years divided by the number of non-alcohol-related fatal crashes among drivers of the same age group [slope]	The analyses carried out demonstrated that the decrease in alcohol related teen's crashes is associated with the introduction of 0.08 BAC law, zero tolerance law, seat belt laws DUI checkpoints and other laws addressing the problem of alcohol among drivers (20 are analysed). On the other hand, fatal alcohol-related crashes increase when keg registration laws increase.

Limitations

There are limitations in the current literature examining the effects of DUI checkpoints and random breath tests. Firstly, it is not always easy to isolate the effect of the law from time trends, the introduction of other alcohol related laws and other enforcement measures. Secondly, most of the studies were conducted in the United States and Australia, so there is a lack of information concerning the impact of these enforcement measures in different environments, i.e. less motorized countries, European (only France and Sweden are analysed) or Asian countries. Finally, the procedures among different countries and jurisdictions may vary: in the meta-analyses by Erke and al. 2009, checkpoints are listed as "all drivers tested" and "not all drivers tested", because procedures are not reported in the studies.

2.2 ANALYSIS METHODS AND RESULTS

Introduction

The effects of random breath tests and DUI checkpoints on road safety can be summarized as follow:

- 1 study with a small but statistically significant reduction of self-reported drunk drivers;
- 1 study whose small positive effect of introducing random breath tests was not statistically significant;

- 1 study with a statistically significant reduction of alcohol-related crashes due to the increase of random breath tests;
- 1 study where relevant and positive effects are related to DUI checkpoints and random breath tests (new and increased enforcement);
- 1 study with a significant positive effect on alcohol-related fatal crashes involving teens.

The quantitative results of the coded studies, along with their general effects on road safety, are shown in Table 2, which is presented in the supporting document.

After the results were reviewed together, in possible consideration of a meta-analysis, the following points were observed:

- a) There is an adequate number of studies. However,
- b) those studies have used different models for analysis;
- c) there are different indicators, and even when they coincide they are not measured in the same way, and
- d) there are already two meta-analyses in the studies coded, that take into account 45 studies.

Description of analysis carried out

Review-type analysis

After considering the previous points, it was decided that a meta-analysis could not be carried out in order to find the overall impact of DUI checkpoints and random breath tests on road safety. In fact, despite the adequate number of studies, meta-analyses have already been performed. Taking the above into consideration, it was decided that both the meta-analysis and the vote count analysis are inappropriate, and thus the review type analysis was selected. Therefore, the effect of random breath tests and DUI checkpoints will be given via a qualitative analysis. All studies except one (whose reduction is not statistically significant) report positive effects of DUI enforcement on road safety: crashes (fatal, alcohol-related, and all types) and self-reported drink driving all diminish. One study investigated the effects of this type of enforcement on alcohol-related fatal crashes among young drivers and reported a consistent and positive result.

Overall estimate for road safety

On the basis of both study and effect numbers, it can be argued that DUI checkpoints and random breath tests have a positive effect on road safety. In just one study the effect is not statistically significant. As mentioned before, these studies have good levels of quality, and are consistent in their results overall: the fact that two studies are meta-analyses controlling for publication bias and combining 45 studies, makes the overall result consistent.

Conclusion

The review-type qualitative analysis carried out showed that introducing and increasing DUI enforcement has a positive impact on road safety.

3 Supporting document

3.1 IDENTIFYING RELEVANT STUDIES

Literature search strategy

The search strategy aimed at identifying recent studies regarding the implementation of Laws and Enforcement for random breath tests and DUI checkpoints. The main database that was consulted was Scopus. In general, only recent (after 1990) journal studies were considered. However, high quality conference papers and reports were also considered. Moreover, reference lists of individual studies are also examined.

Limitations/ Exclusions:

- Search field: TITLE-ABS-KEY
- Published: 1990 to current
- Document Type: "Review" and "Article"
- Language: "English"
- Source Type: "Journal "
- Only Transport Journals were considered
- Subject Area: "Engineering and Psychology"

Database: Scopus

Date: 28th March 2017

search no.	search terms / operators / combined queries	Hits
#1	(„law“ OR „enforcement“)	522,120
#2	(„drunk driving“ OR „drink driving“ OR „DUI“)	5,168
#3	(„random breath“)	421
#4	#1 AND #2	216

Results of Literature research

Database	Hits
Scopus	421
Total number of studies to screen title	421

3.2 SCREENING

The abstracts of relevant studies from the initial literature search results were examined to narrow the scope and to detect studies that would be more appropriate at a first stage. Those abstracts give hints as to whether the full text warrants close examination for coding and inclusion in the project.

Total number of studies to screen title	Hits
Number of articles remaining after screening of the title = Total number of studies to screen abstract	421
Remaining studies after abstract screening	87
Total number of studies to screen full text	87

3.3 ELIGIBILITY

Total number of studies to screen full-text	87
Full-text could be obtained	87
Reference list examined Y/N	Yes
Eligible papers prioritized	9

3.4 PRIORITIZING CODING

- Prioritizing Step A (existing meta-analyses)
- Prioritizing Step B (most recent studies)
- Prioritizing Step C (Journals over conferences and reports)
- Prioritizing Step D (Prestigious journals over other journals and conference papers)
- Prioritizing Step E (Studies from Europe)

3.5 SUPPORTING QUANTITATIVE TABLE

Table 2 is shown below. It includes all quantitative effects from the coded studies for the measures of DUI checkpoints and random breath tests.

Table 2 Quantitative results of coded studies for DUI checkpoints and random breath tests and impacts on road safety.

Number	Author(s); Year; Country	Outcome indicator	Exposure	Quantitative Estimate		Effect on road safety
1 (R)	Cestac J., Kraïem S., Assailly J.P; 2016; France	Self- reported drunk drivers	Roadside alcohol breath test	Slope=-0.003, se=0.001, p<0.05		↓
2 (R)	Elvik R., Høye A., Vaa T., Sørensen M.; 2009; Norway	Fatal accidents	Introduction of random breath testing laws	Per. Ac. Re = -1%, CI [95%]=[-4 -2]		-
3 (RD)	Erke A., Goldenbeld C., Vaa T.; 2009; Norway	All type of crashes	DUI checkpoints	Overall effect	Per. Ac. Re = -14%, CI [95%]=[-18 -11]	↓
				Not all drivers tested- random breath test	Per. Ac. Re = -15%, CI [95%]=[-19 -10]	↓
				All drivers tested-DUI checkpoints	Per. Ac. Re = -13%, CI [95%]=[-17 -8]	↓
				New enforcement	Per. Ac. Re = -9%, CI [95%]=[-12 -5]	↓
				Increased enforcement	Per. Ac. Re = -16%, CI [95%]=[-23 -11]	↓
4 (R)	Ferris J., Mazerolle L., King M., Bates L., Bennett S., Devaney	Ratio of alcohol related crashes per hundred	Increased random breath tests	33 % increase	Ab. Dif.=0.45, CI [95%]=[0.34 0.56]	↓

Number	Author(s); Year; Country	Outcome indicator	Exposure	Quantitative Estimate		Effect on road safety
	M.; 2013; Australia	thousand of licensed drivers per month		50 % increase	Ab. Dif.=0.64, CI [95%]=[0.49 0.80]	↓
				100 % increase	Ab. Dif.=1.10, CI [95%]=[0.83 1.37]	↓
				200 % increase	Ab. Dif.=1.74, CI [95%]=[1.32 2.17]	↓
				203 % increase	Ab. Dif.=1.76, CI [95%]=[1.34 2.18]	↓
				300 % increase	Ab. Dif.=2.20, CI [95%]=[1.67 2.73]	↓
5 (D)	Romano E., Scherer M., Fell J., Taylor E.; 2015; USA	Ratio of alcohol related fatal crashes among young drivers	Frequency of DUI checkpoints	Slope=-0.0220, p<0.001		↓
↓	denotes positive road safety effects		-	denotes unclear or marginal road safety effects		
↑	denotes negative road safety effects		*	denotes that no statistical analysis was conducted for the significance of the effects		

3.6 REFERENCES

List of coded studies

The list of coded studies is presented here. It is noted that concerning the relevant chapters included in Handbook, the Handbook is cited (Elvik et al., 2009).

Cestac, J. Kraïem; S. & Assailly, J.-P. (2016). Cultural values and random breath tests as moderators of the social influence on drunk driving in 15 countries. *Journal of Safety Research*, 56, 89–96. Doi: <http://dx.doi.org/10.1016/j.jsr.2015.12.001>.

Eisenberg, D. (2003). Evaluating the Effectiveness of Policies Related to Drunk Driving. *Journal of Policy Analysis and Management*, 22(2), 249–274. Doi: 10.1002/pam.10116.

Elvik, R., Sogge, C. V., Lager, L., Amundsen, F. H., Pasnin, L. T., Karlsen, R. & Fosli, K. (2012). Assessing the efficiency of priorities for traffic law enforcement in Norway. *Accident Analysis and Prevention*, 47, 146–152. Doi: 10.1016/j.aap.2012.01.017.

- Elvik, R., Høye, A., T. & Sørensen, M. (2009). *The Handbook of Road Safety Measures Second Edition*. Emerald Group Publishing Limited.
- Erke, A., Goldenbeld, C. & Vaa, T. (2009). The effects of drink-driving checkpoints on crashes-A meta-analysis. *Accident Analysis and Prevention*, *41*(5), 914–923. Doi: <http://doi.org/10.1016/j.aap.2009.05.005>.
- Høye, A. (2009). DUI enforcement. *The Handbook of Road Safety Measures, Norwegian (online) version*. Doi: <http://tsh.toi.no/index.html?22743>.
- Ferrisa, J., Mazerolle, L., King, M., Bates, L., Bennett, S. & Devaney, M. (2013). Random breath testing in Queensland and Western Australia: Examination of how the random breath testing rate influences alcohol related traffic crash rates. *Accident Analysis and Prevention*, *60*, 181–188. Doi: <http://dx.doi.org/10.1016/j.aap.2013.08.018>.
- Romano, E., Scherer, M., Fell, J. & Taylor, E. (2015). A comprehensive examination of U.S. laws enacted to reduce alcohol-related crashes among underage drivers. *Journal of Safety Research*, *55*, 213–221. Doi: <http://dx.doi.org/10.1016/j.jsr.2015.08.001>.

Seatbelt law and enforcement



Alfonsi, R., Meta, E., Ammari, A., May 2017

1 Summary

1.1 COLOUR CODE

Green: On the basis of the existing literature, the law mandating the use of seatbelts, and related enforcement activities, produce positive effects on road safety. In combination, they are particularly effective. In general, it can be observed that an increase in seatbelt use reduces/mitigates road safety risk, and reduces the number of fatalities and severe injuries.

1.2 KEY WORDS

seat belt usage, enforcement, law, legislation, primary enforcement law, secondary enforcement law, general deterrence, publicity

1.3 ABSTRACT

Seat belt legislation aims at establishing a system of incentives/ disincentives for road vehicle users, to induce safer traffic behaviour as a result of using this type of protective equipment. The discipline is heterogeneous, as countries or states can address user categories differently (e.g. front seat occupants, rear seat occupants). Law enforcement dictates the way to secure or improve traffic law compliance and it refers both to the surveillance activity and the imposition of penalties. In the United States (examined by most of the studies) the distinction between Primary and Secondary Enforcement Law is significant. The secondary measures allow police to punish the omitted seatbelt use "per se", without requiring the coexistence of other types of violations, and thus produces the best road safety results. The existence of seatbelt legislation, sustained by the enforcement activities, induces a significant safety improvement in the behaviour of road users. This improvement can be seen in terms of seatbelt usage, which is also linked to a decrease in the number of fatalities and a mitigation of injury severity.

1.4 BACKGROUND

1.4.1 What are seatbelt law and enforcement?

Within a safe system approach, the seatbelt law aims at regulating the use of this type of protective equipment by making it compulsory. The actual compliance with the law is achieved through the enforcement activity, which operates at different levels (surveillance, law process, punishment) and in different ways.

1.4.2 How does seatbelt law and enforcement affect road safety?

Seatbelt law and enforcement induce safer behaviour in road users as a result of widespread use of this protective equipment, due to a system of incentives/disincentives (e.g. fines, demerit points). The effectiveness of these varies according to the specific legislative framework (e.g. user categories affected, primary or secondary enforcement law) and the specific characteristics of the enforcement activity (e.g. actual efforts, road user awareness).

1.4.3 Which safety outcomes are affected by seatbelt law and enforcement?

In the literature, the safety effects of seatbelt law and enforcement are measured primarily in terms of seatbelt usage amongst road users, reduction of fatalities, and variation in injury severity.

1.4.4 How is the effect of seatbelt law and enforcement studied?

The effect of seatbelt law and enforcement is typically examined using before-after studies, by comparing the percentage of road users wearing seatbelts, the number of fatalities, and the distribution of injuries among the different categories of severity.

1.4.5 Which factors influence the law and enforcement on road safety?

The effectiveness of the seatbelt law is dependent on the specific framework implemented, in terms of user categories affected, and also on the characteristics of the enforcement system. The enforcement system is effective if implemented in a supportive physical and social environment encompassing road design, laws, regulations, safe traffic culture, and a sensitive penal system.

1.5 OVERVIEW OF RESULTS

The results illustrate that seatbelt law and enforcement have a positive effect on road safety by increasing seatbelt usage, reducing the number of fatalities, and mitigating the severity of the injuries. The combination of law and an effective enforcement system produces the best output. In the United States, the primary enforcement law proves to be more effective than the secondary enforcement law. The primary enforcement law permits the punishment of omitted seatbelt use alone, whilst the secondary law allows it only in the presence of other types of violations.

An analogous effect is produced in the European context. In fact, the implementation of a seat belt Law or the release of more strict regulations (e.g. demerit point system), together with the enforcement activities, are linked to a seatbelt usage increase and a mitigation of the negative consequences of the accidents.

The validity of the results of the coded studies does not seem be affected by limitations due to the methodology.

2 Scientific overview

2.1 THERORETHICAL BACKGROUND

Aim and method of seatbelt Law and enforcement

The introduction of a seatbelt law, in conjunction with revision of the existing laws, aims at defining the use of such protective device as socially desirable. This is deemed to mitigate against the negative consequences for road users in the event of an accident, in terms of fatalities and injury severity. The law sets up a system of incentives/disincentives to encourage road users to comply, and the practical enforcement activities are necessary to make it operative. Seat belt law enforcement, undertaken by the Police authorities, is constituted by the activities of surveillance and penalties imposition. The surveillance largely relies on man-made checks, while the offenders can be punished either by the imposition of fines alone (monetary sanctions), or by a combination of fines and demerit point system penalties (non-monetary sanctions).

Effects and influencing factors

Analogous to the regulation of other road safety issues, seatbelt law design and its related enforcement require primarily a supportive social and cultural environment, where the relevance of the objective pursued by the public authorities is recognized and shared. Moreover, the effectiveness of the enforcement depends on effective penalties, its visibility (citizens' awareness) and on the fair cooperation of all authorities involved in the process.

2.2 CODED STUDIES

2.2.1 Description of studies

Results are predominantly based on studies undertaken in the United States, evaluating the impact of:

- mandatory seatbelt law (Christopher et al, 2007; Wagenaar et al, 1990)
- enhancement of the enforcement through the shift from a secondary to a primary law (Koziol et al., 2013; Douma et al., 2012; Nichols et al., 2014)
- fine levels (Nichols et al., 2014)
- enforcement activity (Thomas et al., 2017)

The studies adopt a before-after methodology, combined with observational approaches. They utilise time-series analysis or employ cross-sectional methodology to compare the performance of the different legislative contexts of States. The considered outcome variables are defined in terms of seatbelt use, fatalities, type of injuries, and use of medical services. The fatalities are addressed overall, and in relation to whether or not a seatbelt was in use. Similarly, the injuries are presented according to the different types. Finally, the use of medical care is presented in terms of length of hospital stay.

The results appear to be unaffected by publication bias.

Table 1 illustrates an overview of the main aspects of coded study (sample, method and outcome).

Table 1 Description of coded studies

Author(s), Year, Country	Measure description	Method of analysis	Outcome indicator
Koziol et al., 2013, United States	Shifting from the secondary to the primary enforcement seatbelt law	Before – after; observational	Injury type
Douma et al, 2017, United States	Shifting from the secondary to the primary enforcement seatbelt law	Observational, before –after	Injury type
Carpenter et al, 2007, United States	Primary enforcement seatbelt law	Quasi experimental	Self-reported seatbelt use; highway fatalities; crash related injuries
Wagenaar et al, 1990, United States	Mandatory safety belt law for front-seat occupants	Time-series	Type of injury; length of stay at hospital
Thomas et al, 2017, United States	Primary enforcement seatbelt law; night time enforcement campaign	Before - after	Night time occupant fatalities; day time occupant fatalities; night-time occupant seatbelt use; day time occupant seatbelt use
Nichols et al, 2014, United States	Primary enforcement seatbelt law; fine levels	Cross- sectional	Seat belt use among occupants involved in fatal crashes

2.3 OVERVIEW OF RESULTS

The coded studies show a positive road safety effect associated with seatbelt law implementation and related enforcement activities. Positive effects can be seen when the law comes into force, but these are sustained and strengthened by enforcement activity. Where applicable, the seatbelt primary enforcement law proves to be more effective than the secondary enforcement law. The investigated outcome variables are: seatbelt use, number of injuries and fatalities, and injury severity. The seatbelt usage shows a general increase with the shifting from the secondary enforcement law to the primary enforcement law (Carpenter et al., 2007; Nichols et al., 2014) together with the conduction of highly visible enforcement campaigns (Thomas et al., 2017). Analogously, the legislative regulation and stricter enforcement are linked to a decrease in the number of fatalities and injuries (Carpenter et al, 2007; Thomas et al., 2017). A general mitigation of the severity of road accident consequences is also observed (Wagenaar et al., 1990; Dumas et al., 2017; Koziol et al., 2013).

Modifying conditions

One factor that might influence the effectiveness of seatbelt law and enforcement is the correct use of the protective equipment. Moreover, the enforcement campaigns are influenced by the visibility of the actions of authorities.

2.4 CONCLUSION

Main results

The analysed studies show that the implementation of mandatory seatbelt law, in conjunction with an effective enforcement system, generates substantially positive road safety consequences in terms of reduction in the number of fatalities, mitigation of the severest type of injuries, and increase in seatbelt usage. In the United States, the primary enforcement law proves to be more effective than the secondary enforcement law. When highly visible to road users, specific enforcement activity is linked to positive road safety consequences.

The results of the coded studies, all originating from the US, seem to be transferred to the European context. In fact, there are analogous evidences in the European literature (ETSC, 2001; Avossa et al, 2007).

3 Supporting document

3.1 CODED STUDIES RESULTS

In the following tables are reported the results of the coded studies.

Table 2 Main outcomes of coded studies for seatbelt law and enforcement.

Author, Year, Country	Exposure variable	Outcome variable / Outcome type	Effects*		Main outcome - description
Koziol et al., 2013, United States	Seatbelt enforcement primary law	Injury rate/1.000 inhabitants; (injury type "K"); age 13-29	(–)	0,1	No significant variation in the injury rate for this type of injury
		Injury rate/1.000 inhabitants; (injury type "A"); age 13-29	(–)	1,1	No significant variation in the injury rate for this type of injury
		Injury rate/1.000 inhabitants; (injury type "B"); age 13-29	(↘)	3,2	The injury rate for this type of injury is significantly smaller of the previous one (3,8)
		Injury rate/1.000 inhabitants; (injury type "C"); age 13-29	(↘)	21,5	The injury rate for this type of injury is significantly smaller of the previous one (22,4)
		Injury rate/1.000 inhabitants; (injury type "O"); age 13-29	(↘)	165,1	The injury rate for this type of injury is significantly smaller of the previous one (173,5)
		Injury rate/1.000 inhabitants; (injury type "K"); age 30-59	(–)	0,1	No significant variation in the injury rate for this type of injury
		Injury rate/1.000 inhabitants; (injury type "A"); age 30-59	(–)	0,7	No significant variation in the injury rate for this type of injury
		Injury rate/1.000 inhabitants; (injury type "B"); age 30-59	(–)	1,6	No significant variation in the injury rate for this type of injury
		Injury rate/1.000 inhabitants; (injury type "C"); age 30-59	(–)	14,6	No significant variation in the injury rate for this type of injury
		Injury rate/1.000 inhabitants; (injury type "O"); age 30-59	(–)	114,8	No significant variation in the injury rate for this type of injury
		Injury rate/1.000 inhabitants; (injury type "K"); age over 60	(–)	1,0	No significant variation in the injury rate for this type of injury

		Injury rate/1.000 inhabitants; (injury type "A"); age over 60	(-)	4,0	No significant variation in the injury rate for this type of injury
		Injury rate/1.000 inhabitants; (injury type "B"); age over 60	(-)	11,0	No significant variation in the injury rate for this type of injury
		Injury rate/1.000 inhabitants; (injury type "C"); age over 60	(-)	88,0	No significant variation in the injury rate for this type of injury
		Injury rate/1.000 inhabitants; (injury type "O"); age over 60	(-)	823,0	No significant variation in the injury rate for this type of injury
		Fatalities by no use of restraint (%)	(↗)	62,9	Significant decrease in the fatalities linked to the no use restraint (- 3,8)
Doumas et al, 2017, United States	Seatbelt enforcement primary law	Expected change in the injury type "K"	(↘)	67,7	Significant decrease for this type of injury
Expected change in the injury type "A"		(↘)	320,8	Significant decrease for this type of injury	
Expected change in the injury type "B"		(↘)	431,8	Significant decrease for this type of injury	
Expected change in the injury type "C"		(↗)	-809,6	Significant increase for this type of injury	
Expected change in the injury type "O"		(-)	721,7	No significant variation for this type of injury	
Carpenter et al, 2007, United States	Seatbelt enforcement primary law	self-reported seatbelt use difference (1991-2005);	(↘)	+45%	Significant percentage increase in the reported seatbelt use between the two periods
highway fatalities (1991-2005);		(↘)	-8%	Significant percentage decrease in the number of fatalities between the two periods	
crash-related injuries (1991-2005)		(↘)	-9%	Significant percentage decrease in the number of crash related injuries between the two periods.	
Wagenaar et al, 1990, United States	Seatbelt law for front seat occupants	% change in the rate of admitted patients with Head injury	(-)	-13,1%	No significant percent change in the weight of this type of injury

		% change in the rate of admitted patients with Neck injury	(-)	-11,3%	No significant percent change in the weight of this type of injury
		% change in the rate of admitted patients with Back injury	(-)	-23,8%	No significant percent change in the weight of this type of injury
		% change in the rate of admitted patients with Thorax injury	(-)	-0,97%	No significant percent change in the weight of this type of injury
		% change in the rate of admitted patients with Abdomen injury	(-)	-14,5%	No significant percent change in the weight of this type of injury
		% change in the rate of admitted patients with Extremity injury	(↘)	-20,4%	Significant reduction in the rate of patients with extremity injuries
		Rate of injuries requiring hospitalization	(↘)	-19,3%	Significant reduction in the rate of the severe injuries
Thomas et al, 2017, United States	Seatbelt enforcement primary law	Day time occupant fatalities	(↘)	- 2,1 (absolute difference)	Significant reduction in the monthly number of fatalities
		Night time occupant fatalities (controlled for day time)	(-)	-2,1 (absolute difference)	Not significant reduction in the monthly number of fatalities
		Day time occupant seat belt use among fatally injured occupants (%)	(↘)	-15,1%	Significant reduction of fatally injured persons wearing a seatbelt
		Night time occupant seat belt use among fatally injured occupants (controlled for day time) (%)	(↘)	-15,5%	Significant reduction of fatally injured persons wearing a seatbelt
		Day time occupant seat belt use among fatal crash involved (%)	(↘)	-13,7%	Significant reduction of fatal crash people involved wearing a seatbelt
		Night time occupant seat belt use among fatal crash involved (controlled for day time)	(↘)	-12,6%	Significant reduction of fatal crash people involved wearing a seatbelt

		Day time occupant fatalities	(↘)	- 4,1 (absolute difference)	Significant reduction in the monthly number of fatalities
		Night time occupant fatalities (controlled for day time)	(-)	-2,9 (absolute difference)	Not significant reduction in the monthly number of fatalities
		Day time occupant seat belt use among fatally injured occupants (%)	(↘)	- 6,1%	Significant reduction of fatally injured persons wearing a seatbelt
	Night time enforcement campaign	Night time occupant seat belt use among fatally injured occupants (controlled for day time) (%)	(-)	-3,6%	Not significant reduction of fatally injured persons wearing a seatbelt
		Day time occupant seat belt use among fatal crash involved (%)	(↘)	-7,1%	Significant reduction of fatal crash people involved wearing a seatbelt
		Night time occupant seat belt use among fatal crash involved (controlled for day time)	(-)	-2,4%	Not significant reduction of fatal crash people involved wearing a seatbelt
Nichols et al, 2014	Seatbelt enforcement primary law	Seat belt usage (%)	(↘)	+9,2% higher the use rate with primary law with respect to secondary law	Significant contribution of the primary law in comparison with the secondary law

*Significant effects on road safety are coded as: positive (↘), negative (↗) or non-significant (-)

3.2 METHODOLOGY

3.2.1 Literature Search strategy

The literature search was conducted in January-March 2017, with the objective of identifying the most recent studies in relation to the contribution of seatbelt law and enforcement to road safety.

The search was conducted using the "Scopus" database and referred to that commonly known as grey literature. The following tables report the Scopus search methodology, the results and the screening steps.

Table 3 Literature search strategy (Scopus database) - Date: 16 January 2017

search no.	search terms / operators / combined queries	hits
#1	"Law" OR "Enforcement"	1,150
#2	"Seat belt" OR "protective device" OR "restraint"	21,340
#3	#1 AND #2	82

Table 6 Results Literature Search

Database	Hits
Scopus (remaining papers after several limitations/exclusions)	82
Total number of studies to screen title/ abstract	82

Table 7 Screening results

Total number of studies to screen title/ abstract	82
-De-duplication	0
-exclusion criteria A (e.g. part of a meta-analysis)	10
-exclusion criteria B (e.g. no measure)	40
-exclusion criteria C (e.g. poor evaluation)	20
-exclusion criteria D	
Remaining studies	12
Not clear (full-text is needed)	6
Studies to obtain full-texts	12

3.3 LIST OF CODED STUDIES

Carpenter, C., Stehr M. "The effects of mandatory seatbelt laws on seatbelt use, motor vehicle fatalities and crash related injuries among youths", 2007, National Bureau of Economic Research - NBER Working Paper No. 13408

Douma, F., Tilahun, N. "Impacts of Minnesota's Primary Seat Belt Law", 2012, University of Minnesota

Nichols, J., Tippetts, S., Fee, J., Eichelberger, A., Haseltine, P. "The Effects of Primary Enforcement Laws and Fine Levels on Seat Belt Usage in the United States", 2014, Traffic Inj Prev. 2014;15(6):640-4.

Koziol, J., Pearlman D., Lovera, F., "Impacts of Rhode Island's Primary Seat Belt Law", 2013, Rhode Island Department of Health

Thomas, F., Blomberg, R., Masten, S., Peck, R., Van Dyk, J., Cosgrove, L. "Evaluation of the Washington Nighttime Seat Belt Enforcement Program", 2017, NHTSA

Wagenaar, A. "Effects of a mandatory safety belt law on hospital admissions", 1990, Accident Analysis & Prevention, Volume 22, Issue 3, June 1990, Pages 253-261

3.4 OTHER STUDIES

Avossa F., Brocco S., Fedeli U., Marchesan M., Spolaore P., Visentin C., Zambon F. "Evidence-based policy on road safety: the effect of the demerit points system on seat belt use and health outcomes", 2007, J Epidemiol Community Health

Bhatti, J., Ejaz, K., Razzak, J. "Influence of an Enforcement Campaign on Seat-Belt and Helmet Wearing, Karachi-Hala Highway, Pakistan", 2011, Ann Adv Automot Med. 2011 Oct; 55: 65-70.

Cohen A., Einav L. "The effects of mandatory seatbelt laws on driving behaviour and traffic fatalities", 2003, The Review of Economics and Statistics, November 2003, 85(4): 828-843

Dee, T. "Reconsidering the effects of seat belt laws and their enforcement status", 1998, Accident Analysis & Prevention Volume 30, Issue 1, January 1998, Pages 1-10

ETSC – European Transport Safety Council, "Raising compliance with road safety law", 2011

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Law and enforcement: Lowering BAC limits & BAC limits for specific groups (novice)



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NTUA, May 2017

1 Summary

1.1 COLOUR CODE

Light Green

The effects of laws introducing BAC limits are mostly positive in reducing crash frequency and reducing especially the number of mainly alcohol-related fatal/injury accidents. The per-se law, together with enforcement and other DWI laws, has a deterrent power that discourages offences. Furthermore, the coded studies have some good levels of quality and consistency. On the other hand, many studies showed no effect on road safety and two studies indicated an increase of fatal crashes. For the reasons mentioned above, the overall impact of BAC laws is characterized as light green (effective).

1.2 KEYWORDS

BAC limits; crash reduction; road safety; safety countermeasures; young drivers; DWI drivers; fatal and injury crashes

1.3 ABSTRACT

Laws limiting blood alcohol concentration have been introduced worldwide in order to diminish the frequency of alcohol-related fatal/injury crashes. These laws (and their implementation) aim to discourage drivers from drinking and driving. Zero tolerance laws were introduced for young drivers, in order to address the issue of driving while impaired among inexperienced drivers. The implementation of these laws, either alone or combined with other DWI laws and enforcement, affects the level of road safety and causes a reduction in the number of crashes. Ten high quality studies involving lowering BAC limits were coded. On the basis of both study and effect numbers, it can be argued that limiting BAC for drivers create positive impacts on road safety. However, some scarce cases reported opposite results, indicating increases in total crashes.

1.4 BACKGROUND

Definition of Blood Alcohol Concentration limits

Blood Alcohol Concentration limits have been introduced in order to reduce the frequency of crashes, especially alcohol-related fatal crashes. The limits investigated in the studies vary from 0.10 to 0.03 for general drivers and between 0.02 and 0.01 for young drivers (less than 21 years old). Over the years, several laws have been passed in order to lower BAC limits, thus dissuading people from driving after drinking. Laws tackling the alcohol problem among novice drivers were implemented because of the significant proportion of crashes involving young people (due to their inexperience).

How do BAC limits affect road safety?

The introduction of legislation for BAC limits has a deterrent effect on driving after drinking: fines and civil/penal responsibility have an impact on drivers' alcohol habits, resulting in a positive effect on road safety. Results show that the implementation of these laws, together with other DUI laws and sanctions, leads to a reduction in the number of alcohol-related accidents.

Which safety outcomes are affected by BAC limits?

The reviewed studies focus mainly on crashes. In some studies, the main focus is estimating the reduction in the number of crashes as a result of changes in BAC limits, either with an absolute difference between before and after the installation or with the calculation of a model. Some of these studies consider just alcohol-related crashes. One study analyses police-reported young drivers in fatal crashes, whereas another investigates self-reported driving after drinking (data from questionnaires).

How is the effect of BAC limits on road safety studied?

This measure is often examined alongside others (i.e. DUI laws, seat belt laws, improved enforcement) and not by itself, since it is difficult to isolate each effect. Models are developed to control for other

measures and for time trends. The most common approach to test the effectiveness of BAC laws is a comparison before and after the introduction of the law or between exposed and non-exposed sites.

1.5 OVERVIEW OF RESULTS

Overall, BAC limits improve the level of road safety: the studies coded report a decrease in crash frequency. BAC limits (in general, and for novice drivers in particular) proved effective in reducing fatal and injury crashes that were alcohol-related. Conversely, one study finds an increase in total crashes, and another finds an increase in the number of fatally injured drivers with no alcohol concentration in their blood. In one study the ratio of novice offences before and after the introduction of BAC limits for young drivers decreased, but only slightly. Finally, one study identifies a reduction of mean BACs, which is not consistent.

Transferability

The coded studies are based on data from several countries; most are from the United States and Australia. Also studies from Canada, Austria, Serbia have been coded. Although this is a good sample for general trends in developed countries, there is a lack of studies representing less motorized countries. Most studies simply distinguish between young drivers and all drivers, and do not take into account specific categories such as professional drivers.

Notes on analysis methods

The methodology applied for capturing the impact of BAC laws on road safety varies considerably between studies. The variation is mainly in terms of the mathematical models. There is also a certain margin for investigating different road user categories and/or other geographical regions. All of the above make the results for BAC limits generally transferable, although relative caution is always required.

2 Scientific overview

2.1 ANALYSIS OF STUDY DESIGNS AND METHODS

After appropriate use of search tools and databases, ten (10) high quality studies were selected and coded to evaluate the effectiveness of laws introducing or lowering BAC limits, both for all drivers and for young drivers. Seven studies (Bartl et al. 2000, Blais et al. 2015, Blomberg 1992, Elvik et al. 2009, Romano et al. 2015, Streff et al. 1997, Tippetts et al. 2005, Zwerling et al. 1998) investigated the effects of BAC limits on crashes (fatal and injury, alcohol-related and non-alcohol-related); Streff et al. 1997 also investigated the number of offences in young drivers; Zivkovic et al. 2013 analysed the mean BAC in drivers, whereas Wagenaar et al. 2001 examined self-reported drivers after drinking.

In order to examine the relationship between the exposures and outcome indicators, different models were used: three studies employed time-series analysis (ARIMA, Box-Jenkins); other studies performed mixed effect models, before and after comparisons. Elvik et al. 2009 performed four meta-analyses taking into account both novice drivers and all drivers.

The first study (Bartl et al. 2000) reports a significant reduction of alcohol-related injury accidents. Blais et al. 2015 also analysed fatally injured drivers, reporting a decrease in those having $BAC > 0$ and an increase in $BAC = 0$ (no statistical analysis was done on the data). They also created a linear-mixed effects model to analyse DWI incidents and persons charged for DWI, which proved to be not statistically relevant. The study carried out by Tippetts and al. (2005) in 19 states (USA) found a statistically significant correlation between fatal crashes and 0.08 BAC limits law in eight jurisdictions and in the overall results. Conversely, in the remaining jurisdictions the results were not statistically relevant and sometimes even negative (an increase of fatal crashes in Idaho, Oregon and Texas).

The meta-analyses of studies carried out by Elvik et al. 2009 examine both fatal accidents in general and alcohol-related crashes in particular, resulting in a statistically significant decrease. However, when analysing the effects of BAC limits for young drivers, the effects are controversial (increase of fatal crashes).

Blomberg (1992) found a strong decrease in the number of reported fatal crashes involving young drivers who had been drinking. Furthermore, a study by Streff et al. (1997) identified a consistent reduction in alcohol-related fatal and severe crashes, whereas no statistical significance was found in other types of crashes. In the report the number of offences prior and after introducing BAC limits for young drivers was also investigated: an increase was observed, but according to the author it was only slight.

When analysing crashes involving novice drivers, Zwerling et al. (1998) observed an overall decrease. Similarly, the models by Romano et al. (2015) were statistically significant for the relationship between alcohol-related fatal crashes involving teens, and the introduction of BAC limits both in general and for the specific category.

The decrease in the mean BAC observed by Zivkovic et al. (2013) was not statistically significant. Wagenaar et al. (2001), examining self-reported drinking and driving, identified a statistically significant percentage change (reduction) when taking into account BAC limits for young drivers.

An overview of the main features of the coded studies (sample, method, outcome and results) is illustrated in Table 1. The studies are marked with [B] or [N] to denote whether they refer to BAC limits in general or to the novice-specific group.

Table 1 Description of coded studies.

Number	Author(s); Year; Country;	Sampling frame for BAC limits investigation	Method for BAC limits investigation	Outcome indicator	Main Result
1 (B)	Bartl G., Esberger R.; 2000; Austria	Official data on injury accidents were collected both 22 months before and after the introduction of the law in 1998	Before-after analysis	Number of alcohol related injury accidents [percentage change]	In the short term there was a significant decrease of the number of alcohol related injury accidents. This could be related also to the publicity campaigns or increased police enforcement.
2 (B)	Blais E., Bellavance F., Marcil A., Carnis L.; 2015; Canada	Data on the number of drivers fatally injured in motor vehicle crashes and the percent of those who had been drinking before the crash were extracted from the Traffic Injury Research Foundation (TIRF) reports in Canada from 1987 to 2010.	Linear mixed effects model	Fatally Injured drivers [absolute difference of averages, slope]; DWI incidents [slope]; Persons charged for DWI [slope]	Administrative BAC laws were effective in reducing the percentage of fatally injured drivers. On the other hand, the introduction of administrative laws did not lead to changes in the DWI incident rate nor in the probability of being charged for DWI.
3 (N)	Blomberg, Richard D.; 1992; USA	The data used is crash-involved had-been-drinking (HBD) young drivers (<21 y.o.) either based on quantitative tests or upon officers' judgement. Data were collected between 1985 and 1990 in Maryland. The law was introduced in 1989. 169,196 data entries were analysed.	Univariate time series model (Box-Jenkins time series)	Number of crash-involved HBD young drivers (< 21 y. o.) [slope]	The reduction in the number of HBD drivers in the state of Maryland due to the introduction of 0.02 BAC limits for novice is analysed through the model. The observed reduction was not the result of a general decrease in alcohol-involved crashes or in all crashes involving drivers under 21.
4 (B)	Elvik R., Høye A., Vaa T., Sørensen M.; 2009; Norway (1)	8 studies were combined to analyse the reduction of fatal crashes due to the introduction of BAC limits laws in 2001 in the USA. The results are consistent between the studies and do not seem to be affected by confounding variables or publication bias.	Meta-analysis; before after	Fatal accidents [percent accident reduction]	A significant reduction of crashes is the result of the meta-analysis. Large variation in the effectiveness of per se laws has been found between different states.
5 (B)	Elvik R., Høye A., Vaa T., Sørensen M.; 2009; Norway (2)	4 studies were combined to analyse the reduction of alcohol related crashes due to the reduction of BAC limits from 0.08 to 0.05 in New South Wales and in Queensland (Australia) in 1980 and 1982 respectively. Fatal crashes, injury crashes and daytime injury crashes are examined (it is not specified if daytime injury crashes are alcohol related).	Meta-analysis; before after	Alcohol related accidents [percent accident reduction]	Lowering BAC limits from 0.08 to 0.05 leads to a reduction of alcohol related fatal and injury crashes. Moreover, in the period analysed, the studies report a reduction of daytime injury crashes.
6 (B)	Elvik R., Høye A., Vaa T., Sørensen M.; 2009; Norway (3)	2 studies were analysed in a meta-analysis to evaluate the effects of lowering BAC limits in Sweden in 1990.	Meta-analysis; before after	Fatal and injury accidents [percentage accident reduction]	The analyses conducted reported a significant decrease of the number of fatal and injury accidents. It is not unlikely that the results are affected by confounding variables (time trends, other DUI laws, doubling of the number of random breath tests in the same time period).
7 (N)	Elvik R., Høye A., Vaa T., Sørensen M.; 2009; Norway (4)	8 studies were combined to analyse the effects of introducing BAC limits (0.01 or 0.02) for young drivers in the USA and Australia.	Meta-analysis; before after	Accidents involving alcohol [percent accident reduction]	The number of fatal accidents involving alcohol with young drivers decreased significantly after the introduction of reduced BAC limits for young drivers. No effects have been found on other fatal accidents or on injury accidents.

Number	Author(s); Year; Country;	Sampling frame for BAC limits investigation	Method for BAC limits investigation	Outcome indicator	Main Result
8 (N)	Romano E., Scherer M., Fell J., Taylor E.; 2015; USA	Annual fatal crashes from 1982 to 2010 are provided by NHTSA's Fatality Analysis Reporting system (NHTSA, 2013b) for all 51 jurisdictions in the USA.	Structural equation modelling (SEM) techniques with Analysis of Moment-Based Structures (AMOS)	Ratio of the number of alcohol-related fatal crashes among drivers aged 15 to 20 years divided by the number of non-alcohol-related fatal crashes among drivers of the same age group [slope]	The analyses carried out demonstrated that the decrease in alcohol related teen's crashes is associated with the introduction of 0.08 BAC law, zero tolerance law, seat belt laws DUI checkpoints and other laws addressing the problem of alcohol among drivers (20 were analysed). On the other hand fatal alcohol-related crashes increase when keg registration laws increase.
9 (N)	Streff F.M., Hopp M.L.; 1997; USA	Data are collected from the Michigan Department of State Master Driving Record(MDR), to determine the number of underage (<21 years old) zero tolerance, drunk driving, offences prior to and subsequent to implementation of the law. Monthly crash, death, and injury frequencies for alcohol-related and single-vehicle night-time crashes were extracted for a 4-year period preceding the zero-tolerance law (January 1990 through October 1994, excluding 1992) and twenty-six months after zero- tolerance enactment (November 1994- December 1996).	ARIMA time series analysis; before after	Ratio of offences per thousand licensed drivers (young drivers) [percentage change]; Alcohol related crashes (young drivers) [slope]; Number of crash injuries (young drivers) [slope]	A decrease in youth had-been-drinking fatal and severe injury crashes, as well as a decrease in fatal and severe crash injuries are the results of the analysis. Because the only changes found are in youth had-been-drinking fatal and serious crashes, the results suggest that zero-tolerance had an effect, significantly reducing the number of youth alcohol-involved fatal and severe injury crashes and subsequent fatal and serious injuries.
10 (B)	Tippetts A. S., Voasa R. B., Fella J. C., Nichols J.L.; 2005; USA	Fatal crashes data were collected from 1983 through 2000 from the Fatality Analysis Reporting System (FARS) for 19 jurisdictions in the US.	Time series analysis; ARIMA analysis; Composite meta-analysis	Drinking drivers in fatal crashes [slope]	16 jurisdictions showed reductions in the drinking drivers ratio following implementation of the .08 law, and eight of the reductions were statistically significant.
11 (N)	Wagenaar A. C., O'Malley P. M., LaFond C.; 2001; USA	Data from questionnaires (1985 - 1998) in high schools all over the US were analysed, three years before the introduction of the law and three years after its introduction. The sample is made of at least 5,000 cases both at baseline and follow-up.	Pre-post design with repeated but separate cross-sectional probability samples	Times driving after drinking alcohol (young drivers) [percentage change of the mean values]	The introduction of BAC limits for young drivers in the US lead to a decrease in the self-reported driving after drinking and driving after heavy drinking.
12 (B)	Zivkovic V., Nikolic S., Lukic V., Zivadinovic N., Babic D.; 2013; Serbia	Data of fatally injured drivers in Serbia were collected from 2006 to 2011 from the national Road Traffic Safety Agency of the Republic of Serbia. To estimate the BAC in crash accidents, 161 fatally injured drivers, who died at the scene of accident before and after the application of the new law are analysed: all victims died at the scene of the incident before being admitted to hospital. Blood samples were obtained during the autopsy, 12-36h after the victim's death.	Kolmogorov-Smirnov test for normal distribution; Student T-test and one-way ANOVA were used in variables with parametric distribution	Mean BAC [absolute difference]	The decrease in the mean BAC is not statistically significant.

Number	Author(s); Year; Country;	Sampling frame for BAC limits investigation	Method for BAC limits investigation	Outcome indicator	Main Result
13 (BN)	Zwerling C, Jones M. P.; 1998; USA	The data on novice drivers' injury and fatal crashes from five studies were analysed in Australia and the United States. Each study takes into account different BAC limits (0.00, 0.02, 0.05) and different drivers' ages (16-21). The number of crashes considered is 20,630 (test group) and 144,847 (control group)	Difference between the ratio of the control group and the ratio of the target group; the ratios are calculated as the crashes after the introduction of the law divided by the sum of crashes before and after the introduction of the law.	Crashes of novice drivers [absolute difference]	All the studies identify a reduction of crashes after the implementation of the law.

Limitations

There are limitations in the current literature examining the effects of introducing BAC limits for drivers in general and for novice drivers specifically. Firstly, it is not always easy to isolate the effect of the law from time trends, the introduction of other DUI laws and other enforcement measures. Some studies have controlled for these possible biases. Secondly, some data have not been statistically tested (no statistical tests). Furthermore, most of the studies come from the United States and Australia, so there is a lack of information concerning the impact of BAC limits in different environments, i.e. less motorized countries, European (only Austria, Sweden and Serbia are analysed) or Asian countries.

2.2 ANALYSIS METHODS AND RESULTS

Introduction

The effects of introducing or lowering BAC limits on road safety can be summarized as follow:

- 5 studies with a statistically significant reduction of alcohol-related fatal and injury crashes;
- 1 study with an observed decrease of fatally injured drivers with BAC>0 and an observed increase of fatally injured drivers with BAC=0, though without any statistical analysis;
- 1 study with statistically significant positive effects and non-statistically significant positive and negative effects on drinking drivers in fatal crashes;
- 1 study with a statistically significant positive effect on alcohol-related crashes when introducing BAC limits for novice drivers, but with a statistically significant negative effect on all type of accidents;
- 1 study whose questionnaire analysis on self-reported drinking drivers showed a significant decrease;
- 1 study with a non-statistically significant reduction in the mean BAC of fatally injured drivers;
- 1 study with non-statistically significant effects on the ratio of offences, when introducing zero tolerance laws for young drivers;
- 1 study without statistically significant effects both on the number of DWI crashes and the number of persons charged with DWI.

The quantitative results of the coded studies, together with their general effects on road safety, are shown in Table 2, which is presented in the supporting document.

After the results were reviewed together, in possible consideration of a meta-analysis, the following points were observed:

- a) There is an adequate number of studies. However:
- b) the studies did not the same model for analysis,
- c) there are different indicators, and even when they coincide they are not measured in the same way,
- d) the sampling frames were different, and
- e) there are already 5 meta-analyses in the studies coded.

Description of analysis carried out

Review-type analysis

After considering the previous points, it was decided that a meta-analysis could not be carried out in order to find the overall impact of BAC limits on road safety. In fact, despite the adequate number of studies and the sampling frames, meta-analyses have already been performed.

Taking the above into consideration, it was decided that both the meta-analysis and the vote count analysis are inappropriate, and thus the review type analysis was selected. Therefore, the effect of laws introducing or lowering BAC limits will be given via a qualitative analysis.

Most of the studies analysed identify positive effects of introducing BAC limits, showing a reduction in alcohol-related fatal/injury crashes, even though these results are not always statistically significant. Conversely, in one study an increase in total crashes is found as a statistically significant effect.

Significant positive effects were also found on self-reported drinking drivers and on police-reported drinking drivers in fatal crashes. In contrast, offences per 1,000 licensed drivers increased after introducing restrictions on BAC for young drivers, though no statistical analysis was performed.

Overall estimate for road safety

On the basis of both study and effect numbers, it can be argued that limiting BAC for drivers in general and novice drivers specifically, has a positive effect on road safety. However, there are cases when there are few isolated negative effects, such as an increase in fatal crashes, but these are in the minority. As mentioned before, these studies have good levels of quality, and are consistent in their results overall. The fact that five studies are meta-analyses that include 27 original studies, also adds to the overall consistency of the results.

Conclusion

The review-type qualitative analysis carried out showed that introducing and lowering BAC limits has a positive impact on road safety.

3 Supporting document

3.1 IDENTIFYING RELEVANT STUDIES

Literature search strategy

The search strategy aimed at identifying recent studies concerned with the implementation of Laws and Enforcement for BAC limits/BAC limits for novice drivers. The main database consulted was Scopus. In general, only recent (after 1990) journal studies were considered. However, high quality conference papers and reports were also considered. Moreover, reference lists of individual studies is also examined.

Limitations/ Exclusions:

- Search field: TITLE-ABS-KEY
- Published: 1990 to current
- Document Type: "Review" and "Article"
- Language: "English"
- Source Type: "Journal"
- Only Transport Journals were considered
- Subject Area: "Engineering and Psychology"

Database: Scopus

Date: 28th March 2017

search no.	search terms / operators / combined queries	Hits
#1	(„law“ OR „enforcement“)	522,120
#2	(„drunk driving“ OR „drink driving“ OR „DUI“)	5,168
#3	#1 AND #2	216

Results of Literature research

Database	Hits
Scopus	216
Total number of studies to screen title	216

3.2 SCREENING

The abstracts of relevant studies from the initial literature search results were examined to narrow the scope and to detect studies that would be more appropriate at a first stage. Those abstracts give hints as to whether the full text warrants close examination for coding and inclusion in the project.

Total number of studies to screen title	Hits
Number of articles remaining after screening of the title = Total number of studies to screen abstract	216
Remaining studies after abstract screening	216
Total number of studies to screen full text	216

3.3 ELIGIBILITY

Total number of studies to screen full-text	216
Full-text could be obtained	216
Reference list examined Y/N	Yes
Eligible papers prioritized	16

3.4 PRIORITIZING CODING

- Prioritizing Step A (existing meta-analyses)
- Prioritizing Step B (most recent studies)
- Prioritizing Step C (Journals over conferences and reports)
- Prioritizing Step D (Prestigious journals over other journals and conference papers)
- Prioritizing Step E (Studies from Europe)

3.5 SUPPORTING QUANTITATIVE TABLE

Below follows Table 2, which includes all quantitative effects from the coded studies for the measures of lowering BAC limits.

Table 2 Quantitative results of coded studies for BAC laws and impacts on road safety.

Number	Author(s); Year; Country	Outcome indicator	Exposure	Quantitative Estimate	Effect on road safety	
1 (B)	Bartl G., Esberger R.; 2000; Austria	Alcohol related injury accidents	Lowering BAC limits from 0.08% to 0.05 %	Per. CH.=-9.37%, CI [95%]=[-14 -6]	↓	
2 (B)	Blais E., Bellavance F., Marcil A., Carnis L.; 2015; Canada	Fatally injured drivers	Lowering BAC limits to 0.05% or 0.04 %	BAC=0.00	Ab. Dif.=-4.6 (Saskatchewan)	↑*
					Ab. Dif.=-10.4 (Manitoba)	↑*
					Ab. Dif.=-11.6 (Nova Scotia)	↑*
					Ab. Dif.=-7.8 (Prince Edward Island)	↑*
					Ab. Dif.=-13.9 (Newfoundland)	↑*
					Slope=8.1, se=1.9, p<0.0001, CI [95%]=[4.3 11.8] (Counties that have introduced the law)	↑
				BAC>=0.05	Ab. Dif.=4 (Saskatchewan)	↓*
					Ab. Dif.=8.8 (Manitoba)	↓*
					Ab. Dif.=8.6 (Nova Scotia)	↓*
					Ab. Dif.=9.3 (Prince Edward Island)	↓*
					Ab. Dif.=8.8 (Newfoundland)	↓*
					Slope=-7, se=1.7, p=0.0001, CI [95%]=[-10.4 -3.6] (Counties that have introduced the law)	↓
				BAC>=0.08	Ab. Dif.=1.5 (Saskatchewan)	↓*
Ab. Dif.=6.5 (Manitoba)	↓*					

Number	Author(s); Year; Country	Outcome indicator	Exposure	Quantitative Estimate			Effect on road safety
					Ab. Dif.=9.3 (Nova Scotia)	↓ *	
					Ab. Dif.=7.6 (Prince Edward Island)	↓ *	
					Ab. Dif.=13.8 (Newfoundland)	↓ *	
					Slope=-5.8, se=1.7, p=0.0010, CI [95%]=[-9.2 -2.4] (Counties that have introduced the law)	↓	
				BAC>=0.15	Ab. Dif.=2.9 (Saskatchewan)	↓ *	
					Ab. Dif.=3.4 (Manitoba)	↓ *	
					Ab. Dif.=11.1 (Nova Scotia)	↓ *	
					Ab. Dif.=1.8 (Prince Edward Island)	↓ *	
					Ab. Dif.=15.9 (Newfoundland)	↓ *	
					Slope=-6.4, se=1.6, p=0.0002, CI [95%]=[-9.7 -3.2] (Counties that have introduced the law)	↓	
DWI incidents	not relevant	Slope=12.3, se=22.5, p=0.5845 (Counties that have introduced the law)	-				
Persons charged for DWI	not relevant	Slope=-0.0180, se=0.0260, p=0.4882 (Counties that have introduced the law)	-				
3 (N)	Blomberg, Richard D.; 1992;USA	Crash-involved reported (have been drinking) young drivers (< 21 y. o.)	Introduction of 0.02 BAC limits for drivers under 21 years old	Slope = -48.3, r ² =0.63			↓
4 (B)	Elvik R., Høye A., Vaa T., Sørensen M.; 2009; Norway (1)	Fatal accidents	Introduction of 0.10 BAC law or replacement of a 0.10 BAC law with a 0.08 BAC law	Per. Ac. Re = -6%, CI [95%]=[-7 -5]			↓
5 (B)	Elvik R., Høye A., Vaa T., Sørensen M.; 2009; Norway (2)	Alcohol related fatal accidents	Lowering BAC limits from 0.08% to 0.05 %	Per. Ac. Re = -2%, CI [95%]=[-17 6]			↓
		Alcohol related injury accidents		Per. Ac. Re = -13%, CI [95%]=[-16 -9]			↓
6 (B)	Elvik R., Høye A., Vaa T., Sørensen M.; 2009; Norway (3)	Fatal and injury accidents	Lowering BAC limits from 0.05 to 0.02	Per. Ac. Re = -10%			↓ *
7 (N)	Elvik R., Høye A., Vaa T., Sørensen M.; 2009; Norway (3)	Accidents	Introduction of 0.02 or 0.01 BAC limits for drivers under 21 years old	Alcohol related	Fatal	Per. Ac. Re = -18%, CI [95%]=[-20 -15]	↓
				All	Fatal	Per. Ac. Re = 3%, CI [95%]=[-3 9]	↑
				Alcohol related	Injury	Per. Ac. Re = -3%, CI [95%]=[-7 0]	↓

Number	Author(s); Year; Country	Outcome indicator	Exposure	Quantitative Estimate					Effect on road safety
8 (N)	Romano E., Scherer M., Fell J., Taylor E.; 2015; USA	Ratio of alcohol related fatal crashes	Introduction of 0.08 BAC law	Slope=-0.0230, p<0.001					↓
			Introduction of zero tolerance law	Slope=-0.0730, p<0.001					↓
9 (N)	Streff F.M., Hopp M.L.; 1997; USA	Ratio of offences per 1000 licensed drivers	Introduction of 0.02 BAC limits for drivers under 21 years old	BAC<0.10	Accident severity: not relevant	Gender: Male	Age<18 y.o.	Ab. Dif.=0.0029	-
				BAC<0.10	Accident severity: not relevant	Gender: Female	Age=18-20 y.o.	Ab. Dif.=0.8262	-
				BAC<0.10	Accident severity: not relevant	Gender: Female	Age<18 y.o.	Ab. Dif.=0.0135	-
				BAC<0.10	Accident severity: not relevant	Gender: Female	Age=18-20 y.o.	Ab. Dif.=0.6997	-
				BAC>0.10	Accident severity: not relevant	Gender: Male	Age<18 y.o.	Ab. Dif.=0.0726	-
				BAC>0.10	Accident severity: not relevant	Gender: Female	Age=18-20 y.o.	Ab. Dif.=0.5307	-
				BAC>0.10	Accident severity: not relevant	Gender: Female	Age<18 y.o.	Ab. Dif.=-0.0020	-
				BAC>0.10	Accident severity: not relevant	Gender: Female	Age=18-20 y.o.	Ab. Dif.=0.3280	-
		Alcohol related crashes		BAC>0.00	Accident severity: Fatal and severe	Gender: Female and Male	Age<21 y.o.	Slope=-16.88, p=0.030, T=2-.25	↓
				BAC>0.00	Accident severity: Non-fatal	Gender: Female and Male	Age<21 y.o.	Slope=-2.33, p=0.860, T=-0.18	-
		Crash injuries		BAC>0.00	Accident severity: Fatal and severe	Gender: Female and Male	Age<21 y.o.	Slope=-22.16, p=0.070, T=-1.84	-
				BAC>0.00	Accident severity: Non fatal	Gender: Female and Male	Age<21 y.o.	Slope=-12.56, p=0.550, T=-0.59	-
10 (B)	Tippetts A. S., Voasa R. B., Fella J. C., Nichols J.L.; 2005; USA	Drinking drivers in fatal crashes	Lowering BAC limits to 0.08	Slope=-0.0361, p=0.3490 (Alabama)					-
				Slope=-0.0267, p=0.3710 (California)					-
				Slope=-0.2856, p=0.1100 (District of Columbia)					-
				Slope=-0.2720, p=0.0010 (Florida)					↓
				Slope=-0.2986, p=0.0330 (Hawaii)					↓
				Slope=0.1981, p=0.9810 (Idaho)					-
				Slope=-0.1125, p=0.0430 (Illinois)					↓
				Slope=-0.2998, p=0.0000 (Kansas)					↓
				Slope=-0.4094, p=0.0000 (Maine)					↓

Number	Author(s); Year; Country	Outcome indicator	Exposure	Quantitative Estimate					Effect on road safety
				Slope=-0.1741, p=0.0330 (Massachussets)					↓
				Slope=-0.1379, p=0.3030 (New Hampshire)					-
				Slope=-0.3097, p=0.0000 (New Mexico)					↓
				Slope=-0.2032, p=0.0900 (North Carolina)					-
				Slope=0.1571, p=0.8750 (Oregon)					-
				Slope=0.0362, p=0.7730 (Texas)					-
				Slope=-0.0452, p=0.4060 (Utah)					-
				Slope=-0.5657, p=0.0220 (Vermont)					↓
				Slope=-0.1786, p=0.0740 (Virginia)					-
				Slope=-0.0856, p=0.1840 (Washington)					-
				Slope=-0.1605, se=0.0562, p=0.0050, t=-2.85, df=18 (Overall)					↓
11 (N)	Wagenaar A. C. , O'Malley P. M., LaFond C.; 2001; USA	Self- reported driving after drinking alcohol	Lowering BAC limits for young drivers	Per. Ch.=0.189 %, p<0.01					↓
		Self- reported driving after drinking ≥5 drinks		Per. Ch.=0.150 %, p<0.05					↓
12 (B)	Zivkovic V., Nikolic S., Lukic V., Zivadinovic N., Babić D.; 2013; Serbia	Mean BAC	Lowering BAC limits from 0.05% to 0.03 %	Ab. Dif.=0.04, p=0.860, t=0.177, df=80					-
13 (BN)	Zwerling C, Jones M. P.; 1998; USA	Crashes of novice drivers	Lowering BAC limits for novice	Australia (Western Australia)	Injury	BAC limit = 0.02	<18	Ab. Dif.=0.007, CI [95%]=[- 0.024 0.037]	-
				Australia (South Australia)	Injury	BAC limit = 0.05	16	Ab. Dif.=0.067, CI [95%]=[0.024 0.110]	↓
				Australia (Western Australia)	Injury	BAC limit = 0.02	17-20	Ab. Dif.=0.031, CI [95%]=[0.013 0.049]	↓
				Australia (Victoria)	Injury	BAC limit = 0.00	first- year drivers	Ab. Dif.=0.001, CI [95%]=[- 0.019 0.021]	-
				United States	Fatal	Not specified	<21	Ab. Dif.=0.048, CI [95%]=[0.380 0.058]	↓
↓	denotes positive road safety effects		-	denotes unclear or marginal road safety effects					

Number	Author(s); Year; Country	Outcome indicator	Exposure	Quantitative Estimate	Effect on road safety
↑	denotes negative road safety effects		*		denotes that no statistical analysis was conducted for the significance of the effects

3.5 REFERENCES

List of coded studies

The list of coded studies is presented here. It is noted that concerning the relevant chapters included in Handbook, the Handbook is cited (Elvik et al., 2009).

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Blais, E., Bellavance, F., Marcil, A. & Carnis, L. (2015). Effects of introducing an administrative .05% blood alcohol concentration limit on law enforcement patterns and alcohol-related collisions in Canada. *Accident Analysis and Prevention*, 82, 101–111. Doi: <http://dx.doi.org/10.1016/j.aap.2015.04.038>.

Blomberg, R.D. (1992). Lower BAC limits for youth: evaluation of the Maryland 0.02 law. Proc. Int. Council. Alcohol Drugs Traffic Safety Conf. 1993. 1277-1288. Doi: <https://ntl.bts.gov/lib/25000/25800/25839/DOT-HS-807-860.pdf>.

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Elvik, R., Alena Høy, A., Vaa T. & Sørensen, M. (2009). The Handbook of Road Safety Measures Second Edition. Emerald Group Publishing Limited.

Hingson, R., Heeren, T. & Winter M. (2000). Effects of recent 0.08% legal blood alcohol limits on fatal crash involvement. *Injury Prevention*, 6, 109–114. Doi: <http://dx.doi.org/10.1136/ip.6.2.109>.

Romano, E., Scherer, M., Fell, J. & Taylor, E. (2015). A comprehensive examination of U.S. laws enacted to reduce alcohol-related crashes among underage drivers. *Journal of Safety Research*, 55, 213–221. Doi: <http://dx.doi.org/10.1016/j.jsr.2015.08.001>.

Streff, F.M, Hopp & M.L. (1997). Evaluation of Michigan's Under Age 21 Zero-Tolerance Alcohol-Impaired Driving Law. UMTRI The University of Michigan Transportation Research Institute. Doi: <https://deepblue.lib.umich.edu/bitstream/handle/2027.42/1219/90527.0001.001.pdf?sequence=2&isAllowed=y>.

Tippetts, A.S., Voas, R.B., Fella, J.C. & Nichols, J.L. (2005). A meta-analysis of .08 BAC laws in 19 jurisdictions in the United States. *Accident Analysis and Prevention*, 37, 149–161. Doi: <http://dx.doi.org/10.1016/j.aap.2004.02.006>.

Wagenaar, A.C., O'Malley, P.M. & LaFond, C. (2001). Lowered Legal Blood Alcohol Limits for Young Drivers: Effects on Drinking, Driving, and Driving-After-Drinking Behaviors in 30 States. *Accident Analysis and Prevention*, 40, 1430–1440.

Zivkovic, V., Nikolić, S., Lukić, V., Zivadinović, N. & Babić, D. (2013). The effects of a new traffic safety law in the Republic of Serbia on driving under the influence of alcohol. *Accident Analysis and Prevention*, 53, 161–165. Doi: <http://dx.doi.org/10.1016/j.aap.2013.01.012>.

Zwerling, C. & Jones, M.P. (1998). Evaluation of the Effectiveness of Low Blood Alcohol Concentration Laws for Younger Drivers. *American Journal of Preventive Medicine*, 16(1S), 76–80. Doi: [http://doi.org/10.1016/S0749-3797\(98\)00114-7](http://doi.org/10.1016/S0749-3797(98)00114-7).

Law and Enforcement -

Distraction:

Laws restricting mobile phone use whilst driving and the enforcement of laws against driving whilst using a mobile phone



Athanasios Theofilatos, NTUA, May 2017

1 Summary

1.1 COLOUR CODE

Grey

The effects of implementing laws and increasing enforcement against mobile phone use while driving are mixed. To date, studies have shown positive, positive without statistical evaluation, non-significant and even negative effects. Currently, as there is only some indication of effectiveness the overall impact of laws and enforcement is characterized as grey.

1.2 KEYWORDS

Distraction; mobile phone; driving; laws; enforcement

1.3 ABSTRACT

Laws and enforcement against mobile phone use while driving are widely used as safety measures to prevent drivers from talking, texting or dialling while driving. In that context, fifteen high quality studies were coded. In general, there is some indication that laws and enforcement have a positive impact on road safety and most specifically on self-reported and observed mobile phone use while driving. However, in a number of studies, statistical evaluation is absent and some other studies indicate non-significant and even negative effects. Meta-analyses showed a negative effect of laws on drivers' mobile phone use and furthermore, there is no evidence of a reduction in crashes or fatalities. Consequently, on a basis of both study and effect numbers, it can be argued that the evidence for a road safety effect of laws and enforcement against mobile phone use is far from conclusive. This topic needs further investigation and statistical evaluation.

1.4 BACKGROUND

Definition of laws and enforcement aiming at mobile phone use while driving

Supported by previous research, concerns about the risks associated with mobile phone use while driving led to the passage of laws limiting use. These laws are widespread in other countries and are increasingly common in the United States. International practice and literature indicates that strong laws with publicized tough enforcement are proven countermeasures to changing driver behaviour. Such laws and enforcement mainly aim to reduce mobile phone use while driving. However, it is difficult to rigorously evaluate such road safety laws and related enforcement. Ideally, information can be obtained to measure meaningful changes in the targeted behaviour (e.g. mobile phone use) following implementation of the law and corresponding changes in crashes, injuries, or fatalities. However, most studies examine the change in mobile phone use after the implementation of the law.

How do laws and enforcement aim at improving road safety?

Mobile phone laws and enforcement aim to change the behaviour of drivers regarding the use of the mobile phone (dialling, messaging, talking etc.) whilst driving and therefore mitigate the consequences (crash, injuries). Usually, these measures prohibit talking on handheld or hands-free mobile phones while driving and are implemented as restrictions for

specific road user groups (e.g. teenagers). Research indicates that such measures should be combined with campaigns in order to reach maximum effectiveness.

Which safety outcomes are affected by mobile phone laws and enforcement?

The reviewed studies focus on various outcomes. The majority of literature examines the stated or observed mobile phone use by drivers. In some studies, however, the focus is on estimating the reduction in the number of crashes, injuries or fatalities.

How is the effect of mobile phone laws and enforcement on road safety studied?

International literature has examined a variety of different approaches and ways to study the effect of mobile phone laws and enforcement. The most common approach to test the effectiveness of this countermeasure is to make a comparison before and after the implementation of the law. In general, there is no distinction between hands-free and handheld mobile phones.

1.5 OVERVIEW OF RESULTS

A first overview of the effects of mobile phone laws and enforcement shows that they tend to increase the level of road safety. In most cases, studies link laws and enforcement to inconsistent effects on mobile phone use while driving, with positive effects (reduction in mobile phone use) as well as non-significant effects being observed. Furthermore, percentage change in mobile phone use is often reported without statistical tests. It is interesting though that reported mobile phone use (through questionnaires) mainly shows a non-significant impact. Interestingly, negative impacts (deteriorating road safety) are also observed. A meta-analysis carried out on observed mobile phone use in teenagers, revealed an overall negative effect on road safety (increased mobile phone use) despite the fact that the studies included show a non-significant effect. Similarly, when all driver age categories are considered the same trend is observed.

With regard to crashes and injuries, the majority of findings in the examined studies show a reduction with a beneficial effect on road safety. However, it should be noted that a) non-significant effects and b) reductions without statistical evaluations are also present. Consequently, no clear conclusions can be drawn.

Transferability

Most of the coded studies are observational and are based on data mainly from the USA and less frequently from other countries (UK, Australia). Some studies examine the reported attitudes (stated) towards law implementation. Although this is a good sample for general trends in developed countries, there is a lack of studies representing less motorized countries. All studies examine cars, without differentiating for different modes and a few studies focus on teenagers. Results are generally considered to be transferable.

Notes on analysis methods

The methodology applied for capturing the impact of mobile phone laws and enforcement on road safety varies considerably between studies, mainly in terms of the mathematical models utilised but also of the outcomes evaluated as dependent variables. There are also certain similarities interpreting road user categories and/or geographical regions. All the above make the results for laws and enforcement generally transferable, though relative caution is always required.

2 Scientific overview

2.1 ANALYSIS OF STUDY DESIGNS AND METHODS

After appropriate use of various search tools and databases, fourteen (14) high quality studies were selected and coded to evaluate the effectiveness of the implementation of laws and enforcement regarding mobile phone use while driving.

Three studies (Burger et al., 2014; Rangland 2012; Jacobson et al. 2012; Lim and Chi, 2013) investigated the effects on speed accident numbers, rates and injuries/fatalities. Other observational studies aimed at investigating the impact of law and/or enforcement on revealed behavior and more specifically mobile phone use (Goodwin et al., 2012; Marquez et al., 2015; McCartt et al. 2004 and 2006; McCartt and Helliga et al. 2007; Truong et al., 2016; Walter et al., 2011). Foss et al. (2009) examined both reported and observed mobile phone use under mobile law restriction, while other studies focused only on reported mobile phone use under increased enforcement (Marquez et al. 2015; Walsh et al., 2008). It is important to note that Foss et al. (2009) and Goodwin et al. (2012) had specific focus on teenage drivers in the USA.

In order to examine the relationship between the laws-enforcement and outcome indicators, the majority of the studies used before and after measurements and statistical models (i.e. generalized linear model with negative binomial distribution error structure, etc.). Some studies (Cosgrove et al., 2010; Foss et al., 2009) did not mention any statistical analysis in all reported effects, but comparisons before and after the implementation and between exposed and non-exposed sites were conducted.

When examining mobile phone restriction laws and enforcement, another popular outcome is frequency either of accidents or of fatalities and injuries. Burger et al. (2014) did not find any total significant crash. Then again, Jacobson et al., (2012) found that handheld law bans significantly reduced annual accidents per 1000 licensed drivers for urban, suburban, rural and very rural areas in New York State. Lim and Chi (2013) showed a significant reduction in fatal accidents resulting from a mobile phone ban for all drivers. However, no significant effects were observed for novice drivers. Finally, Rangland (2012) investigated the percentage change in fatalities and injuries after implementation of mobile ban law in California and reported a reduction in all casualty numbers but without any statistical evaluation.

Limitations

There are a few limitations in the current literature examining the effects of mobile phone restrictions/bans laws and related enforcement on road safety. The first limitation is that a number of studies consider mobile phone use reduction as a measure of effectiveness, which is a secondary parameter and does not directly provide a clear image regarding the number of crashes. Moreover, a few studies do not perform statistical evaluation when reporting crash reduction or mobile phone use reduction after law implementation; thus no robust conclusions can be drawn. Another limitation is that there are no studies concerning European countries let alone less motorized countries such as those in South America or Africa. For a more collective approach, the impact of implementing such measures in these environments should also be captured.

2.2 RESULTS FOR LAWS AND ENFORCEMENT FOR MOBILE PHONE USE WHILE DRIVING

Introduction

The effects of mobile phone use laws and enforcement on road safety, as identified in the coded studies, can be summarized as follows:

- 1 study with a non-significant effect in crash frequency;
- 1 study with a general non-significant effect in crash frequency (with a few exceptions);
- 1 study showing a significant reduction in accident rate;
- 1 study with a positive reduction of mobile phone related accidents and injuries (without statistical evaluation);
- 2 studies with a significant reduction in observed use of the mobile phone while driving (all driver ages included);
- 1 study with a non-significant effect in teenagers' observed use of the mobile phone while driving;
- 5 studies showing inconsistent effects in percentage reduction of drivers using the mobile phone;
- 1 study showing inconsistent effects in observed percentage reduction of drivers using the mobile phone (without statistical evaluation);
- 1 study showing inconsistent effects in stated percentage reduction of drivers using the mobile phone (without statistical evaluation).

The complete detailed results from the coded studies appear on Table 2 which is presented in section 3. After the results were reviewed together, in possible consideration of a meta-analysis, the following points were observed:

- a) There is an adequate number of studies
 - b) The sampling frames had similarities
- However,
- c) Studies have not used the same modelling approach for analysis.
 - d) There are different indicators, but usually stated or revealed mobile phone use has been examined.
 - e) Number of crashes and fatalities are rarely examined.

Description of analysis carried out

Meta-analysis

After considering the previous points and since observed mobile phone use is more important than intentions to use the mobile phone by means of questionnaire, it was decided that a meta-analysis could be carried out in order to find the overall impact of laws and enforcement on road safety, regarding the following two important aspects: a) teenagers observed mobile phone use while driving after implementing laws aiming to prevent young drivers from talking on the phone while driving and b) a more general effect of laws and enforcement on mobile phone use while driving overall.

In the former case, the following studies were considered:

- Goodwin et al.; 2012

- Foss et al.,2009

Although only 2 studies were considered, the results were very interesting since a negative effect of law and enforcement on mobile phone use was found. However, results should be interpreted with care as with similar approaches in the literature (Roshandel et al., 2015). A fixed effects meta-analysis was applied. More specifically, the overall estimate of the odds ratio to use a mobile phone while driving after teenager laws was implemented was investigated. The results showed a surprisingly significant negative effect at a 95% level (p -value < 0.01). The overall estimate for the odds ratio was found to be 1.1, as shown in Figure 1, meaning that after the laws implementation, teenagers were 1.1 times more likely to use a mobile phone while driving. The results of the meta-analysis showed no heterogeneity (Q -test=0.02, p -value=0.8876) and also no publication bias as the funnel plot (Figure 2) was symmetrical.

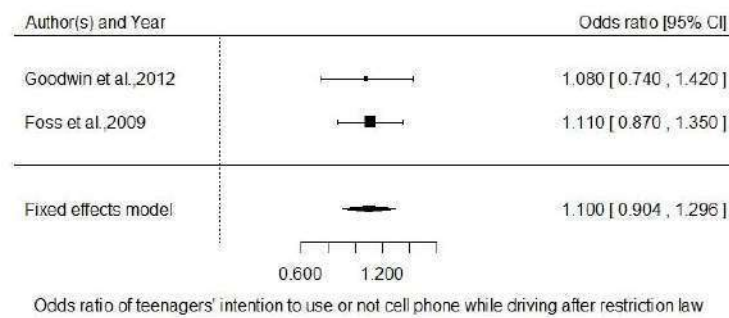


Figure 1: Forest plot for the odds ratio of teenagers' observed mobile phone use while driving after restriction laws applied.

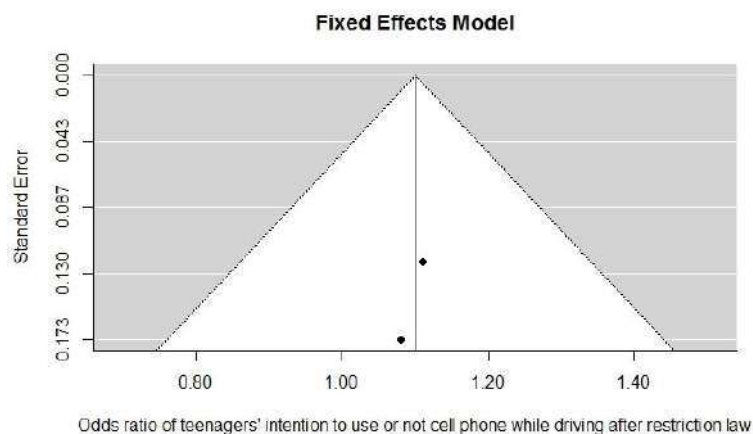


Figure 2: Funnel Plot for estimates of teenagers' mobile phone use while driving when law restriction laws are implemented.

In the latter case, the following studies were considered:

- Goodwin et al.; 2012

- Foss et al.,2009
- Truong et al., 2016
- McCartt and Hellinga, 2007

The results also showed a surprisingly significant negative effect at a 95% level (p -value < 0.01). The overall estimate for the odds ratio was found to be 1.1026, as shown in Figure 3, meaning that after the laws and enforcement implementation, drivers were about 1.1 times more likely to use a mobile phone while driving. The results of the meta-analysis showed no heterogeneity (Q -test=0.3055, p -value=0.9590). Finally, no publication bias was indicated as the funnel plot (Figure 4) was symmetrical and the test for funnel plot asymmetry was non-significant (p -value=0.7292).

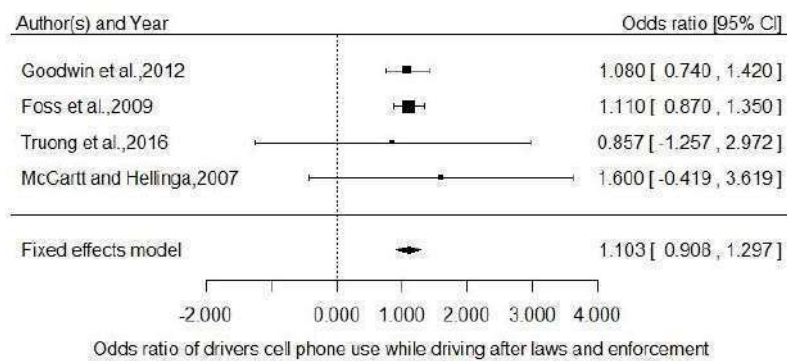


Figure 3: Forest plot for the odds ratio of drivers' observed mobile phone use while driving after restriction laws and enforcement applied.

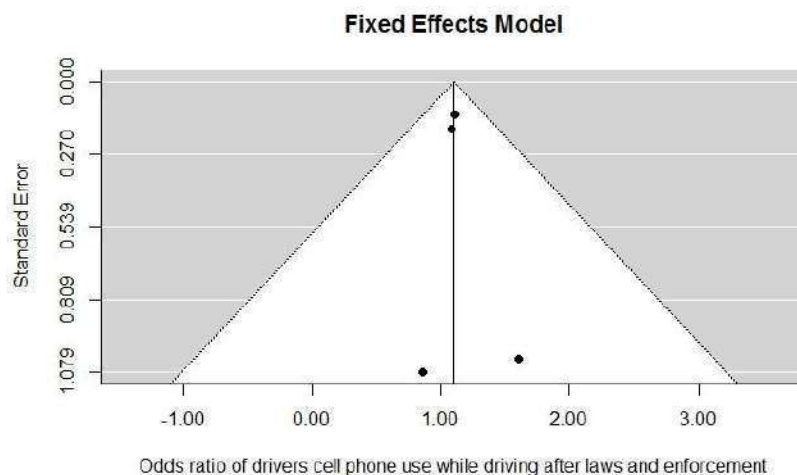


Figure 4. Funnel Plot for the odds ratio of drivers' observed mobile phone use while driving after restriction laws and enforcement applied.

Vote-count analysis

Finally, a vote count analysis was conducted. In vote count analyses, each study is considered to have one vote for or against the countermeasure. The results are summarized in Table 1.

Table 1: Vote count analysis results for laws and enforcement for mobile phone use.

Outcome definition	Tested in number of studies	Result (number of effects)			Result (number of effects)-without statistical evaluation		
		↑	-	↓	↑*	-	↓*
Crash Reduction	1	-	3	-	-	-	-
Injury and Fatality reduction	4	-	7	11	-	-	12
Observed mobile phone use	9	7	15	21	2	-	8
Reported mobile phone use	2	2	6	-	2	1	2
Total Studies = 14							

Overall estimate for road safety

On the basis of the coded studies, it can be conjectured that the implementation of laws and enforcement for mobile phone use while driving has a mixed and inconsistent overall impact on road safety, since various different effects were identified (e.g. positive, positive without statistical evaluation, non-significant and even some negative effects). Consequently, there is no clear evidence of effectiveness. For these reasons, the overall impact of laws and enforcement is characterized as grey, as more consistent work is needed.

Conclusion

The meta-analyses and the vote count analysis showed that laws and enforcement for mobile phones have an unclear effect on road safety (intention to use mobile phone, observed mobile phone use, crashes and fatalities). While in absolute numbers a lot of the effects of these measures are positive, there are non-significant and negative impacts as well. For these reasons, it can be argued that the impacts of law and enforcement on mobile phone distractions are unclear and need further investigation.

3 Supporting document

3.1 IDENTIFYING RELEVANT STUDIES

Countermeasure: Laws and Enforcement for distraction (mobile phone)

Literature search strategy

The search strategy aimed at identifying recent studies regarding the implementation of Laws and Enforcement for distraction (mobile phone). The main database that was consulted was Scopus. In general, only recent (after 1990) journal studies were considered. However, high quality conference papers and reports were also considered. Moreover, reference lists of individual studies is also examined.

Limitations/ Exclusions:

- Search field: TITLE-ABS-KEY
- Published: 1990 to current
- Document Type: "Review" and "Article"
- Language: "English"
- Source Type: "Journal"
- Only Transport Journals were considered
- Subject Area: "Engineering and Psychology"

Database: Scopus

Date: 28th March 2017

search no.	search terms / operators / combined queries	Hits
#1	(„law“ OR „enforcement“)	522,120
#2	(„mobile phone“ OR „cell phone“)	21,628
#3	#1 AND #2	136

Results of Literature research

Database	Hits
Scopus	136
Total number of studies to screen title	136

3.2 SCREENING

The abstracts of relevant studies from the initial literature search results were examined to narrow the scope and to detect studies that would be more appropriate at a first stage. Those abstracts give hints as to whether the full text warrants close examination for coding and inclusion in the project.

Total number of studies to screen title	288
Number of articles remaining after screening of the title = Total number of studies to screen abstract	136

Remaining studies after abstract screening	136
Total number of studies to screen full text	34

3.3 ELIGIBILITY

Total number of studies to screen full-text	34
Full-text could be obtained	34
Reference list examined Y/N	Yes
Eligible papers prioritized	14

3.4 PRIORITIZING CODING

- Prioritizing Step A (most recent studies)
- Prioritizing Step B (Journals over conferences and reports)
- Prioritizing Step C (Prestigious journals over other journals and conference papers)
- Prioritizing Step D (Studies from Europe)

No meta-analyses were found.

3.6 SUPPORTING TABLES

The first table of the Supporting Document concerns an overview of the main features of the coded studies (sample, method, outcome and results) (Table 2). *L* denotes the law measure and *ENF* the enforcement measure.

Table 2: Description of coded studies.

Number	Author(s); Year; Country;	Sampling frame	Method of analysis	Outcome indicator	Main Result
1	Burger et al.; 2014; USA [L]	A California Highway Patrol panel accident data was used for California freeways from January 1st, 2008 to December 31st, 2008, we examine whether this policy reduced the number of accidents on California highways.	Negative binomial regression models, controlling for unobserved time-varying effects	Accident frequency [number of daily accidents]	There is no evidence of a state-wide decrease in accidents as a result of the mobile phone use ban.

2	<p>Cosgrove et al.;2010;USA [ENF]</p>	<p>Cell phone observations were taken at 15 sites in each intervention area, plus 15 sites in Albany, 15 in Stamford, and 7 sites in Bridgeport. Sites were selected from road segments based on traffic volume estimates. Three of the sites in each area were highway off-ramps. The rest of the sites were identified from the highest volume segments, assuring that they were geographically dispersed throughout the areas. Therefore all selected sites were at traffic light controlled intersections.</p>	<p>Simple before-and-after observation [descriptive statistics]- Percentage change</p>	<p>Observed handheld phone use while driving</p>	<p>Observed cell phone use decreased in both sites by the end of the second wave of the Phone in One Hand, Ticket in the other demonstration program. Before the distracted driving programs began, observed cell phone use in Syracuse was about half that of the rest of the Nation and Connecticut was close to average. Both States have had handheld cell phone bans while driving for some time – 2001 for New York and 2005 for Connecticut. After the second wave of the high visibility enforcement campaign, hand-held cell phone use decreased 38% in Syracuse (from 3.7% to 2.3%) and 58% in Hartford (from 6.8% to 3.1%).</p>
3	<p>Foss et al.;2009;USA [L]</p>	<p>Teenage drivers were observed at high schools in North Carolina 1–2 months before and approximately 5 months after the law took effect.</p>	<p>Odds ratio; Relative difference</p>	<p>Teenager cell phone use while driving and Self-reported cell phone use while driving-often [often, sometimes, rarely, never]</p>	<p>The results of the logistic regression model used to make a direct statistical comparison between the pre- and post law rates of cell phone use. Based on the odds ratio for “cell phone law” (i.e., the interaction of state and survey wave), cell phone use among teenage drivers in North Carolina increased an estimated 11% relative to the increase in South Carolina, although this increase is not statistically significant (OR = 1.11, 95% CI = 0.87, 1.41).</p>

4	<p>Goodwin et al.;2012;USA [L]</p>	<p>Observations were conducted at the same 25 high schools in North Carolina. High schools are one of the few locations where the driving population is predominantly drivers who are 16 and 17 years old and, therefore, are known to be subject to the cell phone restriction. All observations were conducted as students left school in the afternoon. Observers usually positioned themselves near the exits of school parking lots, although it was sometimes possible to observe teenage drivers at controlled intersections on roads leading away from schools. To control for any seasonal effects in cell phone use among young drivers, observations were conducted at the same time of year as previously. Observations began October 17, 2008, and were completed December 5, 2008, approximately two years after the cell phone restriction went into effect.</p>	Odds ratio	<p>Teenager cell phone use while driving [Yes/No]</p>	<p>Although there was a decline in cell phone use from 2006 to 2008 in North Carolina, after adjusting for other measured variables, the decline was not reliably associated with the cell phone law (OR = 1.08, 95% CI = 0.74, 1.56). Overall, North Carolina's cell phone restriction continues to have no measurable effect on the behavior of teenage drivers. Although there was a broad decrease in cell phone use among teenage drivers by two years after the restriction took effect, phone use decreased similarly in South Carolina which has no cell phone restriction.</p>
5	<p>Jacobson et al.;2012;USA [L]</p>	<p>Ten states and Washington DC have passed laws prohibiting the use of hand-held wireless devices while driving. Many of these states have enacted these laws recently, five within the last three years, and hence, the long term effects of their bans cannot be analyzed. As the enforcement of the hand-held ban in New York began with limited penalties on November 1, 2001 and was enforced in full as of March 1, 2002, the years 1997–2001 are considered the pre-law period and the years 2002–2008 are the post-law period. Four groups were used in the analysis, classifying the counties as (A) dense urban, (B) urban/suburban, (C) rural, and (D) very rural designations.</p>	Regression model	<p>Accident rate [measured by the number of personal injury accidents per 1000 licensed drivers per year]</p>	<p>These estimates suggest that a hand-held ban in New York was effective in reducing accidents in all but very rural counties and that the ban was more effective in counties with higher driver densities. These results suggest that targeted hand-held bans in counties with more drivers per mile of roadway may be more effective at reducing accident rates than bans that apply to all counties.</p>

6	<p>Lim and Chi;2013;USA [L]</p>	<p>33 states have passed cell phone laws targeting only young and novice drivers, while 10 states have similar laws for all drivers regardless of age. The efficacy of state cell phone laws in reducing non-alcohol related fatal crashes involving drivers under the age of 21 is examined. Overall, data were used from the 48 contiguous states between 1996 and 2010.</p>	<p>Negative binomial regression</p>	<p>Accident frequency [number of fatal accidents]</p>	<p>The results of this study showed that there was insufficient evidence that a cell phone ban for only young and novice drivers reduced non-alcohol related fatal crashes. However, the effect of a handheld cell phone ban for all drivers was highly significant.</p>
7	<p>Márquez et al.;2015;Colombia [ENF]</p>	<p>A total of 176 individuals were interviewed. The mean age of the individuals interviewed was 36. All respondents reported that they had an active mobile phone.</p>	<p>Integrated choice latent variables model (ICLV)</p>	<p>Mobile phone use while driving [Yes/No]</p>	<p>Fines significantly reduce mobile phone use while driving because despite the non-payment culture that characterizes the population from which the sample was drawn, it was still reasonable to assume that the deterrent effect of the fine would be reflected in the model. Therefore, the cost of the fine is an attribute of great importance in order to control the behavior of drivers regarding the use of mobile phones.</p>
8	<p>McCartt et al.;2004;USA [L]</p>	<p>Effective 1 November 2001, New York became the only state in the United States to ban drivers' handheld cell phone use. Connecticut is an adjacent state without such a law. 50 033 drivers in New York, 28 307 drivers in Connecticut.</p>	<p>Relative difference [difference in proportions]</p>	<p>Percentage of drivers using the mobile phone</p>	<p>Drivers' use of handheld cell phones declined substantially in the first few months after New York's ban on such use, based on observations conducted in four upstate communities. Most of this initial decrease dissipated during the subsequent year. Initial publicity about the law declined, and there was no publicized targeted enforcement campaign.</p>

9	<p>McCartt et al.;2006;USA [L]</p>	<p>Daytime observations of drivers were conducted at signalized intersections in D.C. in March 2004, several months before the law took effect on July 1, 2004, and again in October 2004. As a comparison, observations also were conducted in areas of Virginia and Maryland located close to the D.C. border. Maryland and Virginia placed no limitations on drivers' phone use. Use was observed for 36,091 vehicles in D.C., 25,151 vehicles in Maryland, and 28,483 vehicles in Virginia.</p>	<p>Relative difference [difference in proportions]</p>	<p>Rate of talking on handheld phone while driving; Talk on the handheld phone while driving [Yes, No]</p>	<p>The rate of talking on hand-held cell phones among drivers in D.C. declined significantly from 6.1% before the law to 3.5% after. Phone use declined slightly in Maryland and increased significantly in Virginia so that, relative to the patterns of hand-held phone use in the two states, phone use in D.C. declined 50%. Hand-held phone use in D.C. declined comparably among drivers of vehicles registered in all three jurisdictions. D.C. police issued 2,556 citations and 1,232 warnings for cell phone violations during July-November 2004.</p>
10	<p>McCartt and Hellinga; 2007;USA [L]</p>	<p>Drivers' daytime hand-held cell phone use was observed in DC and nearby areas of Virginia and Maryland, states without bans. Observations were conducted several months before the ban, shortly after, and 1 year later. The number of vehicles observed in all three surveys combined was 51,945 in DC, 36,796 in Maryland, and 43,033 in Virginia.</p>	<p>Relative difference [difference in proportions]</p>	<p>Rate of talking on handheld phone while driving; Talk on the handheld phone while driving [Yes, No]</p>	<p>The rate of talking on hand-held phones declined significantly from 6.1 percent before the law to 3.5 percent shortly after; when measured 1 year later, use was 4.0 percent, still significantly lower than baseline. Based on increases in rates of talking on hand-held phones in Maryland and Virginia, longer-term phone use in DC was estimated to be 53 percent lower than would have been expected without the ban. Declines in DC were identified for drivers of vehicles registered in all three jurisdictions.</p>

11	Rangland;2012;USA [L]	Data from the Statewide Integrated Traffic Records System (SWITRS), the collision data base for California maintained by the California Highway Patrol, we conducted a brief descriptive analysis of fatalities and injuries related to distracted driving and cell phone use during the periods before and after implementation of the July 1, 2008 law banning the use of hand-held cell phones while driving in the state.	Simple before-and-after observation [descriptive statistics]- Percentage change	Number of casualties	The results of these descriptive analyses suggest a consistent reduction in fatalities and injuries related to hand-held cell phone use after implementation of a law banning the use of hand-held cell phones while driving in California on July 1, 2008. A similar reduction was noted for hands free cell phone fatalities and injuries. Further studies of the impact cell phone bans on traffic fatalities and injuries should focus specifically on crashes involving distracted driving and cell phone use, comparing these with crashes not involving cell phone use.
12	Truong et al.;2016;Vietnam [ENF]	An observation survey was undertaken at 12 sites, which were distributed over five urban districts of Hanoi, Vietnam, including two districts in the city centre area. Each site was surveyed during a two-hour peak period from 16:30 to 18:30 for two weekdays and one weekend day. A total of 26,360 riders were observed, consisting of 24,759 motorcyclists and 1601 electric bike riders.	Binary and multinomial logistic regression models	Mobile phone use while driving [Yes/No]; Calling operation while using the mobile phone; Screen operation while using the mobile phone [Calling operation while using the mobile phone not using the mobile phone]	Results of this study revealed that the overall prevalence of mobile phone use while riding among motorcyclists and electric bike riders in Hanoi, Vietnam was 8.4%. The binary logistic and the multinomial logistic model showed that police presence was significantly associated with reduced use of mobile phones for calling, but not for screen operation.
13	Walsh et al.;2008; Australia [ENF]	Data were collected over a period of 4 days in early December 2006 at large petrol (gas/filling) stations on major highways north and south of Brisbane, Queensland. The sites were chosen as their location near urban areas on the outskirts of the city makes them regularly used by commuters and, also, they are on the major travel routes used by people on holidays or travelling long distances. Participants were recruited in eating areas located inside the petrol stations during both morning and afternoon time periods. All persons	Linear regression models.	Intention to call while driving; Intention to text message [from (1)extremely unlikely to (7) extremely likely]	Perceived risk of being caught and fined by the police (apprehension), but not perceived risk of having a crash, significantly predicted intention to text message while driving in Scenarios 2 and 3. Unexpectedly, apprehension risk emerged as a significant negative, rather than positive, predictor of intentions in these two scenarios.

		entering the eating area were approached. Potential participants were screened to determine if they held a provisional or open driver's licence and if they used a mobile phone at least once a day. In all, 1250 people met the criteria for the study.			
14	Walter et al.;2011;UK [ENF]	A busy urban area under modern conditions. Operation Radar ran for four weeks and increased the visible presence of police on a six mile stretch of the A23 in South London. Two teams of six officers and one sergeant were deployed in two shifts per weekday on the six mile route, using both static and mobile policing methods in a mixture of vehicles. The operation was carried out five days per week between 6th and 30th May 2008, with the exception of the Bank (public) holidays on 5th and 26th May.	Simple before-and-after observation [descriptive statistics]	Percentage change of drivers using of handheld phone while driving; Percentage change of drivers using of hands-free phone while driving	The baseline level of hand-held mobile phone use by drivers on the A23 was 1.8%, compared with 3.3% at the halo sites. No change in hand-held phone use was observed during the operation at the A23 sites but there was a small drop at the halo sites compared to the baseline level – almost entirely driven by a large decrease at a single site during the operation.

Below follows Table 3, which includes all quantitative effects from the coded studies for the measures of laws and enforcement on mobile phone use.

Table 3: Quantitative results of coded studies for law and enforcement impacts on road safety.

Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative estimate		Effect on road safety	
1	Burger et al.; 2014; USA [L]	Accident frequency [number of daily accidents]	Law ban	Time window: 1/1–12/31	Slope: -0.015; St.Error: 0.009	-	
				Time window: 4/1–9/30	Slope: 0.001; St.Error: 0.001	-	
				Time window: 6/1–7/31	Slope: 0.007; St.Error: 0.018	-	
2	Cosgrove et al.; 2010; USA [ENF]	Observed handheld phone use while driving	Mobile phone enforcement Wave 1	Location: Connecticut; Area: Hartford	Gender: All; Age: All	Percentage change: -2.3%	↓*
				Location: Connecticut; Area: Bridgeport/Stamford	Gender: All; Age: All	Percentage change: -0.9%	↓*

Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative estimate		Effect on road safety	
				Location: New York; Area: Syracuse	Gender: All; Age: All	Percentage change:-0.5%	-
				Location: New York; Area: Albany	Gender: All; Age: All	Percentage change: -1.1%	↓*
				Location: Connecticut; Area: Hartford	Gender: All; Age: 16-24	Percentage change: -1.1%, p-value: <0.06 (90% significance)	↓
				Location: Connecticut; Area: Hartford	Gender: Female; Age: 16-24	Percentage change:-0.7%, p-value: <0.05	↓
				Location: New York; Area: Syracuse	Gender: Female; Age: All	Percentage change: -0.6%, p-value: <0.05	↓
			Mobile phone enforcement Wave 2	Location: Connecticut; Area: Hartford	Gender: All; Age: All	Percentage change:-1.5%, p-value: <0.01	↓
				Location: Connecticut; Area: Bridgeport/Stamford	Gender: All; Age: All	Percentage change:-0.3%	↓*
				Location: New York; Area: Syracuse	Gender: All; Age: All	Percentage change:-0.9%, p-value: <0.01	↓
				Location: New York; Area: Albany	Gender: All; Age: All	Percentage change:-0.6%	↓*
				Location: Connecticut; Area: Hartford	Gender: Female; Age: 16-24	Percentage change:-1.4%, p-value: <0.05	↓
				Location: New York; Area: Syracuse	Gender: Female; Age: All	Percentage change:-0.6%	↓*
3	Foss et al.;2009;USA [L]	Teenager cell phone use while driving [Yes/No]	Teenage driver cell phone restriction	Odds ratio: 1.11; 95% CI: [0.87-1.41]		-	
		Self-reported cell phone use while driving[often, sometimes, rarely, never]		Relative difference: -11		↓*	
				Relative difference: -9		↓*	
				Relative difference: 8		↑*	
				Relative difference: 11		↑*	
4	Goodwin et al.;2012;USA [L]	Teenager cell phone use while driving [Yes/No]	Teenage driver cell phone law	Odds ratio: 1.08; 95% CI: [0.74-1.56]		-	
5	Jacobson et al.;2012;USA [L]	Accident rate [measured by the number of personal injury accidents per 1000 licensed	Handheld ban law	Urban/Suburban	Slope: -0.697; St.error: 0.246	↓	
				Rural	Slope: -0.419;	↓	

Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative estimate			Effect on road safety
		drivers per year]				St.error: 0.152	
				Very rural		Slope: -0.273; St.error: 0.151	↓
6	Lim and Chi;2013;USA [L]	Accident frequency [number of fatal accidents]	Cell phone ban for novice drivers	Time window: 1996-2010	Age: <21 years old	Slope: -0.036; St.error: 0.023	-
				Time window: 1998-2010	Age: <21 years old	Slope: -0.039; St.error: 0.024	-
				Time window: 2000-2010	Age: <21 years old	Slope: -0.037; St.error: 0.025	-
				Time window: 2000-2010	Age: <15 years old	Odds Ratio: 1.026	-
				Time window: 2000-2010	Age: 15-17 years old	Odds Ratio: 0.975	-
				Time window: 2000-2010	Age: 18-20 years old	Odds Ratio: 0.951	-
			Cell phone ban for all drivers	Time window: 1996-2010	Age: <21 years old	Slope: -0.088; St.Error: 0.032	↓
				Time window: 1998-2010	Age: <21 years old	Slope: -0.088; St.Error: 0.034	↓
				Time window: 2000-2010	Age: <21 years old	Slope: -0.108; St.Error: 0.038	↓
				Time window: 2000-2010	Age: <15 years old	Odds Ratio: 0.969	-
				Time window: 2000-2010	Age: 15-17 years old	Odds Ratio: 0.861	↓
				Time window: 2000-2010	Age: 18-20 years old	Odds Ratio: 0.879	↓
7	Márquez et al.;2015;Colombia [ENF]	Mobile phone use while driving [Yes/No]	Enforcement [Fines]	Slope: -1.812; t-test=-5.68			↓
8	McCartt et al.;2004;USA [L]	Percentage of drivers using the mobile phone	Laws restricting mobile phone use	Location: Connecticut	Short-term vs pre-law observations	Relative difference (in proportions): -0.1; 95% CI: [-0.4, 0.5]	-
				Location: Connecticut	Follow-up vs short-term observations	Relative difference (in proportions): 0.4; 95% CI: [-0.1, 0.9]	-
				Location: Connecticut	Follow-up vs pre-law observations	Relative difference (in proportions): 0.4; 95% CI: [-0.2, 0.9]	-
				Location: Connecticut	Short-term vs pre-law observations	Relative difference (in proportions): -1.2; 95% CI: [-1.5, -0.9]	↓

Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative estimate			Effect on road safety
				Location: New York	Follow-up vs short-term observations	Relative difference (in proportions): 1; 95% CI: [0.7, 1.2]	↑
				Location: New York	Follow-up vs pre-law observations	Relative difference (in proportions): -0.2; 95% CI: [-0.6, 0.2]	-
9	McCartt et al.; 2006; USA [L]	Rate of talking on handheld phone while driving	Law on Drivers' Hand-Held Cell Phone Use	Location: Washington DC	Transport mode: all	Relative difference: -43; 95% CI: [-48, -37]	↓
				Location: Maryland	Transport mode: all	Relative difference: -9; 95% CI: [-18, 1]	-
				Location: Virginia	Transport mode: all	Relative difference: -34; 95% CI: [-48, -21]	↓
				Location: Washington DC	Transport mode: passenger vehicles	Relative difference: -44; 95% CI: [-50, -38]	↓
				Location: Washington DC	Transport mode: taxi cabs	Relative difference: -15; 95% CI: [-39, 18]	-
				Location: Washington DC	Transport mode: other commercial vehicles	Relative difference: -50; 95% CI: [-70, -18]	↓
		Location: Washington DC		Transport mode: all	Odds Ratio: 0.5; 95% CI: [0.44, 0.56]	↓	
10	McCartt and Hellinga; 2007; USA [L]	Rate of talking on handheld phone while driving	Law restricting mobile phone	Location: Washington DC; Transport mode: all	Short-term vs pre-law observations	Relative difference: -43; 95% CI: [-48, -37]	↓
				Location: Washington DC; Transport mode: all	Follow-up vs short-term observations	Relative difference: 13; 95% CI: [1, 27]	↑
				Location: Washington DC; Transport mode: all	Follow-up vs pre-law observations	Relative difference: -35; 95% CI: [-35, -29]	↓
				Location: Maryland; Transport mode: all	Short-term vs pre-law observations	Relative difference: -9; 95% CI: [-18, 1]	-
				Location: Maryland; Transport mode: all	Follow-up vs short-term observations	Relative difference: 39; 95% CI: [26, 54]	↑
				Location: Maryland; Transport mode: all	Follow-up vs pre-law observations	Relative difference: 27; 95% CI: [15, 40]	↑

Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative estimate			Effect on road safety
				Location: Virginia; Transport mode: all	Short-term vs pre-law observations	Relative difference: 34; 95% CI: [21, 48]	↑
				Location: Virginia; Transport mode: all	Follow-up vs short-term observations	Relative difference: 4; 95% CI: [-6, 14]	-
				Location: Virginia; Transport mode: all	Follow-up vs pre-law observations	Relative difference: 39; 95% CI:[26, 53]	↑
				Location: Washington DC; Transport mode: passengers vehicles	Short-term vs pre-law observations	Relative difference:-44; 95% CI: [-50, -38]	↓
				Location: Washington DC; Transport mode: passengers vehicles	Follow-up vs short-term observations	Relative difference: 15; 95% CI:[2, 30]	↑
				Location: Washington DC; Transport mode: passengers vehicles	Follow-up vs pre-law observations	Relative difference:-36; 95% CI: [-43, -29]	↓
				Location: Washington DC; Transport mode: taxicabs	Short-term vs pre-law observations	Relative difference:-50; 95% CI: [-70, -48]	↓
				Location: Washington DC; Transport mode: taxicabs	Follow-up vs short-term observations	Relative difference: 3; 95% CI: [-43, 87]	-
				Location: Washington DC; Transport mode: taxicabs	Follow-up vs pre-law observations	Relative difference:-49; 95% CI: [-69, -15]	↓
				Location: Washington DC; Transport mode: other commercial vehicles	Short-term vs pre-law observations	Relative difference: 15; 95% CI: [-39, 18]	-
				Location: Washington DC; Transport mode: other commercial vehicles	Follow-up vs short-term observations	Relative difference: 3; 95% CI: [-29, 48]	-
				Location: Washington DC; Transport mode: other commercial vehicles	Follow-up vs pre-law observations	Relative difference:-13; 95% CI: [-38, 22]	-
		Talk on the handheld phone while driving [Yes, No]		Location: all; Transport mode: all	Exposed vs non-exposed	Slope: 0.47; 95% CI: [0.42, 053]	-
11	Rangland;2012;USA [L]	Fatalities-total	Mobile phone law	Percentage change=-22.1%			↓*
		Fatalities-non distracted driving related		Percentage change=-21.7%			↓*
		Fatalities-distracted driving related		Percentage change=-29.8%			↓*

Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative estimate		Effect on road safety
		Fatalities-mobile phone related		Percentage change=-47.2%		↓*
		Fatalities-handheld phone related		Percentage change=-47%		↓*
		Fatalities-hands-free phone related		Percentage change=-48.5%		↓*
		Injuries-total		Percentage change=-12.7%		↓*
		Injuries-non distracted driving related		Percentage change=-11.7%		↓*
		Injuries-distracted driving related		Percentage change=-22%		↓*
		Injuries-mobile phone related		Percentage change=-37.4%		↓*
		Injuries-handheld phone related		Percentage change=-50%		↓*
		Injuries-hands-free phone related		Percentage change=-23.6%		↓*
		12		Truong et al.;2016;Vietnam [ENF]	Mobile phone use while driving [Yes/No]	Enforcement [Police presence]
Calling operation while using the mobile phone [Calling operation while using the mobile phone not using the mobile phone]	Odds Ratio: 0.6840; 95% CI: [0.58, 0.805]		↓			
Screen operation while using the mobile phone [Calling operation while using the mobile phone not using the mobile phone]	Odds Ratio: 1.067; 95% CI: [0.884, 1.289]		-			
13	Walsh et al.;2008; Australia [ENF]	Intention to call while driving [from (1)extremely unlikely to (7) extremely likely]	Enforcement [Likelihood of being caught and fined]	Scenario: 100km/hr, late	Slope: 0.06	-
				Scenario: 100km/hr, no hurry	Slope: 0.06	-
				Scenario: traffic lights, late	Slope: 0.04	-
				Scenario: traffic lights, no hurry	Slope: 0.00	-
		Intention to text message [from (1)extremely unlikely to (7) extremely likely]		Scenario: 100km/hr, late	Slope: 0.13	-
				Scenario: 100km/hr, no hurry	Slope: 0.16	↑
				Scenario: traffic lights, late	Slope: 0.17	↑
				Scenario: traffic lights, no hurry	Slope: 0.09	-

Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative estimate			Effect on road safety
14	Walter et al., 2011; UK [ENF]	Drivers using of handheld phone while driving [percent change]	Increase of the level of enforcement	before-during	A23	Percentage change: 0%	-
					Halo	Percentage change -0.7%	↓*
				before-after	A23	Percentage change: -0.2%	-
		Drivers using of hands-free phone while driving [percent change]		before-during	A23	Percentage change: 0.3%	-
					Halo	Percentage change: -0.6%	↓*
				before-after	A23	Percentage change: 0.7%	↑*
↓	denotes positive road safety effects	-	denotes unclear or marginal road safety effects				
↑	denotes negative road safety effects	*	denotes that no statistical analysis was conducted for the significance of the effects				

3.7 REFERENCES

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3.7.2 Other studies considered

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Increasing traffic fines


Goldenbeld, Ch., July 20th 2017

1 Summary



1.1 COLOUR CODE: LIGHT GREEN

There is evidence that higher fines are associated with less traffic violations, but effects may be limited in time and place. Therefore, this measure is considered as probably effective (light green).

1.2 KEY WORDS

Fine, penalty, sanction, increase, offence, violation, repeat offenders, recidivism, road crash

1.3 ABSTRACT

Penalties for traffic violations, e.g. in the form of fines, are part of the traffic law enforcement chain. According to deterrence theory, a sufficiently high chance of detection of a violation and a sufficiently high penalty will deter road users from committing traffic violations. This synopsis describes the effects of fine increase on several road safety indicators. Studies on fines and road safety have linked the increase in fines to changes in traffic violations, changes in recidivism (re-offending), and changes in crashes. A 2016 meta-analysis indicated that fine increases between 50 and 100% are associated with a 15% decrease in violations; that fine increases of up to 50% do not influence violations, and that fine increases over 100% are associated with a 4% increase in violations and thus tended to be counterproductive. The effects of fine increase on recidivism are mixed, but the more severe and frequent offenders do not seem to be influenced by fine increases. An increase of fines was associated with a 5-10% reduction in all crashes, and a 1-12% reduction in fatal crashes. In general, studies had insufficiently controlled for confounding factors and results should be interpreted cautiously. Moreover, most studies looked at the effect immediately after a change in fines and at places with high enforcement levels. Therefore, the possibility that the reported effects are limited in time and place cannot be excluded.

1.4 BACKGROUND

Why are penalties necessary in traffic?

Traffic laws regulate the interactions between road users and the interactions between road users and the road environment. They intend to promote the safe and rapid flow of traffic. Unintended errors and unconscious violations by road users can be largely prevented by means of self-explaining road layouts, understandable and realistic traffic regulations, and good traffic education (Wegman & Aarts, 2006). However, even in a perfectly designed traffic system some groups of road users may still be inclined to violate the traffic rules. Therefore the enforcement and punishment of traffic offenders is a last, but necessary step aimed at preventing road users from intentionally violating the traffic regulations.

What is the aim of traffic penalties?

Traffic offenders can be penalised in various ways: fines, (temporary) driving licence suspensions, confiscation of their vehicles, penalty points, mandatory participation in rehabilitation programmes, prison sentences or community service. The practice of imposing penalties serves a number of social goals (SWOV, 2013): retribution (somebody has to 'pay'), protection of society (those not participating in traffic cannot commit offences), influencing the offender's behaviour to prevent repetition of the undesirable behaviour (specific deterrence) and influencing the behaviour of all citizens (general deterrence through the normative effect of the law and penalties).

Do increased fines lead to less traffic violations?

Evidence shows that the size of fines has an effect on violation behaviour. Studies have shown that higher fines are associated with lower violations in the areas of speeding, red light running, and seat belt use (Bar-Ilan & Sacerdote, 2001; Elvik & Christensen, 2007; Nichols et al, 2010; Moolenaar, 2014). It should be kept in mind that studies showing that increasing fines reduce traffic violations have used measurements shortly after the introduction of the fine increase and at places with frequent traffic surveillance. Therefore, the possibility that the reported effects are limited in time and place cannot be excluded.

Do increased fines lead to less accidents?

According to a review by Elvik (2016), increases in fixed penalties are associated with a reduction of the number of accidents, varying between 1 and 12%. However, most studies did not control sufficiently well for potentially confounding factors and therefore any simple, causal interpretation should be treated with caution.

Which factors influence the effect of increase of fines on road safety?

According to deterrence theory, the most important moderator variable with respect to increases in traffic fines is the risk of apprehension: increasing penalties will improve compliance with traffic rules, but only when the risk of apprehension is sufficiently high; when the risk of apprehension is low, increasing fixed penalties will not make a noticeable difference for deterrence (Zaal, 2004; Elvik, 2016; SWOV, 2013). More indirect, there is a likely effect of the perceived fairness of the fine. Yagil (1998) found that, especially for young drivers, the perceived fairness of punishment is one of the important determinants of traffic law compliance. If road users consider fines to become too high, it might reduce the perceived fairness of the fine, and the increase of the fine might lose its effect. Also the fairness of fines perceived by police could play a role: if they assess sanctions as too high or unfair, they might be less inclined to apply them, and as such reduce the chance of apprehension (e.g. see Elvik, 2015; 2016).

How is the effect of fines on road safety measured?

Studies on fines and road safety have linked the increase in fines to 1. changes in traffic violations, 2. changes in recidivism and 3. changes in crashes.

1.5 OVERVIEW OF RESULTS

- A 2016 meta-analysis indicated that fine increases of:
 - Less than 50% did not influence violations
 - Between 50 and 100% were associated with a 15% decrease in violations.
 - More than 100% were associated with a small increase in violations and thus tended to be counterproductive.
- There is mixed evidence on the effects of penalty/fine increases on recidivism. Heavy traffic offenders (including alcohol offenders and frequent offenders) appear not to be influenced by fine increases.
- A 2016 review reported a 5-10% decrease in all crashes and a 1-12% decrease in fatal crashes following penalty increases. However, most studies had not (sufficiently) controlled for confounding factors and these results should be interpreted with some caution.
- The main factor that affects the effectiveness of fine increases is the risk of apprehension. The increase of penalties will be more effective if risk of apprehension is (sufficiently) high. More indirect there is a likely effect of perceived fairness of (increased) fines. If fines or fine increases are perceived as unfair this may prompt resistance from both drivers and enforcement bodies.
- Although studies show that increasing the fines has a (limited) beneficial effect on traffic violations it should be kept in mind that the effects were often measured shortly after the introduction of the measure and at places with frequent traffic surveillance. The effects may therefore be limited in time and place.

2 Scientific Overview



This scientific overview on the effects of fine increases first describes knowledge on fine increases and traffic safety from the general literature (Section 2.1), it then describes characteristics of coded studies on fine increases (Section 2.2.), major results of the coded studies (Section 2.3), and it ends with main conclusions (Section 2.4).

2.1 LITERATURE REVIEW

More severe penalties, including the increase of fines, aim to reduce the number of (increased or widespread) traffic violations.

Evidence shows that the size of fines has actual effect on violation behaviour. Bar-Ilan & Sacerdote (2001) used the so-called price elasticity of fines to look at the relation between increasing fines and red light running. On the basis of data from Israel and the US, they estimated that each percent increase of fines had led to a decrease in red light running of about 0.20% (the price elasticity was -0.20). In the Netherlands, research has also been done into the price elasticity of fines (Moolenaar, 2014). After several years of no adjustments to traffic fines, on April 1st 2008 fines were raised with 20% on average. Using a regression model that corrected for GDP, unemployment, season, yearly trend, gender and age, Moolenaar (2014) estimated the price elasticity of speeding fines at section control systems at -0.14. In other words: it was estimated that increasing the fine rate by 1% would decrease the number of violations by 0.14%. This estimate is slight smaller than in earlier studies mentioned above.

In the area of seatbelt use there are also indications that the size of the fine influences violation behaviour. A Norwegian study showed that increasing the fixed penalty for not wearing seat belts by 100 NOK (15 USD) was associated with an increase of about 10 percentage points in wearing rate in urban areas, and some 2.5–5 percentage points increase in wearing rate in rural areas (Elvik & Christensen, 2007). This correlation was also found in the US (Nichols et al., 2010): an increase of the fine from 25 to 60 dollars improved the use of seatbelts by 3 to 4 percentage points and an increase of 25 to 100 dollar increased seatbelt use by 6 to 7 percentage points.

A few studies used the method of stated preferences (a kind of survey approach) to investigate the effect of the levels of fines and enforcement on self-reported speeding behaviour. Ryeng (2012) reported that the speeds driven by other drivers and enforcement levels were more powerful determinants of self-reported speed behaviour on 80 km/h rural roads than the level of fines. For example, for car drivers who indicated to prefer driving 85 km/h on an 80 km/h road, a doubling of the fine led to an average speed reduction of less than 1 km/h, whereas quadrupling the enforcement hours led to nearly 2.5 km/h average speed reduction, for a majority of drivers who reduced speed from 85 to 75 km/h. It must be noted, however, that Ryeng only varied the level of fines by a factor of 2, whereas enforcement levels were quadrupled. In another stated preference study, Hössinger & Berger (2012) found that the levels of enforcement and fines determined frequency of speeding to the same extent when the relative increase factor was kept constant. An increase of enforcement density with a factor of 8.3 was associated with a self-reported reduction in speeding frequency of 61%; an increase in the amount of the fine by the same factor (from 36 to 300 Euros) was associated with a similar reduction (59%).

Traffic fines elicit emotional reactions that may influence the impact of fines and, indirectly, the impact of fine increases. Corbett (1995) found that emotional reactions to traffic penalties tended to be stronger if the penalty or the method of detection was considered to be unfair. Related to this, McKenna (2007) reported that compliance with traffic rules is more likely if the enforcement and its methods are perceived as legitimate. Some studies have highlighted the role of the perceived legitimacy or fairness of police intervention. For example, Paternoster et al. (1997) found that the perceived fairness of an encounter with the police was a more important preventive influence on recidivism than either the severity or type of penalty. Yagil (1998) also found that, especially for young drivers, the perceived fairness of punishment is one of the important determinants of traffic law compliance. Concerning drinking and driving, Mazerolle et al. (2012) showed that police officers who communicated fairness principles during random breath testing actions (i.e. expressing neutrality, trustworthy motives, positive feedback, and engaging citizens in the policing approach) positively affected citizens' perception of the police as well as their commitment to safer behaviour. Watling & Leal (2012) found that the likelihood of engaging in illegal traffic behaviour was greater when the perceived legitimacy of enforcement of this behaviour was less. The importance of procedural justice in improving rule compliance has also been shown in other areas such as tax compliance (Verboon & Van Dijke, 2011).

2.2 METHODOLOGY

A systematic literature study was undertaken to identify scientific studies on the relationship between the size of traffic fines and their impact on traffic behaviour and safety. A recent meta-analysis by Elvik (2016) includes most of the studies in this field so far, focusing on effects on violation rates or crashes. This meta-analysis presents the most recent and complete evidence on the relationship between traffic fine levels and traffic violations (speed, seat belt) and safety. It should be noted that this meta-analysis, like the review, focused on monetary fines and thus it only partially includes literature about higher penalties for drinking and driving. The penalties for drinking and driving are often not restricted to a monetary fine but include licence suspension, rehabilitation programme, community service or imprisonment. Besides the meta-analysis, three additional studies on fine increases have been coded, two from Australia and one from the Netherlands. These studies used large-scale fine databases to examine the changes in the chance of re-offending after an increase in fine level.

2.3 ANALYSIS AND RESULTS

The meta-analysis by Elvik (2016) presented the following major findings:

- An increase of fixed penalties up to 50% was not associated with a change in violations.
- Both the results of the random-effects analysis and the fitted polynomial indicate that increasing fixed penalties by between 50 and 100% were associated with a reduction of the rate of traffic violations (mainly speeding violations, also seat belt violations).
- Increasing fixed penalties by more than 100% was associated with a 4% increase in violations .

In the three studies not included in the meta-analysis by Elvik, the focus was on repeat offending (recidivism) of specific groups of traffic offenders (Moffat & Poynton, 2007; Popping, 2012; Watson et al., 2015). These studies tend to indicate small positive or no effects of higher fines on the chance of reoffending.

Table 1 summarises the main outcomes of the four coded studies on traffic fines and traffic behaviour and safety.

Table 1: Study main outcomes (↑ = expected increase in road safety; ↓ = expected decrease in road safety; — = no road safety effect expected).

Study	Penalty change	Offender group	Outcome Indicator	Potential safety effect	Effect- Description
Elvik, 2016, international	Less than 50% increase of fixed fine	Drivers general	Rate of violations (speeding and seat belt)	—	Increasing fixed penalties by up to 50% was <i>not associated</i> with any change of the rate of violations.
	50-100% increase of fixed fine	Drivers general	Rate of violations (speeding and seat belt)	↑	A 50 to 100% increase in fixed penalties was associated with a 15% reduction of the rate of violations
	> 100% increase of fixed fine	Drivers general	Rate of violations (speeding and seat belt)	↓	A > 100% increase was associated with a 4% increase in the rate of violations.
Moffat & Poynton, 2007, Australia	Higher fine amount or longer period of disqualification	6 offender groups: 3 groups alcohol offenders, speed offenders, driving while disqualified, other driving offences	Recidivism: probability of returning to court for a traffic offence	—	Neither the fine amount nor the length of licence disqualification were significant predictors of the probability of returning to court.
	Longer period of licence disqualification	Speed offender group	Probability of returning to court for a traffic offence	↓	A longer period of licence disqualification increased the probability of subsequent driving offences.
Popping, 2012, Netherlands	20% fine increase	Speed offender 3 days before/ after fine change	Probability to reoffend (short time window)	↑	A lower probability on a re-offence was achieved for the 3 day period (Tuesday/Wednesday/Thursday)-group just before and after the fine raise.
		Frequent speed offenders (> 4 speed fines past 12 months)	Probability to reoffend	—	No effect on recidivism for frequent speed offenders
		Speed offenders 1 month before/ after fine change	Probability to reoffend (long time window)	↓	The probability of a re-offence within 12 months was around 1.6% higher for the 1 month after-group.
		Speed offenders 1 month before/ after fine change	Time to reoffend	↑	After the fine increase it took 7 days longer to reoffend.
		Speed offenders 1 week, 3 days, 1 day before/after fine change	Time to reoffend	—	The point-estimates for time to reoffend were all around 0 (NS), indicating a negligible time effect of higher fines.

Study	Penalty change	Offender group	Outcome Indicator	Potential safety effect	Effect- Description
		Speed offenders 1 month before and after fine change	size of speeding offence	↗	At the first re-offence, offenders from the 1 month after group tended to exceed the maximum speed level at 0.319 km/hour less than the 1 month before group of offenders, suggesting that speeding offences were smaller.
Watson et al., 2015, Australia	fine increases (11% to over 100%) + licence suspension (> 40 km over speed limit)	Speed offenders	% drivers reoffending	↗	A significant 6.3% reduction of drivers re-offending in the 2003 (post-penalty change) cohort
			Average number of subsequent speeding offences committed	—	No statistically significant difference between the pre- and post-change cohorts.
			Overall frequency of offending	↗	The average number of offences reduced significantly in the 2003 (post penalty change) cohort by 5.8%. Fewer speeding offences, on average, were committed by offenders following the increase in penalties, regardless of the index offence severity, previous speeding offence history or detection method.
			Length of delay to re-offence	↘	The average time between index offence and re-offending significantly shortened after the penalty change (N = 286 days 2003 cohort vs. 312 days 2001 cohort).
			The average number of additional offences (i.e., subsequent to the index offence)	—	The average number of additional offences committed did not significantly change following the increase in penalties, regardless of factors such the severity of the index offence, speeding offence history or speed detection method

2.4 CONCLUSIONS

On the basis of the reviewed evidence we conclude:

- There is evidence that higher fines may lead to reduced speeding, red light running, and seat belt violations. However, effects may be limited in time and place and dependent upon the presence of traffic enforcement.
- A too large increase in fines (> 100%) seems to have a lesser or even counterproductive effect on level of traffic violations.
- There is mixed evidence concerning the effect of higher fines on reducing recidivism, ranging from small positive effects to no effects at all.

3 Supporting document



3.1 DESCRIPTION OF STUDIES

Meta-analysis on increased penalties

The meta-analysis by Elvik (2016) on the relationship between fine size and road safety included studies of effects of changes in traffic fines on speed offences and seat belt offences. In these studies, effects on the total population of drivers in a city or area were measured. The random effects meta-analysis included nine studies of changes in compliance with a total of 43 estimates of effect. Thirty six of these estimates originated in three countries: Norway, Sweden and Switzerland. A second degree polynomial was fitted to the 43 data points concerning changes in the size of fixed penalties and changes in the percentage of cars speeding. The meta-analysis presented two major findings:

- An increase of fine size up to 50% was not associated with a change in traffic violations (mostly speeding measures, also seat belts (far less))
- Both the results of the random-effects analysis and the fitted polynomial indicate that increasing fixed penalties by between 50 and 100% was associated with a reduction of the rate of traffic violations (mainly speeding violations, also seat belt violations).
- An increase of fixed penalties by more than 100% was associated with a 4% increase in violations, suggesting a counterproductive effect.

Additional research not covered by meta-analysis

In a number of other studies not included in the meta-analysis by Elvik, the focus is on repeat offending (recidivism) of specific groups of traffic offenders (Moffat & Poynton, 2007; Popping, 2012; Watson et al., 2015). These studies tend to indicate small or no effects of higher fines on the chance of reoffending.

In Australia, Moffat and Poynton (2007) examined the history and subsequent reoffending of 70,000 road users who were fined for a driving offence, including drink-driving, speeding, driving while disqualified and some other offences, between 1998 and 2000. The researchers studied re-offending among six subgroups of offenders who had been sentenced by court: low range, mid-range, high range alcohol offenders, offenders who had driven while disqualified, speeding offenders, and other offenders. Subsequently, offenders in each of the subgroups were divided into two groups, a high penalty group and a low penalty group. A Heckman 2-step model was estimated to determine the effects of receiving a higher fine by comparing the offender groups with high and low fines. The study findings suggest that substantial increases in fines did not have a significant impact in deterring recidivist offenders. It appeared that for these subgroups of traffic offenders neither the fine amount nor the length of licence disqualification were significant predictors of the probability of returning to court. Unexpectedly, for persons convicted of speeding offences an association between licence disqualification and recidivism was found, indicating that a longer period of licence disqualification actually increased the probability of subsequent driving offending.

Watson et al. (2015) examined the impact of increased speeding penalties in April 2003 in Queensland, Australia. The research focused on four measures of recidivism:

1. the proportion of offenders who re-offended in a given follow-up period (absolute specific deterrent effect);

2. the overall frequency of re-offending during the follow up period (the net absolute and marginal specific deterrent effect);
3. the length of delay to re-offence (marginal specific deterrent effect among re-offenders); and
4. the average number of re-offences (another measure of the marginal specific deterrent effect among re-offenders).

The results provided support for the proposition that statistically significant reductions in the proportion of offenders who re-offend would be found after the introduction of more severe penalties. However, the findings suggest that more persistent and problematic offenders, as classified by the severity of their index offence and the extent of their previous offence history, are less amenable to behaviour change. The effect sizes for all significant findings were small and almost half of the post-penalty change cohort (49%) had re-offended within two years of their index offence.

Analysing fine data on Dutch speed offenders before and after 20% fine increase, Popping (2012) like Watson and colleagues found mixed results. For the total sample and the sample of small speed offenders (only one fine in the past 12 months) he found a rather small 'reducing effect' on reoffending of about 2% for the 3 day-subsample immediately following the change in fines. The 'reducing effect' was not present for the group of heavy offenders (more than four fines in the past 12 months). For this group he did not find significant effects of the higher fines on recidivism.

Table 1 summarises the information on the main characteristics of the coded studies.

Table 1: Summary of methodological characteristics of coded studies

Author, Year, Country	Study type, penalty increase measure	Sample, Measurement	Analysis
Elvik, 2016, international	Meta-analysis on the effect of increasing monetary fines on traffic violations (speeding and seat belt violations)	A random effects meta-analysis included 9 studies of changes in compliance with a total of 43 estimates of effect. 36 of these estimates originated in three countries: Norway, Sweden and Switzerland	A random effect meta-analysis was performed in order to assess the presence of a dose-response relationship between changes in fixed penalties and changes in the rate of violations. Concerning speeding violations second degree polynomial was fitted to the 43 data points concerning changes in the size of fixed penalties and changes in the percentage of cars speeding.
Moffat & Poynton, 2007, Australia	In New South Wales the average fine amount imposed by the Local Courts had increased at double the inflation rate over the period 1995-2005, rising from \$358 in 1993 to \$608 in 2005. The study concerns the effectiveness of financial penalties in reducing recidivism rates of convicted offenders.	The study examined the history and subsequent reoffending of app. 70,000 persons who received a court imposed fine for a driving offence between 1998 and 2000. This included drink-driving (low-range, mid-range and high-range prescribed concentration of alcohol offences), drive whilst disqualified, speeding and 'other driving' offences.	The study attempted to control for selection bias in recidivism analyses by simultaneously estimating 2 regression equations (a selection equation and an outcome (or recidivism) equation) by the Heckman 2-Step Model. The main outcome measure in the study was recidivism: a count variable indicating the number of reappearances before the court for any new driving offences within five years of their reference offence being determined.
Popping, 2012,	The study investigated the effect of a 20% increase of	The data were obtained from the Central Fine Collection Agency, containing all	Using difference-in-difference models, the researcher looked at:

Author, Year, Country	Study type, penalty increase measure	Sample, Measurement	Analysis
Netherlands	<p>finest for speeding on recidivism.</p>	<p>individuals that received a fine in March and April of 2007 and 2008. This included 1,976,063 offenses of 1,337,014 individuals. Beside the offences of road users in this period the researcher also had information on all other traffic offences of these offenders between January the 1st of 2005 and 31 December of 2010. The data included the fines for offences of exceeding the maximum speed by up to 30 km/h within built-up areas and 40 km/h outside built-up areas. The data only included persons who are living in the Netherlands. Each observation contained information about this fine and offence.</p>	<ul style="list-style-type: none"> - All offenders from March and April 2008 (1 month period) - The offenders one week before and one week after the cut-off (1 week period) - The offenders the Tuesday to Thursday before and the Tuesday to Thursday after the cut-off (3-day period) - The offenders of only the Wednesday before and the Wednesday after the cut-off (1 day period) <p>The researchers also looked separately at results for all offenders, heavy offenders (> 4 fines) and light offenders (1 fine only).</p>
Watson et al., 2015, Australia	<p>Cohort study on recidivism in Queensland. Three major changes were made to the speeding penalty regime in 2003:</p> <ul style="list-style-type: none"> - the number of offence categories was increased from 4 to 5, effectively narrowing the range of speeds covered by a number of the categories; - the monetary fines for all offences were increased, with the largest increases applicable to the highest categories; - automatic licence suspension and an eight demerit point penalty was introduced for the highest offence category. 	<p>The researchers collected traffic offence data for two cohorts of speeding offenders, collected two years prior and subsequent to the April 2003 penalty change. The two cohorts consisted of motorists who committed a speeding offence in May 2001 (before the penalty increase) and those who committed a speeding offence in May 2003 (after the penalty increase). The first recorded offence in the month was regarded as the index offence. There were 44,232 motorists in the 2001 cohort and 40,224 in the 2003 cohort.</p>	<p>The analysis distinguished four recidivism measures:</p> <ol style="list-style-type: none"> 1. the proportion of offenders who re-offend in a given follow up period; 2. the overall frequency of re-offending during the follow up period; 3. the length of delay to re-offence; and 4. the average number of re-offences

Main review conclusions

- A 2016 meta-analysis indicated that
 - Monetary fine increases up to 50% are not associated with change in violations.
 - Monetary fine increases between 50-100% are associated with a 15% decrease in violation.
 - Monetary fine increases over 100% are associated with a 4% increase in violations and thus tended to be counterproductive.
- There is mixed evidence on the effects of penalty/fine increases on recidivism. Heavy traffic offenders (including alcohol offenders and frequent offenders) appear not to be influenced by fine increases.
- A 2016 review reported a 5-10% decrease in all crashes and a 1-12% decrease in fatal crashes following fine increases. However, most study methods insufficiently controlled for confounding factors. Hence, results should be interpreted cautiously.

- The main factor that affects the effectiveness of fine increases is the risk of apprehension. The increase of penalties will be more effective if risk of apprehension is (sufficiently) high. More indirectly there is a likely effect of perceived fairness of (increased) fines. If fines or fine increases are perceived as unfair this may prompt resistance from both drivers and enforcement bodies.

3.2 LITERATURE SEARCH

The literature on higher fines (penalties/sanctions) and traffic risk was searched for in the international database Scopus on January 3rd 2016. Scopus is the largest international peer-reviewed database. A meta-analysis by Elvik in 2016 covered studies in the period 1989-2016. In view of this, the literature was searched over the most recent period 2014-2016; the search terms were searched in title, abstract and keywords. Table 3 describes the search terms and logical operators and the number of hits for the search on traffic fines and road safety.

Table 3: Used search terms and logical operators

No	Search terms/logical operators/combined queries	hits
1	(TITLE-ABS-KEY (fine OR penalty OR penalties OR sanction OR "higher fines" OR "increased fines" OR "increased penalties") AND TITLE-ABS-KEY ("traffic violation" OR "road safety")) AND PUBYEAR > 2013	58

In a first screening round (see Table 4), the 58 publications together with references were screened on potential relevance for coding. The main criteria for exclusion for coding were:

- The publication does not concern a study regarding the effect of fine size on violations or accidents.
- Written in non-English.
- Better or more complete results were published earlier or later in another publication (duplication).
- General review-like text.

Table 4: Initial selection of studies after the first screening round

Selection steps	Not selected first round	Selected first round
Excluded: No actual crash/violation reduction by higher fines studied	52	
Excluded: Non-English	2	
Selected after initial screening		4
Added after screening references (studies by Moffat & Poynton, Popping, Watson et al.)		3
Total selected		7

The seven selected studies were further screened on relevance for coding in a second screening round. In the second round the same criteria were used but were checked on full-text copies of the papers. Table 5 presents the results of this second screening round and describes the final decisions

Table 5: Selection of studies to be coded in second screening round

	Reference	Relevant	Coded
1	Meta-analysis starting point: Elvik, R. (2016). Association between increase in fixed penalties and road safety outcomes: A meta-analysis. <i>Accident Analysis and Prevention</i> , 92, 202–210.	Yes	Yes
2	Hössinger, R. & Berger W.J. (2012). Stated response to increased enforcement density and penalty size for speeding and driving unbelted. <i>Accident Analysis and Prevention</i> , 49, 501-511.	Yes, but unusual methodology makes this study difficult to code. Moreover, use of self-report to hypothetical situations raises some doubt about external validity.	No
3	Killias, M., Villettaz, P. & Nunweiler-Hardegger, S. (2016). Higher Fines—Fewer Traffic Offences? A Multi-Site Observational Study. <i>European Journal on Criminal Policy and Research</i> , 22, 619-634.	Yes, but already included in Elvik meta-analysis	No
4	Jiang, X.-C. & Zeng, Y.-S. (2016). Research on step punishment intensity model of illegal parking. <i>Zhongguo Gonglu Xuebao/China Journal of Highway and Transport</i> , 29, 124-133.	Relevant but only available in Chinese language	No
5	Moffat, S. & Poynton, S (2007). The deterrent effect of higher fines on recidivism: Driving offenses. The NSW Bureau of Crime Statistics.	Yes	Yes
6	Popping, H. (2012). Do Higher Fines Reduce Recidivism? Evidence from a Twenty Percent Increase in (Dutch) Traffic Fines. Master Thesis Econometrics and Management Science Erasmus University Rotterdam (EUR)	Yes	Yes
7	Watson, B., Siskind, V., Fleiter, J.J., Watson, A., & Soole, D. (2015). Assessing specific deterrence effects of increased speeding penalties using four measures of recidivism. <i>Accident Analysis and Prevention</i> , 84, 27-37.	Yes	Yes

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Driving hours and rest time / hours of service regulations for commercial drivers



Goldenbeld, Ch., July 20th 2017

1 Summary

1.1 COLOUR CODE

Light green

Some but not all studies indicate that regulations concerning driving times and rest time or hours of service have reduced commercial driver fatigue and fatigue-related accidents. The impact of hours of service regulations on fatigue and accident risk depends upon multiple factors, including enforcement and monitoring, economic market pressure, and types of affected driver schedules.

1.2 KEYWORDS

Commercial driver fatigue, driving and rest time regulations, Hours of Service regulations, HOS, Truck drivers, Enforcement, Monitoring intervention, Sleepiness, Accidents, Transport sector

1.3 ABSTRACT

'Driving hour and rest time' or 'hours of service' (HOS) regulations are regulations that limit when and for how long drivers of commercial motor goods or passenger vehicles are allowed to drive and/or work during a particular period. The purpose of these regulations is to reduce driver fatigue and to reduce fatigue-related accidents. The levels of enforcement of these regulations were found to vary and to be low in many countries. Both in Europe and in USA high violation levels of the regulations have been noted. In Europe there is no direct evidence that HOS regulations have reduced average driving times, driver fatigue, or accidents. In the USA the evidence of the safety effectiveness of HOS regulations is mixed. Both positive and negative findings have been reported, in terms of change in driving and rest time, sleep, and accidents. There is evidence that increased or improved monitoring or enforcement of HOS regulations leads to higher compliance and more safety.

1.4 BACKGROUND

In the current document the concept of Hours of Service or its abbreviation HOS is used when referring to the regulations about driving hours, working hours, breaks and rest times of commercial drivers.

Why are there Hours of Service regulations?

Hours of service regulations are implemented in most countries to reduce the risk of accidents and to improve working conditions in the commercial transport sector. By imposing limitations on daily and weekly working and driving time and by imposing necessary rest breaks, the regulations strive to reduce fatigued driving and reduce accompanying accident risk.

What are the main characteristics Hours of Service regulations?

Hours of Service regulations prescribe maximum limits for the amount of driving and working within certain time periods, and minimum requirements for the number and duration of break and rest periods that must be taken by drivers (Goel & Vidal, 2014). Compulsory break and rest periods have a large effect on the total travel durations. Typically, for long-distance haulage truck drivers, the total travel time is twice as long as the pure driving time (Goel & Vidal, 2014).

How is the effect of Hours of Service on road safety measured?

The effectiveness of HOS regulations in changing behaviour and accidents of commercial drivers has been measured in a variety of ways:

- self-reports of driving times and/or driving fatigue by commercial drivers
- actual measurement of driving behaviour of commercial truck drivers
- simulation models calculating fatigue level under different regulations and driving scenarios
- changing trends in (fatigue-related) commercial vehicle accidents

1.5 OVERVIEW OF RESULTS

- In Europe it has not been possible to study the impact of HOS regulations on road safety due to the difficulty that, besides these regulations, numerous other road safety measures have been implemented and that available accident data do not allow the identification of the cause of an accident.
- In Europe the enforcement levels of HOS regulations vary greatly and several EU countries report high levels of non-compliance.
- European stakeholders mostly believe that the HOS regulations have a positive or at least neutral effect on road safety.
- A worldwide comparison of driving and working time regulations indicates that the highest risk is associated with the regulations in Canada and Australia due to short minimum rest duration which may lead to accumulated sleep loss.
- There is evidence that the USA 2013 Hours of Service regulation decreased risk and accidents. However, there are also indications of no effect.
- HOS legislation can have different effects on driver fatigue depending upon specific driver schedules and the actual changes made to these schedules.
- There is evidence that enforcement and monitoring of driving and working time regulations increases compliance and safety.

1.6 NOTES ON RESEARCH METHODS AND TRANSFERABILITY

In Europe no research has directly studied the effects of changes in HOS legislation on commercial driver fatigue and fatigue-related accident risk, e.g. by using a before-after design, a time series design or an accident analysis design. In USA the impact of changes in HOS regulations (2003-2004 and 2011-2013) on driver fatigue and accident risk have been evaluated by various research methods, such as accident analysis, naturalistic driving, behavioural monitoring, before and after surveys, and simulation. Besides the legislative changes, the effects of electronic monitoring of compliance with HOS rules and of the enforcement of fatigued driving have also been studied in the USA. Besides diversity in research methods, the transport industry itself has a diversified landscape where different transport sectors may possibly be differentially affected by changes in legislation. Not only do the research methods vary widely, there are also many different outcome indicators, including reported amount of sleep, reported falling asleep behind the wheel, modelled fatigue, fatigue-related crashes, modelled crash risk. This diversity of approaches precludes a meta-analysis on the subject.

Since the evaluation studies were mostly done in the American legislative context, there is a limited transferability to Europe. Nevertheless, there are some general lessons that can be learnt from the American research. In general terms, this research points to the importance of monitoring and enforcement of HOS, the importance of considering the combination of both long working hours and driving hours for understanding driver fatigue, and the importance of understanding how legislation affects specific driver schedules in different driving sectors. These general lessons also seem relevant for Europe, but applying them to Europe will necessitate European research and data.

2 Scientific Overview

This scientific overview first describes HOS-regulations and enforcement in **Section 2.1**; it then describes knowledge on driver HOS regulations and traffic safety from the general literature (Section 2.2). Section 2.3 describes the characteristics of the coded studies on effects of driving and working regulations, while Section 2.4 describes the major results of the coded studies.

2.1 HOS REGULATIONS

European regulations concerning Hours of Service

In the European Union, the regulation (EC) No 561/2006 and the national implementation of Directive 2002/15/EC impose limitations on driving and working hours of commercial drivers. In Regulation (EC) No 561/2006 a distinction is made between four driver activities: rest periods, breaks, driving time, and other work. The rest periods stipulate the times which a driver may freely dispose of and their purpose is to give drivers enough time to sleep (Goel & Vidal, 2014). The breaks are meant as short recuperative periods during which a driver must not carry out any work. The driving time is the time during which a driver is driving; it includes time during which a vehicle is briefly stationary for traffic-related reasons, e.g., traffic jams. Other work refers to non-driving work activities such as time spent for loading or unloading, cleaning and technical maintenance, customs, etc. (Goel & Vidal, 2014).

Directive 2002/15/EC requires that a commercial driver must not work for more than six hours without taking at least 30 minutes of break time. It also requires that, if a truck driver works for more than nine hours, at least 45 minutes of break time must be taken. It allows that the break time can be taken in 2 or 3 periods of at least 15 minutes each. This Directive lists additional rules for night work (Goel & Vidal, 2014).

Enforcement

In EU the use of a digital tachograph is mandatory in commercial road transport. ETSC (2011, p. 8) describes the legal provisions as follows:

“Under Regulation (EC) n° 561/2006, the driving and rest time periods must be recorded and compliance with these rules must be regularly monitored. Digital tachographs are required by law. Regulation (EEC) n° 3821/85 of 20 December 1985 provided the legal basis for the installation of recording equipment (analogue tachographs) in road transport. The tachograph has been mandatory since 29 September 1986, and digital tachographs were introduced with the Regulation 2135/98/EC53. This Regulation amended Regulation (EEC) n° 3821/85 so that today Regulation (EEC) n° 3821/85 covers both analogue and digital tachographs. The digital tachographs must be fitted into goods vehicles that come into scope of the Drivers’ Hours rules and which were brought into service after 1st May 2006.”

The same report describes the legal basis for the enforcement of compliance with driving and rest time periods (ETSC, 2011, p.8):

“Member States are obliged to enforce Directive 2006/22/EC55, as amended by Directive 2009/4/EC and Directive 2009/5/EC, this determines the minimum level of enforcement required to ensure compliance with the rules set out in the Driving Times and Rest Periods and the Tachograph Regulations. It provides common methods to undertake roadside checks and checks at the premises of undertakings as well as strengthening cooperation between Member State authorities in charge

of road transport enforcement.” (to be clear, in this citation ‘undertakings’ refers to ‘transport undertakings’ or ‘transport companies’).

In 2014 the tachograph legislation (Regulation of the European Parliament and the Council (EU) N°165/2014) was revised requiring Member States to exchange information electronically in order to ensure that the digital tachographs are properly used. A subsequent regulation ((EU) No 2016/68) sets out, among other things, the obligatory connection of Member States to the so-called “TACHOnet” by March 2018. TACHOnet will help in exchanging information between Member States allowing for more efficient monitoring and enforcement of driving hour and tachograph rules (https://ec.europa.eu/transport/modes/road/social_provisions/tachograph/tachonet_en, retrieved at 24 April 2017).

HOS regulations worldwide

Table 1 illustrates the main characteristics of the different regulations in Europe, USA and other countries (Goel & Vidal, 2014).

Table 1: Characteristics of HOS regulations worldwide.

Characteristic fatigue regulation	US	Canada	EU (basic)	EU (all)	Australia (std).	Australia (BFM*)
Duration of a long rest period	10	8	11	9	7	7
Driving time between two long rest periods	11	13	9	10	12	14
On-duty time between two long rest periods	14+	14+	12.25	14.25	12	14
Time elapsed between two long rest periods	14+	16+	13	15	17	17
Driving time within six days	60	70	56	56	72	72
On-duty time within six days	60+	70+	60	60	72	72

* Australian motor carriers accredited in the National Heavy Vehicle Accreditation Scheme (NHVAS) may operate according to the Basic Fatigue Management (BFM) option

As can be seen in Table 1, all HOS regulations require long rest periods to be regularly taken. Requirements on when to take these rest periods and on their minimum duration differ between the regulations (Goel & Vidal, 2014). With 11 hours, the longest continuous rest period is required by the basic regulations in the European Union in which rest periods may neither be split nor reduced, and driving time may not be extended (Goel & Vidal, 2014). The accumulated amount of driving between two long rest periods differs considerably ranging from 9 or 10 hours in the European Union to 13 hours in Canada and 14 hours in Australia if the Basic Fatigue Management (BFM) option is used (Goel & Vidal, 2014).

2.2 OVERVIEW OF THE LITERATURE

The relationship between HOS and road safety

European research on the effect of changes in HOS rules for commercial drivers is very scarce (Windisch et al., 2016). In USA, the research on effects of HOS on the safety of commercial drivers has focused on HOS rule changes in 2003 (Hanowski et al., 2007, 2009; McCartt et al., 2008), and in 2011-2013¹ (GAO, 2015; Goel, 2014; Goel & Vidal, 2014; Van Dongen & Mollicone, 2014). A few studies have specifically examined whether the frequency and quality of monitoring and enforcement will enhance the safety effects of commercial fatigue laws (Hickman et al., 2016; Mohlman, 2013).

In a comprehensive literature review on the relationship between drivers, HOS and truck operations' efficiency and safety, Min (2009) found that one of the main factors that affected safety was driver fatigue. Various factors were related with fatigue so an optimal balance between driving hours and rest periods should be figured out. A major finding from the literature was the high level of rule violations due to economic benefits.

In a review on commercial driver fatigue research the National Academies of Sciences, Engineering and Medicine (2016) observes that HOS regulations need to take into account the trade-off between the economic advantages of transporting goods more quickly and the disadvantages of increasing accident risk. In order to make such a trade-off it might be helpful to have knowledge about how increases in accident risk are linked to increases in the number of hours of service permitted. The National Academy is doubtful about the use of such knowledge: "However, given the multivariate causal structure of accidents, such a construct can be provided only by fixing all the other causal factors at levels that they rarely if ever obtain, and therefore, such a statement would not be useful to support the development of policies." (National Academy of Sciences, Engineering and Medicine, 2016; p. 125)

HOS regulations that are intended to reduce driver fatigue and fatigue-related accidents may introduce new safety risks. For example, the American Transportation Research Institute (2013) argued (and provided data) that the 2013 legislative changes were successful in reducing night time driving. However, Murray & Simpson (2015) found indications that the resulting shift to daytime driving in more congested traffic conditions was associated with accident rates that were higher than those under night time driving. In other words, exposure to fatigue due to night time driving would be substituted for exposure to more dangerous traffic conditions, with a possible negative road safety result. Such an unintended negative side effect, however, could not be confirmed by GAO (2015).

Despite the presence of HOS regulations worldwide, it is necessary to observe that commercial drivers still face various health and safety risks given the long hours on the road involving multiple and interacting work stressors (i.e., delivery pressures, irregular shifts, ergonomic hazards) (Hege et al., 2015). The work environment of commercial drivers has been linked with multiple health problems including musculoskeletal and pulmonary disorders, cardiometabolic comorbidities, overweight and obesity disorders, and fatigue and sleep disorders (Hege et al., 2015).

EU findings on HOS regulations

The data collected in the European Working Conditions survey (EWCS) suggests that general compliance with Directive 2002/15/EC is low (Windisch et al., 2016). The results show that in 2010, 37% of the group of commercial drivers stated that they typically work more than 48 hours per week

¹ The Hours of Service of Drivers Final Rule was published in the Federal Register on December 27, 2011; the effective date of the Final Rule was February 27, 2012, and the compliance date of remaining provisions was July 1, 2013.

(Windisch et al., 2016, p. 125). The shares of workers reporting hours in excess of the working time limits were largely stable over the period 2005-2010, indicating that there have not been substantial improvements over time (Windisch et al., 2016). Interviews with drivers were carried out for the EWCS study. Their responses suggested that average working times have improved for EU-15 drivers, but remained stable or deteriorated for EU-13 drivers over the past 10 years (Windisch et al., 2016, p. 127; EU 15 refers to original EM member states; EU 13 refers to newer EU-members Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia).

Overall, it can be concluded that the objectives of the EU Working Time Directive to limit working time to 48h per week and hence reduce fatigue are far from fully achieved. Since enforcement statistics for the Working Time Directive are generally not available, the main source of information on compliance levels is from direct reports from drivers (Windisch et al., 2016; p. 127). On the basis of published surveys, there is evidence of low compliance with working time provisions across the EU, with between 40% (Europe) and 90% (Germany) of drivers reporting that they typically work more than 48h per week (Windisch et al., 2016, p. 127). This general picture of low compliance was also verified by interviews with drivers conducted by the study team. Although compliance among short-distance (<50km) transport operations appeared to be higher (according to a German survey (Lohre et al., 2014, cited by Windisch et al.), it is not clear whether this is due to the Directive or due to the nature of the operations (meaning that the schedules tend to involve shorter weekly working hours). Nor is it clear whether this is a general conclusion applicable to the EU, or if the finding is specific to Germany (Windisch et al., 2016, p. 127).

2.3 DESCRIPTION OF THE CODED STUDIES

A systematic literature study was undertaken to identify scientific studies on the relationship between hours of service regulations and their possible impact on driver fatigue and fatigue-related accident risk. Eleven studies were identified and coded. All of these were conducted in the USA. The coded studies used very different methods:

- Accident analysis (Anderson et al., 2017, GAO, 2015)
- Naturalistic driving method (Hanowski et al., 2009; Soccolich et al., 2013)
- Behavioural monitoring (Hanowski et al., 2007; Hickman et al., 2016; Van Dongen & Mollicone, 2014)
- Survey (McCartt et al., 2008)
- Accident and enforcement data analysis (Mohlman, 2013)
- Simulation (GAO, 2015; Goel, 2014; Goel & Vidal, 2014)

The diversity of research methods is one of the reasons why results are difficult to compare between studies. Also, the research has concentrated on different main HOS changes in the USA (HOS 2003-2004, HOS 2011-2013) and on different priority issues (e.g. 11th hour driving; restart provision). See Section 3.1 for more details about the HOS changes.

2.4 RESULTS

11 studies were coded on effects of hours of service regulations on driver fatigue and fatigue-related behaviour or accidents.

The evidence concerning effects of HOS 2003/2004 on driver fatigue and accidents is mixed and inconclusive (Hanowski et al., 2007; McCartt et al., 2008, Soccolich et al., 2013). There was some evidence that under HOS 2003 the increase in permitted driving time from 10 to 11 hours was not associated with increased accident risk (Soccolich et al., 2013) and that drivers were getting more sleep (Hanowski et al., 2007; McCartt et al., 2008). However, there were also indications of more reports of falling asleep behind the wheel (McCartt et al., 2008).

There is also some evidence that the new USA 2013 HOS rule decreased risk and fatal accidents (Goel, 2014; GAO, 2015; Van Dongen & Millicone, 2014). However, there are also indications of no effect on total accidents and injury accidents (GAO, 2015; Andersons, 2017). Using a bio-mathematical modelling approach to truck driver fatigue it was shown that legislation can have different effects on driver fatigue depending upon the specific driver schedules and the actual changes made to these schedules (GAO, 2015). There is evidence that enforcement and monitoring of HOS regulations increases compliance and safety (Hickman et al., 2016; Mohlman, 2013). A worldwide comparison of HOS regulations indicates that the highest risk is associated with the driver fatigue regulation in Canada and Australia due to short minimum rest duration which may lead to accumulated sleep loss (Goel & Vidal, 2014).

Overview results

Below we summarise the main findings:

- In Europe it has not been possible to study the impact of HOS regulations on road safety due to the difficulty that besides these regulations numerous other road safety measures have been implemented and that available accident data do not allow the identification of the cause of an accident (Windisch et al., 2016).
- In Europe the enforcement levels of HOS regulations vary greatly and several EU countries report high levels of non-compliance.
- European stakeholders mostly believe that the HOS regulations have a positive or at least neutral effect on road safety.
- A worldwide comparison of driving and working time regulations indicates that the highest risk is associated with the regulations in Canada and Australia due to short minimum rest duration which may lead to accumulated sleep loss (Goel & Vidal, 2014).
- There is evidence that the USA 2013 Hours of Service regulation decreased risk and accidents (Goel, 2014, GAO, 2015, Van Dongen & Millicone, 2014). However, there are also indications of no effect (GAO, 2015; Andersons, 2017).
- HOS legislation can have different effects on driver fatigue depending upon specific driver schedules and the actual changes made to these schedules (GAO, 2015).
- There is evidence that enforcement and monitoring of driving and working time regulations increases compliance and safety (Hickman et al., 2016; Mohlman, 2013)

3 Supporting Documents

3.1 DESCRIPTION OF STUDIES

Evaluations of HOS 2003-2004 rule change

Studies by Hanowski et al. (2007, 2009), McCartt et al. (2008) and Soccolic et al. (2013) have investigated how 2003 HOS rules affected driving and driving fatigue of commercial truck drivers in USA. The HOS regulations were amended on 30 September 2003 and implemented on 4 January 2004. After the change, drivers were allowed to "reset" their weekly 70-hour limit to zero, by taking 34 consecutive hours off-duty. This provision was introduced to combat the cumulative fatigue effects that accrue on a weekly basis; and to allow for two full nights of rest (e.g., during a weekend break). Other central components to the revision were a 2-h extension of off-duty time from 8 to 10 h, and a one-hour increase in allowable driving time, from 10 to 11 h (see Table 2).

Table 2: 2003-2004 change HOS regulations USA truck drivers (taken from: Rader, 2003)

	HOS rules before 2003	2003 changes (in bold) (implemented January 2004)
Daily driving limits	10 driving hours after 8 off duty; up to 16 hours driving per 24-hour period	11 driving hour after 10 off duty; up to 14 hours driving per 24-hour period
Daily off-duty requirements	After driving 10 hours or working 15 hours, not allowed to drive again until after taking 8 hours off duty.	After driving 11 hours or if 14 hours have passed since driver started duty, not allowed to drive again until after taking 10 hours off duty.
Sleeper berth exception	Can split required 8 hours off duty into 2 periods in a sleeper berth (period must be 2 hours or more)	Can split required 10 hours off duty into periods in a sleeper berth (period must be 2 hours or more)
"Restart" provision	No provision	Can restart official work after 34 consecutive hours off.
Weekly driving limits	60 hours in 7 days or 70 hours in 8 days	60 hours in 7 days or 70 hours in 8 days, but "restart" provision allows up to 77 hours in 7 days , 88 hours in 8 day
Work-hour limits	No daily work hour limits No weekly work hour limits	No change
Monitoring for compliance with rules	Handwritten logbooks; voluntary use of automated recorders permitted	No change

The naturalistic driving study by Hanowski et al. (2007) included 73 drivers; data was collected through a combination of video devices, specialised software and personal questionnaires. The analysis concentrated on identifying how sleep hours affected critical incidents, i.e. accidents or conditions close to accidents. Critical incidents were identified through sensors which reported unusual conditions such as sudden accelerations. By comparing the amount of sleep of drivers in the study with previous studies/data, it appeared that drivers were likely getting more sleep under the revised HOS regulations. However, the conclusions were not uniformly positive. The researchers concluded that even though the 2003 HOS regulations provided more time for drivers' sleep,

accidents still occurred. Long driving hours were found to greatly affect drivers' performance as 58 incidents were reported after 10 hours of driving. It was found that for the drivers involved in these incidents the average sleep quantity in the 24 hours preceding the incident was significantly lower than their overall sleep quantity, the difference being more than one hour of sleep. The Hanowski et al. (2007) study did not assess sleep quality or the cumulative effects of insufficient sleep.

In their evaluation of the 2004 HOS rule change, McCartt et al. (2008) concluded that the rule change did not decrease driver fatigue. The reported incidents of falling asleep at the wheel of the truck increased between 2003 (before the rule change) and 2004 and 2005 (after the change); In 2003, 13% of drivers in Pennsylvania and 12% of drivers in Oregon reported dozing at the wheel at least once in the past month; in 2005, 19% of drivers in Pennsylvania and 21% of drivers in Oregon reported this (McCartt et al., 2008). In the same study it was found that drivers reported substantially more hours of driving after the rule change. Most drivers reported that they regularly used the new restart provision in the new ruling, enabling them to increase the amount of weekly driving. On the positive side, they reported daily off-duty and sleep time to be increased. The result of increased sleep time was also found in the Hanowski et al. (2007) study.

Hanowski et al. (2009) focused on the question whether there is an increased risk resulting from commercial drivers driving in the 11th driving-hour as compared to the 10th driving-hour. This was not the case in this study.

The hypothesis of increased risk in the 11th driving-hour was again tested in a study by Soccolic et al. (2013). This naturalistic study aimed to find out the relationship between on the one hand driving hours and time of day, and on the other hand the probability of a safety critical event (SCE). In this study an SCE was defined as a crash, near-crash, crash-relevant conflict, or an unintentional lane deviation. Data of a sample of 97 truck drivers was collected providing a combination of video and sensor data and questionnaires. Data were analysed by various regression models. According to this study, a typical 14 hour workday consisted of 66% driving operations, 23% non-driving operations and 11% rest periods. The analysis showed that SCE risk was significantly higher in the 1st hour of driving than in the 11th; however, there was not any noticeable difference comparing the 10th with the 11th hour (confirming earlier findings by Hanowski et al., 2009). Additionally, it was found that if driving operations were conducted close to the end of a 14 hour work day, the SCE risk was higher. The positive role of rest breaks during a typical workday was also confirmed. Soccolic et al. (2013) indicate that the increase in driving time from 10 to 11 hours in itself (as a single factor) may have no negative safety consequences. The researchers conclude that driving hours do not provide a full account of the work of truck drivers, and that the combination of work and driving hours merits more research attention.

Evaluations of HOS rule change 2011-2013

New proposed HOS regulations went into effect in July 2013 requiring drivers to include a 30-minute rest break over an 8-hour period and that they keep the maximum number of working hours at 70 hours in 8 days (Hege et al., 2015). However, with the 34-hour restart provision (i.e. the provision that after a break of 34 hours, a new period of 60 hours in 7 consecutive days or 70 hours in 8 consecutive days will start), drivers can still legally accumulate up to 84 hours per week (Hege et al., 2015). The American Transportation Research Institute (2013) reported that following the implementation of the new HOS rule, 67% of drivers reported a decrease in pay and 80% of motor carriers experienced productivity loss since the rules took effect, with nearly half stating that they require more drivers to haul the same amount of freight. This could stimulate drivers to drive and work more. With the increasing lack of accessible and affordable healthcare resources for truckers (33.5% of our sample had no insurance), drivers may not have the means to seek medical assistance or consider the health effects of their long and irregular hours, including sleep consequences (Hege

et al., 2015). According to Hege et al. (2015), even with the newest HOS rules, almost a quarter of the survey sample frequently or always violated these rules. This finding corroborates the earlier work of McCartt et al. (2008), which found that drivers violated the HOS rules between a quarter to a third of the time over a 3-year period. High violation levels of HOS regulations have also been reported in Europe (Windisch et al., 2016).

Anderson et al. (2017) investigated the safety efficacy of the 1 restart per 168-h restriction. They described this change as follows (p. 163):

"In July 2013, the restart changed from unlimited to only one restart per 168-h period. The ability to take more than one restart per 168-h period provided drivers with the opportunity to be on duty more hours than the 60 h per 7 days provision or 70 h per 8 days provision. Using unlimited restarts, under the 60-h provision, a truck driver could obtain 78.4 duty hours per week. Under the 70-h provision, using unlimited restarts, a truck driver could obtain 81.66 duty hours per week. The updated HOS regulation, which limits a driver to one restart per 168-h period, decreases the total number of duty hours to 70 for the 70-h provision and to 60 for the 60-h provision. This is approximately a 16.6% reduction for the 70-h provision, and a 30% reduction for the 60-h provision."

For the study, 60 months of retrospective accident data in Ohio were analysed. The 12-month span from July 2013 to June of 2014 was named post-HOS data. The 48 months span from July 2009 to June 2013 was named pre-HOS data. They found the following trends:

- The number of injuries and property damage accidents involved and caused by truck drivers was significantly higher in 48 month pre-HOS than 12 month post-HOS period, but there was no effect on the number of fatalities. These findings were explained by the general downward trend in truck accidents.
- The two HOS changes (the 1 restart per 168-h restriction and the 1 a.m. to 5 a.m. provision) did not significantly change the continuing downward trend of accidents involving trucks.
- After the HOS changes, the percentage of fatalities caused by truck drivers was significantly higher (p value =0.026) than the year preceding the changes.

Anderson et al. (2017, p.172) concluded: "This research has shown that truck drivers within Ohio are not causing a smaller percentage of fatalities, injuries, or property damage, the exact opposite of the intent of HOS."

Research on modifying conditions

The coded studies indicate a number of factors that may modify the impact of legislation on driver fatigue and crash risk:

- the strictness of the legislation itself,
- the level of monitoring and enforcement,
- the actual driver schedules that are most likely to result from legislation, and
- the change in type of exposition that may result from the revised legislation.

Strictness of legislation

Goel & Vidal (2014) compared the possible road safety impact of different legislations on driving hours and rest times worldwide. To evaluate the impact on road safety, they used the fatigue and risk index calculator available from the Health and Safety Executive (Spencer et al., 2006). This calculator was used to estimate the average relative risk of the occurrence of an accident given a specific work schedule. They found that the risk associated with Canadian regulations was notably higher compared to regulations in the United States and European Union, and that the standard and BFM rules of Australian regulations had the largest risk indices. According to these researchers, the short minimum rest duration of seven hours in Australia and eight hours in Canada leads to a

relatively strong increase in risk due to expected accumulated sleep loss throughout the course of a work schedule (Goel & Vidal, 2014).

Enforcement and monitoring level

Mohlman (2013) found that states that trained state patrol officers about fatigued driving, that had fatigued driving programmes, and that had officers who used driving cues to detect fatigue tended to be safer than those that did not provide such training. Hickman (2016) found that trucks equipped with Electronic Logging Devices (ELD) that monitored compliance with HOS regulations had a 12% and 5% significantly lower accident rate than non-ELD equipped trucks for total accidents ($p < .001$) and preventable accidents ($p < .001$), respectively. The ELD cohort had 53% and 49% significantly lower driving-related ($p < .01$) and non-driving related ($p < .001$) HOS violations than the non-ELD cohort, respectively.

Actual driving schedules

The expected reduction in driver fatigue will depend upon how under the new rule regime the old and new driver schedules actually differ. GAO (2015) found that (expected) peak fatigue scores under (simulated) schedules that were not compliant with the 2011 HOS rule were higher than the scores under schedules that were compliant with the 2011 HOS rule. For most schedules (scenarios) the authors conclude that the new rules would lower peak fatigue scores and lower the risk of driver fatigue.

Change in type of exposition

Another type of expected schedule change due to HOS 2011-2013 was a shift from night time to early morning driving. Industry stakeholders observed that the 1 to 5 a.m. provision (i.e. that the required 34 hours off before a new restart can be initiated should include two consecutive 1 a.m. to 5 a.m. periods) of the 2011 HOS rule could result in an increase in accidents involving commercial trucks during morning peak hours (i.e., 5 a.m. to 9 a.m.). The truckers who previously drove during the middle-of-the-night hours would tend to shift their driving to the early and mid-morning timeframe. To test this possibility, GAO (2015) developed statistical models to examine whether, conditional on the number of accidents that occurred, there was a change in the likelihood of truck accidents occurring between 5 a.m. and 9 a.m. after the HOS rule went into effect. The researchers found no such change. However, Murray and Simpson (2015; not coded) found indications that accidents may have shifted to other days and times as consequence of changed driving schedules.

Conclusions

- In the EU it has not been possible to study the impact of HOS regulations on road safety due to the difficulty that besides these regulations numerous other road safety measures have been implemented and that available accident data do not allow the identification of the accident cause.
- In the EU enforcement levels of HOS regulations vary greatly; in various EU countries high levels of non-compliance have been reported.
- EU stakeholders mostly believe that HOS regulations have a positive or at least neutral effect on road safety levels.
- A worldwide comparison of HOS regulations indicates that the highest risk is associated with the regulations in Canada and Australia due to short minimum rest duration which may lead to accumulated sleep loss.
- In the USA studies into the effects of changes in HOS regulations differ widely in method; in addition their research questions are frequently limited to one part of a multifaceted HOS change.
- There is some evidence that the new USA 2013 HOS rule decreased fatigue-related risk and fatigue-related accidents. However, there are also indications of no effect.

- Findings of whether or not fatigue-related risk during night times has been substituted by other types of risk (e.g. risk due to driving in congested traffic conditions) are inconclusive.
- Legislation can have different effects on driver fatigue depending upon specific driver schedules and the actual changes made to these schedules.
- There is evidence that enforcement and monitoring of HOS regulations will increase compliance and safety.

In conclusion, the evidence concerning the effects of HOS rule changes in USA shows a broad range of findings, mostly in a positive direction, but also in a negative direction.

3.2 TABLE OVERVIEWS OF STUDY CHARACTERISTICS AND RESULTS

Table 3 presents an overview of study characteristics (aim, sample, method, analysis).

Table 3: Overview of study methodologies – Hours of service regulation

	Author, Year, Country	Type of study	Study aim, sample	Method, analysis
1.	Hanowski et al., 2007, USA	Analysis of sleep data	This study compared sleep of truck drivers before and after HOS rule 2003 which extended off-duty time from 8 to 10 h. One rationale given by FMCSA was the additional 2 h of off-duty time would provide drivers with "substantially more opportunity to obtain restorative sleep". Data were obtained from 82 truck drivers (81 male, 1 female) working for 1 of 3 licensed trucking companies (mean age 39.1 years; range = 24–58 yrs.). Selection criteria for participation included drivers not wearing glasses and driving primarily at night. Of the drivers that participated in this study, 73 drivers wore wrist actigraphs and had at least seven full days of reliable sleep data.	Data for all analyses were collected from commercial vehicle drivers as they drove their normal revenue-producing runs. Two methods were used to determine mean sleep quantity. Method #1 included analysis of all full days (1440 min) that did not include more than 120 min where the system was removed from the wrist (which was obvious from the actigraph output). Method #2 consisted of analysis of complete weeks of data, comprised of seven consecutive days (Monday to Sunday).
2.	McCartt et al., 2008, USA	Interviews	This study assessed changes in long-distance truck drivers' reported work schedules and reported fatigued driving after the 2004 HOS rule change. A total of 1,921 drivers participated during 3 interview waves. Approximately 350 drivers were interviewed in each state in 2003 and in 2004; smaller samples of 236 drivers in Pennsylvania and 287 in Oregon were interviewed in 2005 due to inclement weather. Participation rates in each state were high in each survey year (range 88–98%). Non-participating drivers were primarily those who were hurrying to complete their trips or unable to speak fluent English.	Interviews were conducted with samples of drivers of large trucks passing through roadside commercial vehicle weigh stations on interstate highways
3.	Hanowski et al., 2009, USA	Naturalistic Driving	This study used naturalistic driving data to evaluate the effects of 2004 change in HOS regulations for commercial drivers. Data were collected during a Field Operational Test (FOT) of a Drowsy Driver Warning System (DDWS). Data collection for the FOT began in May 2004 and ended in September 2005. A total of	Two main analyses were done: <ul style="list-style-type: none"> - Critical incidents as a function of driving hours for hours 1 to 11 - Critical incidents as a function of driving hours for hours 1 to 11, for drivers who drove 11H (within subjects!)

	Author, Year, Country	Type of study	Study aim, sample	Method, analysis
			103 drivers participated in the study (102 males, 1 female; mean age = 40.03 years; age range = 24–60 years). Participants were long-haul and line-haul drivers. trucking companies, and 7 fleet locations (in Virginia and North Carolina), were used in this study. Unobtrusive data collection equipment was installed in 46 commercial trucks	
4.	Mohlman, 2013, USA	Data analysis	This study used statistical models to analyse the effectiveness of fatigued driving enforcement techniques on accident frequency and injury severity of fatigue involved accidents.	State patrol agencies from 49 states were surveyed (Hawaii did not have a state patrol agency). Additionally, accident data were retrieved to complement the survey data. Data resources included the Fatal Accident Reporting System (FARS) database and the Highway Safety Information System (HSIS) database. The 3 accident models estimated using information from the telephone survey provided some evidence as to successful fatigued driving enforcement techniques
5.	Socolich et al., 2013, USA	Naturalistic Driving	Naturalistic data collection was done to assess driving risk at different hours, shifts, and before and after breaks which are possible under the hours-of-service (HOS) regulations. Data from 97 drivers was used for analyses (91 were male and 5 were female, 1 missing; average age 44 yr.; range: 21–73 yrs.; average 9.13 years of experience driving CMVs (range: 4 weeks to 54 years). 4 for-hire trucking companies participated in the study. All drivers and companies were volunteers and recruited for the study. The study included about 735,000 miles of continuous driving data	The main outcome variable was the occurrence of a safety critical event (SCE). Safety-critical events included accidents, near-accidents, accident relevant conflicts, and unintentional lane deviations. To compare how a driver's performance changed over driving hours 1–11, an analysis was performed on a driving data set, which only included duty periods with driving into the 11th driving hour. To compare risk of SCE occurrence between driving hour–work hour combinations, odds ratios were calculated on two driving hour–work hour combinations at a time.
6.	Goel, 2014, USA	Simulation approach	This research studied the revised hours of service regulations for truck drivers in the USA which entered into force in July 2013. The revised HOS regulations restricted the usage of the '34-h restart' provision and introduced a new provision, which requires that drivers must only drive if a period of at least 30 min of off-duty time is taken within the last 8h.	The simulation approach calculated accident risk and transportation costs for four HOS rule scenarios: 1. old HOS rule 2003; 2. new HOS rule 2013; 3. new HOS rule 2013 with max daily driving time limit reduced to 10 hours; 4. new HOS rule 2013 with max daily driving time limit reduced to 9 hours The scenarios 3 and 4 had not been implemented in practice. The calculations for these four scenarios were made for conditions with time windows and without time windows.
7	Goel & Vidal, 2014, international	Vehicle routing and truck driver scheduling modelling	In this study the researchers used computational experiments for various sets of regulations in the United States, Canada, the European Union, and Australia to provide an international assessment of the impact of different rules on transportation costs and accident risks.	The vehicle routing and truck driver scheduling problem was addressed with a new (hybrid genetic) algorithm in computational experiments. To evaluate the impact of hours of service regulations on road safety, the researchers used the fatigue and risk index calculator available from Health and Safety Executive (2006). This calculator

	Author, Year, Country	Type of study	Study aim, sample	Method, analysis
				<p>can be used to estimate the average relative risk of the occurrence of an accident given a specific work schedule. An index of two represents a twice as high average accident risk as an index of one. The researchers normalized the risk indices with respect to the average risk associated with the EU (No split) rule set.</p>
8.	Van Dongen & Mllicone, 2014, USA	Behaviour monitoring	<p>Researchers conducted the field study (from January until July 2013) with drivers whose duty schedules used the restart provisions of the previous hours-of-service (HOS) regulations. A total of 106 CMV drivers (100 men, 6 women; ages 24–69) completed the study. Participating drivers provided a total of 1,260 days of data and drove a total of 414,937 miles during this field study</p>	<p>The drivers' electronic duty logs were used to identify the periods when they were on duty and when they were driving and to define their duty cycles and restart breaks. Wrist activity monitors measured drivers' sleep/wake patterns. Drivers' fatigue levels were measured three times per day by means of a Psychomotor Vigilance Test (PVT) and by means of subjective sleepiness scores. A truck-mounted lane tracking system measured lane deviation (variability in lateral lane position).</p>
9.	GAO, 2015 (Fatigue modelling, Appendix V), USA	Modelling	<p>To assess whether the 2011 HOS rule change could result in less fatigued drivers and potentially fewer fatigue-related accidents, GAO researchers used a bio-mathematical fatigue model—the Fatigue Audit InterDyne™ (FAID) model—to assess the risk of driver fatigue for schedules that comply with the 2011 HOS rule and similar schedules that do not.</p>	<p>The FAID model provides a fatigue score based on the start and end time of a work shift. The higher the FAID score, the higher the risk of fatigue. The researchers created different scenarios through which to test the risk of driver fatigue given rule-induced alterations to driver schedules. The researchers compared fatigue levels under 8 simulated scenarios for 8 drivers groups:</p> <ol style="list-style-type: none"> 1. drivers working maximum allowed hours during daytime 2. drivers working maximum allowed hours during night-time 3. drivers working 70-hour shifts during night-time hours ; 4. drivers working 60-hour shift during night time hours 5. drivers working 6 consecutive 10-12 hour shifts between 10 p.m. and 10 a.m.; 6. drivers working 6 consecutive 10 hour shifts from 12 a.m. to 10 a.m.; 7. drivers working between 10- and 14-hours per day for 5 days, reaching the drop-off destination and going off-duty for 34 hours (a restart), then driving home and taking 3 days off as the next restart; 8. (a) drivers working 12-hour shifts for 5 consecutive days from 8 p.m. to 8 a.m. (next 2 days off-duty; restart) or (b) drivers working 13-hour shifts for 4 consecutive days from 8 p.m. to 9 a.m. (the next 3 days off-duty; restart).
10.	GAO, 2015, (Crash analysis (Appendix VII), USA	Data analysis	<p>To analyse the safety effects of the 2011 HOS rule, GAO researchers undertook two separate analyses to</p> <ol style="list-style-type: none"> 1. assess the overall effect on the numbers of accidents and 2. assess the effect on the relative number of accidents between 5 a.m. and 9 a.m. <p>Among other things the 2011 HOS rule added the following provisions:</p> <ul style="list-style-type: none"> - The two-night provision: Drivers choosing to use the restart provision must include two-night time rest 	<p>To assess the effects GAO researchers developed 2 ordinary least squares regression models that controlled for trucking volume and seasonal variation (Model 1), and in one case also controlled for the unusual winter weather in December 2013 to February 2014 (Model 2). In Model 1 there was no control for the possible influence of the harsh winter December 2013 through February 2014. Model 2 estimated the same effects as model 1 for each of the three groups of accidents</p>

	Author, Year, Country	Type of study	Study aim, sample	Method, analysis
			<p>periods from 1 a.m. to 5 a.m.</p> <ul style="list-style-type: none"> - The 168-hour limit: Drivers can only use the restart provision once per week (every 168 hours). - 30-minute rest break: Drivers are required to take a 30-minute, off duty break at some point during the first eight hours of work, i.e., a work shift, to continue to operate a commercial vehicle. 	but included an additional dummy variable to account for any independent effect on the numbers of accidents due to the unusually disruptive winter weather from December 2013 to February 2014.
11.	Hickman et al., 2016, USA	Behavioural monitoring	<p>This study tested 2 specific hypotheses:</p> <ul style="list-style-type: none"> - Trucks equipped with an Electronic Logging Device (ELD) will have a significantly lower accident rate than trucks without an ELD. - Trucks equipped with an ELD will have a significantly lower HOS violation rates than trucks without an ELD. 	There were 4 major outcome variables: all accidents, preventable accidents, driving-related HOS violations, non-driving related HOS violations. A preventable accident is one in which the carrier driver failed to exercise every reasonable precaution to prevent the accident. This is not the same as at-fault, which is a legal determination. The driving-related HOS violations included 11-hour rule violation, 14-hour rule violation, 16-hour rule violation, and 60/70-hour rule violation. Non driving-related HOS violations included driver's record of duty status not current, log violation (general/form and manner), driver failing to retain previous 7 days of logs, false report of driver's record of duty status, no driver's record of duty status, no log book, and malfunctioning ELD.
12.	Anderson et al., 2017, USA	Data analysis	<p>This study investigated the safety efficacy of the 1 restart per 168-h restriction and 1 a.m. to 5 a.m. provision that was enacted in July of 2013 through parametric and non-parametric statistical analysis on accidents involving trucks within the state of Ohio. One of the major aspects of the HOS regulations is the number of restarts a driver can utilise. In July 2013, the restart changed from unlimited to only one restart per 168-h period.</p>	60 months of retrospective data were analysed. The 12-month span from July 2013 to June of 2014 was named post-HOS data. In order to avoid seasonality fluctuations, the researchers grouped the other 48 months into four years starting in July and ending in June (named pre-HOS data). This provided a total of 5 years of data that could be broken down by months, by year, and by pre- and post-HOS. Four of these 5 years, or 48 of the 60 months, detailed accidents involving trucks regulated under the unlimited restart provision and 1 year, or 12 months, detailed accidents involving trucks regulated under the 1 restart per 168-h restriction combined with the 1 a.m. to 5 a.m. provision.

Table 4 summarises main outcomes of the coded studies. For details about the HOS changes in 2003-2004 and the HOS changes in 2011-2013 we refer to Section 3.1.

Table 4: Summary of results for studies examining hours of service regulations and expected effect on road safety (↗ = expected positive road safety effect; ↘ = expected negative road safety effect; - = no effect expected)

	Study	Evaluated regulation	Indicator	Main outcome - Description	Expected Safety Effect
1.	Hanowski	HOS 2003	Amount of sleep as	Drivers were getting more sleep per night under	↗

	Study	Evaluated regulation	Indicator	Main outcome - Description	Expected Safety Effect
	et al., 2007 USA		measured over a 7-day period	new HOS as compared to under the old HOS regulations	
2.	McCartt et al., 2008, USA	HOS 2003	Reported driving hours	Drivers reported driving more hours after the rule change 2004 than before.	↘
		HOS 2003	Reported sleep	In 2004 and 2005 surveys, one fifth to a third of drivers reported getting more sleep under the new work rule and two-thirds to three-quarters reported getting the same amount of sleep	↗
		HOS 2003	Reported violations weekly limit of driving	Drivers in 2004/2005 were more likely than drivers in 2003 to report that they never exceeded the weekly limit	↗
		HOS 2003	Reported 10-hours off-duty time	The proportion of drivers who reported at least 10 hours off-duty was significantly lower in 2005 than in 2004 (74–78% vs. 62%)	↘
		HOS 2003	Reported rule violations	No change: reported rule violations were common before and after 2004 rule change.	—
		HOS 2003	Reported falling asleep behind the wheel	In 2003, 13% of drivers in Pennsylvania and 12% of drivers in Oregon reported falling asleep at the wheel; in 2005, 19% of drivers in Pennsylvania and 21% of drivers in Oregon reported doing so.	↘
3.	Hanowski et al., 2009, USA	HOS 2003/11 th driving hour	Safety critical event 1 st hour	There was a peak in the relative frequency of critical incidents in the 1st driving-hour. All comparisons between 1st driving hour and other hours were significantly indicating that drivers were more likely to be involved in a critical incident during the 1st hour than during another hour. This is a 'neutral' finding concerning the hypothesis of enhanced risk in the 11 th driving hour.	—
		HOS 2003/11 th driving hour	Safety critical events hrs 2-11	The driving hours (i.e., 2nd through 11th) were not consistently different from each other in terms of critical-incident relative frequency	—
		HOS 2003/11 th driving	Safety critical event 11 th driving hour	There was not a significant increase in the incident rate between the 11th driving-hour and any other driving-hour. This suggests that time-on-task was not a good predictor of accident risk (with the exception of the 1st driving-hour).	—
4.	Mohlman, 2013, USA	Fatigued driving enforcement	Fatigue-related accidents	Three fatigued driving enforcement techniques (training fatigue identification; use of driving cues to detect fatigue; fatigue driving programmes) had a positive, significant effect on safety by reducing number of accidents or reducing severity of fatigue-related accidents.	↗
		Fatigued driving enforcement	Fatigue-related accidents	Three fatigued driving enforcement techniques (use of public service announcements & driver education; driver interview as part of stopped vehicle procedure; stopping drivers if belief that driver is fatigued) were positively related to improved safety but effects were not significant.	—

	Study	Evaluated regulation	Indicator	Main outcome - Description	Expected Safety Effect
		Fatigued driving enforcement	Fatigue-related accidents	One enforcement technique, the use of driving cues for detection of driving fatigue, reduced number of fatigue-related accidents and severity of fatigue-related accidents.	↗
5.	Socolich et al., 2013, USA	HOS 2003-11 th late driving /late work hour combination	Safety Critical Event at end 14 h shift	The combination of driving hour–work hour did show a negative time-on-task effect for driving hours that occurred late in the 14 h workday. Though driving for 11 h was not shown to increase the risk of an Safety Critical Event (SCE) as compared to the 10th driving hour, if drivers drove deep into their 14-h shift, SCE risk increased.	↘
		HOS 2003/11 th driving hour	Safety Critical Event in 11th hour	The 11th driving hour did not present an increase in risk of SCE occurrence as compared to the 8th, 9th, or 10th driving hour.	—
		HOS 2003 – Rest break	Safety Critical Event	The analysis into effects of breaks on SCE rates 1 hour before and 1 hour after breaks showed that the magnitude of the decrease in SCE rate ranged from 28% to more than 50% (depending upon type of break), in other words, breaks produce positive safety effects.	↗
6.	Goel, 2014, USA	HOS 2013	Modelled accident risk	Compared to old HOS 2003 rule, the simulation approach estimates that under conditions of time windows on average the new HOS rule 2013 will reduce accident risk by 2.1% against 0.2% increased transportation costs (reduction 0.7% accident risk against 0% increase transportation costs without time windows).	↗
		HOS 2013/Max 10 hours daily driving limit	Modelled accident risk	The new HOS rule 2013 in combination with a max 10 hours daily driving limit will reduce accident risk by 5.4% against transportation cost increase by 0.7% (reduction accident risk by 4.7% and 1% increase transportation costs without time windows).	↗
		HOS 2013/Max 9 hours daily driving limit	Modelled accident risk	The new HOS rule 2013 in combination with a max 9 hours daily driving limit will reduce accident risk by 9.1% against a 0.7% increase in transportation costs (reduction accident risk by 10.1% and 1.7% increase transportation costs without time windows).	↗
7	Goel & Vidal, 2014, international	International comparison HOS regulations	Modelled accident risk	Compared to the EU no split reference category, the modelled accident risk in other countries was somewhat higher: - 4% higher in US current - 3% higher in US 2013 HOS - 6% higher in Canada - 1% higher EU split - 3% higher EU all - 8% higher Australia standard - 10% higher Australia	↗
8.	Van Dongen & Millicone, 2014, USA	Restart break with 2 or more night-time periods	Lapses of attention	Drivers exhibited less lapses of attention, especially at night, during duty cycles preceded by a restart break with two or more night-time periods as compared to duty cycles preceded by a restart break with only one night-time period.	↗
		Restart break	Subjective sleepiness	Drivers reported lesser sleepiness during duty cycles	↗

	Study	Evaluated regulation	Indicator	Main outcome - Description	Expected Safety Effect
		with 2 or more night-time periods		preceded by a restart break with two or more night-time periods compared to a restart break with only one night-time period.	
		Restart break with 2 or more night-time periods	Lane deviation	Drivers showed decreased lane deviation at night and in the morning and afternoon (but not in the evening) during duty cycles preceded by a restart break with two or more night-time periods as compared to duty cycles preceded by a restart break with only one night-time period.	↗
9.	GAO, 2015 (Fatigue modelling, Appendix V), USA	HOS 2011-2013	Modelled peak fatigue scores	For 7 out of 8 scenarios peak fatigue scores under simulated schedules that were compliant with 2011-2013 HOS rule were lower than the scores under simulated schedules that were not compliant with 2011-2013 HOS.	↗
10.	GAO, 2015, (Crash analysis, (Appendix VII), USA	HOS 2011-2013	Fatal accidents	Fatal accidents were reduced after rule change after holding other factors constant.	↗
		HOS 2011-2013	Injury accidents	No significant change	—
		HOS 2011-2013	Total crashes	Total accidents increased after rule change after holding other factors constant.	↘
		HOS 2011-2013	Total accidents	Adding the dummy variable for 2013-2014 winter in Model 2 rendered the effect of the rule change on total accidents insignificant.	—
		HOS 2011-2013	Accidents occurring 9-5 a.m.	After control for factors road, weather, and lighting conditions, trucking gross volume, and whether the accident occurred during a weekday or on the weekend, the rule change appeared to have no significant effect on the likelihood of total accidents occurring between 5 a.m. and 9 a.m.	—
11.	Hickman et al., 2016, USA	Monitoring compliance HOS regulations (2008-2012)	Accident rate	Trucks equipped with an Electronic Logging Device (ELD) that monitored compliance with HOS regulations had a 12 and 5% significantly lower accident rate than non-ELD equipped trucks for total accidents (P < .001) and preventable accidents (P = .001).	↗
		Monitoring compliance HOS regulations (2008-2012)	Violation rate	The ELD cohort had 53 and 49% significantly lower driving-related (p = 0.01) and non-driving related (p < .001) HOS violation rates than the non-ELD cohort.	↗
12.	Anderson et al., 2017, USA	HOS 2013 new restart provision	Number of injuries/property damage accidents	The number of injuries, and property damage accidents involved and caused by truck drivers was significantly lower in 12 months post HOS than in 48 month pre-HOS. This finding could be explained by the general downward trend in truck accidents.	—
		HOS 2013 new restart provision	Fatalities	The number of fatalities involved and caused by truck drivers did not significantly differ between 48 month pre-HOS and 12 month post-HOS period.	—
		HOS 2013	Accident trend	The 2 HOS changes (1 restart per 168-h restriction	—

Study	Evaluated regulation	Indicator	Main outcome - Description	Expected Safety Effect
	new restart provision		and 1 a.m. to 5 a.m. provision) did not significantly change the continuing downward trend of accidents involving trucks	
	HOS 2013 new restart provision	Number accident 12 months period	When analysed using 12-month periods, post-HOS number of accidents involving or caused by truck drivers is not significantly different than the prior 12 months in any category.	—
	HOS 2013 new restart provision	Percent of accidents caused by truck drivers	Percent of accidents caused by truck drivers from July 2013 to June 2014 increased for fatalities, injuries and property damage accidents but not significantly (p-values between 0.113 and 0.247).	—
	HOS 2013 New restart provision	Percent of fatalities caused by truck drivers	The percent of fatalities caused by truck drivers was significantly higher (p =0.026) than the previous year, which was not regulated by the 1 restart per 168 h restriction and the 1 a.m. to 5 a.m. provision.	↘

3.3 LITERATURE SEARCH

The literature on the behavioural and accident effects of HOS regulations was searched for in the international database Scopus on January 10th 2017. Scopus is the largest international peer-reviewed database. Since the literature up until about 2008 was covered quite well (Amundsen & Sagberg 2003; Golias, 2012; Min, 2009), it was decided to limit the search period to 2008-2017. The search terms were searched in title, abstract and keywords. Table 5 describes the search terms and logical operators and the number of hits for the search on driving hour legislation and traffic risk

Table 5: Used search terms and logical operators in Scopus, Date: 10 January 2017

No	Search terms/logical operators/combined queries	hits
1	(TITLE-ABS-KEY (fatigue OR drowsiness OR sleepiness OR sleep OR "driving hour" OR hos) AND TITLE-ABS-KEY (crash OR accident OR "road safety" OR sleep OR "driving time" OR "driving hours" OR "rest time" OR hos OR "hours-of-service") AND TITLE-ABS-KEY (driver) AND TITLE-ABS-KEY (legislation OR rule OR law OR regulation)) AND PUBYEAR > 2007	219

The search resulted in 219 hits. In a first screening round these 219 references were screened on potential relevance for coding based on title and abstract information. Also references were screened for further references. Criteria for not selecting publications in the first round were:

- study is not concerned with the safety effects of commercial driver fatigue regulation,
- study written in non-English language,
- better or more complete results were published earlier or later in another publication (duplication).
- general review-like text.

Table 6 shows that 192 studies were rejected after this first round of screening, largely because the publication did not report on safety effects of regulations on driving hours and rest times. Many of the references concerned studies on sleep problems of drivers and on drowsiness detection.

Table 6: Initial selection of studies after the first screening round

Steps in selection	Not selected first round	Selected first round
No actual crash/violation reduction by fatigue law studied	207	
Selected after initial screening		12
Added after screening references		9
Total selected		21

Twelve studies were selected based on the first round and nine additional publications were identified after screening the references. The resulting 21 studies were further screened on relevance for coding in a second screening round. In the second round the same criteria were used but were checked on full-text copies of the papers. Table 7 presents the results of this second screening round and describes the final decisions concerning coding. In total 11 studies were identified as suitable for further coding. It should be noted that the GAO report contained different types of methods and analyses concerning possible effects of HOS regulations. Two of the analyses in this report (reported in Appendices V and VII) were coded and described separately.

Table 7: Selection of studies to be coded in second screening round

	Reference	Relevant	Coded
1	Amundsen, A.H. & Sagberg, F. (2003) Hours of service regulations and the risk of fatigue- and sleep-related road accidents. TOI, Oslo.	Yes but general review text	No
2	Anderson, J.R., Ogden, J.D., Cunningham, W.A., Schubert-Kabban, C. (2017). An exploratory study of hours of service and its safety impact on motorists. <i>Transport Policy</i> , 53, pp. 161-174	Yes	Yes
3	Bello, D. (2010). Clock ticking on hours-of-service ruling: Transportation officials face deadline for reviewing 2008 rule. <i>Safety and Health</i> , 181 (3), pp. 38-40.	Not research paper but magazine paper	No
4	GAO (2015). Motor carrier safety. Additional Research Standards and Truck Drivers' Schedule Data Could Allow More Accurate Assessments of the Hours of Service Rule. GAO-15-641. United States Government Accountability Office, Washington.	Yes. This report contains several different analyses to be separately coded.	Yes.
5	Goel, A. (2014). Hours of service regulations in the United States and the 2013 rule change. <i>Transport Policy</i> , 33, 48-55.	Yes	Yes
6	Goel, A. & Vidal, T. (2014) Hours of Service Regulations in Road Freight Transport: An Optimization-Based International Assessment. <i>Transportation Science</i> , 48(3),391-412.	Yes	Yes
7	Golias, M. (2013). Evaluating the hours-of-service rule via GPS/GIS truck trip data. IFTI, Herff College of Engineering.	Contains literature review earlier studies impacts legislation	No
8	Hanowski, R.J., Hickman, J., Fumero, M.C., Olson, R.L., Dingus, T.A. (2007). The sleep of commercial vehicle drivers under the 2003 hours-of-service regulations. <i>Accident Analysis and Prevention</i> , 39 (6), pp. 1140-1145	Yes	Yes

	Reference	Relevant	Coded
9	Hanowski, R.J., Hickman, J.S., Olson, R.L., & Bocanegra, J. (2009) Evaluating the 2003 revised hours-of-service regulations for truck drivers: the impact of time-on-task on critical incident risk. <i>Accident Analysis and Prevention</i> , 41, 268–275.	Yes	Yes
10	Hall, R.W. & Mukherjee, A. (2008). Bounds on effectiveness of driver hours-of-service regulations for freight motor carriers. <i>Transportation Research Part E</i> 44, 298–312.	This study calculates upper bounds for possible safety effect under possible new HOS-regulations. It does not provide any direct estimate of road safety savings by the existing HOS regulation enacted in 2004.	No
11	Hickman, J.S., Guo, F., Camden, M.C., Dunn, N.J., Hanowski, R.J. (2016). An observational study of the safety benefits of electronic logging devices using carrier-collected data. <i>Traffic Injury Prevention</i> , pp. 1-6. Article in Press.	Yes	Yes
12	Jones, C. B., Dorrian, J., Rajaratnam, S.M.W. & Dawson, D. (2005). Working Hours Regulations and Fatigue in Transportation: A Comparative Analysis. <i>Safety Science</i> , 43, 225-252.	Qualitative analysis encompassing the whole domain of transportation (not just road transport). No empirical data on effect legislations.	No
13	Mansfield, D., Kryger, M. (2015). Regulating danger on the highways: Hours of service regulations. <i>Sleep Health</i> , 1 (4), pp. 311-313..	Relevant, but qualitative review	No
14	McCartt, A.T, Hellinga, L.A., & Solomon, M.G. (2008). Work Schedules of Long-Distance Truck Drivers Before and After 2004 Hours-of-Service Rule Change. <i>Traffic Injury Prevention</i> , 9:201–210,	Yes	Yes
15	Mohlman, C. (2013). Driver fatigue enforcement techniques and their effect on accidents. <i>Civil Engineering Theses, Dissertations and Student Research</i> , Paper 61, University Of Nebraska.	Yes	Yes
16	Ryers, C. (2014). Truck drivers and fatigue: Efficacy studies of the restart rules. <i>Truck Drivers and Fatigue: Efficacy Studies of the Restart Rules</i> , pp. 1-147.	Yes, but recent studies in this book have been coded. The original source material should be coded.	No
17	Socolich, S.A., Blanco, M., Hanowski, R.J., Olson, R.L., Morgan, J.F., Guo, F., Wu, S.-C. (2013). An analysis of driving and working hour on commercial motor vehicle driver safety using naturalistic data collection. <i>Accident Analysis and Prevention</i> , 58, pp. 249-258.	Yes	Yes
18	Van Dongen, H.P.A., Belenky, G., Vila, B.J. (2011). The efficacy of a restart break for recycling with optimal performance depends critically on circadian timing. <i>Sleep</i> , 34 (7), pp. 917-929.	Yes, but Van Dongen & Mollicone (2014) is the more recent and best source on this subject	No
19	Van Dongen, H.P.A. & Mollicone, D.J. (2014). Field study on the efficacy of the new restart provision for hours of service. RRR-13-058. <i>Sleep and Performance Research Center & Pulsar Informatic</i> , Washinton.	Yes	Yes
20	Windisch, E., Gibson, G., Loehr, E., Rass-Masson, N., Meura, L., Morel, S., Markowska, A., Pastori, E. & Sitran, A. (2016). Ex-post evaluation of social legislation in road transport and its enforcement. Final report	Yes, but no quantitative data	No

	Reference	Relevant	Coded
	Study contract no. MOVE/D3/2014-256.		
21	Young, J. (2013). Simulation-based truck fleet analysis to study the impact of federal motor carrier safety administration's 2013 hours of service regulation changes. Proceedings of the 2013 Winter Simulation Conference - Simulation: Making Decisions in a Complex World, WSC 2013, art. no. 6721703, pp. 3395-3405.	This study concentrates on effect of new HOS regulations on fleet operations, No effect on driving behaviour or accidents studied.	No

3.4 REFERENCES

Coded studies

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Demerit Point Systems



Goldenbeld, Ch., July 20th 2017

1 Summary

1.1 COLOUR CODE

Light green

There is some indication that the countermeasure can reduce road safety risk, however in practice the effects wear off rather quickly.

1.2 KEYWORDS

demerit (penalty) point systems, traffic offences, non-monetary penalty, enforcement, licence, intervention

1.3 ABSTRACT

With a demerit point system, demerit points are meted out to traffic offenders in addition to the normal penalty. Generally, more demerit points are meted out when the offence is more serious. If a defined points' limit is exceeded, suspension of the licence follows. In most cases the traffic offender needs to prove that he is capable of driving safely by following a driving course or by some other measure. A 2012 worldwide meta-analysis indicated that point systems had a positive effect in reducing the number of traffic violations as well as the number of accidents, fatalities and injuries. However, the effects wore off in less than 18 months. This is probably due to low / decreasing levels of enforcement resulting in a small chance that traffic offences are detected. It can be expected that point systems achieve longer lasting safety effects when enforcement levels are sufficiently high and sustained over time. In addition, a demerit point system can be expected to be more effective when the system includes a broad scope of major dangerous traffic violations (speed, alcohol, red light, use of seat belts/helmet/child restraints, dangerous overtaking, priority rules, headway distance), when intermediate measures (such as warning letters and educational measures) are targeted at specific groups of offenders, and when the point system, including its communication and administration, is simple, transparent and fair.

1.4 BACKGROUND

What is a Demerit Point System (DPS)?

With a demerit point system (DPS), demerit points are meted out to traffic offenders in addition to the normal penalty, e.g. a fine. Generally, more demerit points are meted out when the offence is more serious (SWOV, 2012; Schagen & Machata, 2012). If a defined points' limit is exceeded, suspension of the licence follows. In most cases the traffic offender the needs to prove that he is capable of driving safely by following a driving course or by some other measure in order to get his licence reinstalled.

Which countries have DPS?

In 2012, 21 out of 27 EU Member States had a DPS (Goldenbeld et al., 2012). In 2016, Portugal introduced a DPS. Also several countries outside Europe apply a DPS: in Australia all states and territories have a DPS; in Canada all provinces and one of the three territories have a DPS; and in the USA 42 of the 51 states have a DPS (Goldenbeld et al., 2012).

How does a DPS lead to road safety?

Theoretically, a DPS contributes to road safety through the mechanisms of prevention, selection, and correction. Schagen & Machata (2012) describe these mechanisms as follows (page 8/9):

- **Prevention**
A DPS is meant to prevent drivers from reoffending by holding out the prospect of additional punishment when committing several offences, and consequently, collecting a defined number of penalty points within a particular time span.
- **Selection**
If the prevention mechanism has failed and drivers reoffend to the point where they exceed the critical threshold of points then additional punishment is applied, normally consisting of a ban from driving. As such the DPS selects the persistent offenders and excludes/suspends them, at least temporarily, from driving.
- **Correction**
In order to regain a driving licence, suspended drivers usually have to attend a rehabilitation course and retake their driving test. These are corrective actions to teach and convince those involved to become safer drivers.

How is the effect of point systems on road safety measured?

The effects of DPS have been measured in terms of:

- Traffic accidents and traffic injuries
- Traffic violations
- Health-related outcomes (traffic-related hospital data)

Evaluation studies applied different research methods including before-after studies with or without control group, quasi-experimental studies, time-series studies and cross-sectional studies (Goldenbeld et al., 2012).

1.5 OVERVIEW OF RESULTS

- A 2012 meta-analysis showed that the strong initial positive safety impact of a DPS - 15 to 20% reductions in accidents, fatalities and injuries - wore off in under eighteen months.
- An evaluation of the Danish DPS found that for speed-related offences receiving one point, one point or more, or receiving two points versus one, reductions in frequency of such offences were observed, to the extent of 9%, 11%, and 33% respectively. Slightly lower percentages were found for the analysis on general traffic violations.
- The wearing off effect of DPS is mainly attributed to the fact that the increased levels of enforcement and publicity associated with the start of the point system could not be sustained over longer periods of time.
- In theory, a DPS will achieve stronger effects when the supporting systems – i.e. levels and type traffic enforcement, publicity, intermediate measures (e.g. warning letters), rehabilitation courses, and administration - are better designed and performed.

1.6 NOTES ON RESEARCH METHODS

Although quite a few DPS evaluation studies have been conducted, many of them have methodological shortcomings (Møller & Kallberg, 2012). In particular, most evaluation studies do not enable disentanglement of the effects of the DPS itself and concomitant measures such as increased enforcement levels, higher fines, and publicity campaigns. Moreover, the diverse basic features of the DPS make it difficult to compare results in order to come to conclusions about the optimal design. In view of this, Møller & Kallberg (2012) conclude that we still need high quality studies to assess the effects of DPS, both on a national as well as an international level.

2 Scientific Overview

This scientific overview on the safety effects of demerit point systems first describes knowledge on point systems and traffic safety from the general literature (Section 2.1), and it then describes characteristics of coded studies on point systems (Section 2.2) and the major results of the coded studies (Section 2.3). The chapter is closed with an overview of main findings (Section 2.4).

2.1 OVERVIEW OF THE GENERAL LITERATURE

Point systems may differ from each other in a number of ways (Klipp et al., 2011; Schagen & Machata, 2012):

- Types of offences included
- Type of liability (owner or driver liability)
- Number of points assigned to each offence
- Adding points towards a threshold or deducting points from an original credit of points
- Lifetime of points, i.e. the period of time after which points for an offence are cancelled
- Type of corrective, educational or punitive measures taken when a threshold of points has been reached

Klipp et al. (2011) describe the main characteristics of the European DPS. They report that in most European countries points are added towards a critical threshold and a minimum of four offences is needed before further measures are taken. Many countries distinguish two levels: after a certain amount of points the offender receives a warning; after reaching the critical amount of points, the licence is withdrawn. The licence withdrawal period varies between one to twelve months; six months is the most common period in Europe. In most European countries it is necessary for the driver to be identified in order to allocate points (driver liability as opposed to owner liability). The lifetime of points ranges between six months up to five years (for criminal offences up to 11 years). The lifetime may depend on being a novice driver, a professional driver, re-offending in that period and seriousness of offence.

In order to function properly, DPS are supported by three measures:

- Traffic enforcement and communication
A sufficiently high level of enforcement is essential for the success of a DPS. This level of enforcement must be sustained over time, ideally complemented with (media) communication and information. If people consider it unlikely that an offence will be detected, a DPS will not be sufficiently deterrent. Insufficient enforcement levels are considered the main reason that the effects of a DPS tend to wear off rather soon after their introduction (Schagen & Machata, 2012).
- Intermediate measures and rehabilitation measures
Intermediate measures are put into action when a driver approaches the critical threshold of points, before the licence is withdrawn. As part of intermediate measures strategy, it is recommended to first send out a warning letter. Generally, after licence withdrawal a driver is required to participate in a rehabilitation course. Rehabilitation courses used should only be those which have a proven effect on re-offending among specific groups of offenders (Goldenbeld et al., 2012).
- Fast and reliable monitoring of collected points and consequences
A DPS is expected to perform better if simple, clear, fast and largely automated administrative procedures are applied (Schagen & Machata, 2012).

Møller & Kallberg (2012) reviewed most of the studies on demerit point systems (DPS). They point out some shortcoming in the DPS evaluation studies. Most studies did not enable disentanglement of the effects of the DPS and concomitant measures such as increased enforcement levels, higher fines, and publicity campaigns. Hence, it is not certain whether reported effects are the results of the introduction of the DPS as such or of one or several of the other measures.

Møller & Kallberg cite the following effects on offences from different national studies:

- In *Italy*, the number of traffic offences was reduced by 39% after the introduction of the point system; the reduction was largest for offences that were included in the point system.
- In the *United Kingdom* the point system has reduced speeding offences of drivers who are in danger of losing their licence for the next offence.
- Studies conducted in *Australia* and the *UK* found that the period between offences increased when the penalty points of drivers approached the point limit.

In the same review Møller & Kallberg report the following safety outcomes:

- In *Italy*, after the introduction of point systems in 2003, road accidents were reduced by about 10% and traffic fatalities by about 25%. Another Italian study showed that there were 13% less injuries requiring hospital treatment in the year following the introduction of the DPS.
- In *Ireland* the annual number of road accident fatalities fell from 409 to 333 after the implementation of DPS.
- In *Spain* the DPS reduced the number of highway accident fatalities by 12.6%, but the effect disappeared within two years after the introduction.
- In *Canada* the risk of a fatal accident in the month after a conviction for a traffic offence was 35% lower than in a comparable month with no conviction for the same driver; this effect was greater for speeding violations with penalty points than without.

2.2 DESCRIPTION OF CODED STUDIES

A total of four studies were coded. One was a meta-analysis of 2012 that included 26 individual studies. In addition, three more recent studies were identified, one from Spain, one from Italy and one from Denmark. Table 1 presents information on the main characteristics of these four coded studies.

Table 1: Overview of main characteristics of coded studies

Author(s), Year, Country	Study type	Sample/Measurement	Analysis
Castillo-Manzano & Castro-Nuño, 2012, international	Meta-analysis	The researchers performed a meta-analysis on 26 DPS studies. Both random and fixed effects models were used to estimate effects on: 1. road accidents, fatalities and injuries (24 effect estimates), 2. driving violations (18 effect estimates), 3. Traffic-related health care outcomes (8 effect estimates) and 4. duration of demerit point safety effect (20 effect estimates).	Both random and fixed effects models were used. The random and fixed effects models produced similar results, but the random effects models were considered to be the best models for these data.
Gras et al., 2014, Spain	Survey	A cross sectional survey was carried out among 1452 young people (52.8% female) aged 19–30 years (mean age = 21.5; S.D. = 2.5). All participants were students in their first three years studying at the University of	Questions were asked about engagement in five categories of risky traffic behaviour before and after the introduction of the DPS: <ol style="list-style-type: none"> 1. drink-driving/riding, 2. driving/riding under the influence of

Author(s), Year, Country	Study type	Sample/Measurement	Analysis
		Girona (Spain). The distribution of students by faculty was: Nursing (3.7%), Psychology (8.5%), Education (27.2%), Science (15.1%) and Engineering (45.4%), which was broadly representative of the University's student population. Most (84.9%; 80.9% females/89.4% males) participants drove a car, rode a motorcycle or both in the six months before the introduction of the DPS. Data were collected two years after the implementation of the DPS.	<p>drugs,</p> <ol style="list-style-type: none"> 3. speeding, 4. use of safety equipment, and 5. using a handheld mobile phone while driving/riding.
Basili et al., 2015, Italy	Econometric analysis	The researchers used data concerning the demerit point changes of 50,000 drivers observed over the period between July 1st 2003 (start of DPS in Italy) and May 20th 2009, selected from among all drivers included in the Italian Traffic Police's database on May 20th 2009. In the Italian version of the DPS, points are deducted from an original credit of points. The drivers included in the sample all had the same (maximum) initial credit of demerit points (20 points).	The researchers used a latent variable model for dichotomous responses. The model specifies the conditional expectation of the response variable, given observed covariates and latent unobserved explanatory variables. A dummy variable was used as the measure for committing an infraction/violation (i.e. the response variable). In the model some explanatory variables varied both across individuals and time (Age, Past Infractions, Driving Course, Licence Type, and Residual Points), while others varied only across individuals and were time constant (Sex, Nationality, and Region) or varied across years and were constant across individuals (Year).
Abay, 2017, Denmark	Econometric analysis	The researchers used a difference-in-differences approach to identify the causal impact of the demerit points assigned. With this approach the researcher compared the offence behaviour of drivers who were assigned one or more demerit points (treatment group) during the treatment period with those who got only fine (control group), before and after the introduction of the point system. The before period covered January 2003 – August 2005. The after period covered January 2007 – December 2009. The treatment group (at least one point) comprised 33,370 drivers. The control group (no points) 10,895 drivers.	<p>To quantify the treatment effect of the demerit points assigned, the researcher estimated the following Difference-in-Differences (DID) equation:</p> $ydt = \beta_0 + \beta_1 Td + \beta_2 post + \beta_3 (Td * post) + \beta_4 Xd + dm + \varepsilon dt$ <p>Where ydt stands for our measure of driving behaviour, Td represents treatment indicator for drivers who are assigned one or more demerit points during the treatment period, while $post$ indicates post-DPS period (2007-2009). β_1 captures pre-DPS possible differences in driving behaviour between the treated and control group drivers. The time trend indicator, $post$, captures some aggregate time (trend) factors that could cause change in driving behaviour, even in the absence of the DPS reform. The parameter the researcher is most interested in was β_3, an interaction effect of treatment indicator and post-reform period. β_4 captures the effect of other pre-reform characteristics of drivers which can affect driving behaviour. The observable variables in Xd are measured at 2004, immediately before the reform. dm stands for geographic (municipality) dummies that absorb exposure of drivers to traffic control.</p>

2.3 RESULTS OF THE CODED STUDIES

The main results of the coded studies on penalty points systems are described below (also summarised in Table 2).

The meta-analysis

Castillo-Manzano & Castro-Nuño (2012) performed a meta-analysis on 26 demerit point studies worldwide. Both random and fixed effects models were used to estimate effects on: 1. road accidents, fatalities and injuries (24 effect estimates), 2. driving violations (18 effect estimates), 3. traffic-related health care outcomes (8 effect estimates) and 4. duration of demerit point safety effect (20 effect estimates). The random effects analyses showed that point systems were associated with:

- a 16% decrease in accidents, fatalities and injuries,
- a 27% decrease in driving violations, and
- a 52% decrease in traffic-related healthcare outcomes.

In addition, it was found that:

- on average, the effects lasted for 15.9 months, and
- the effects wore off in less than 18 months.

Additional studies not covered by meta-analysis

Gras et al., 2014 (Spain)

The DPS was introduced in Spain in July 2006. In Spain, drivers start with a credit of 12 points (8 points for novice drivers). Points are gradually removed if certain traffic violations are committed, such as exceeding the speed limit, driving while intoxicated, or using a hand-held mobile phone, culminating in licence suspension if all points are lost. Only serious violations result in loss of points, with the number of points removed varying with the severity of the offense. Several months before its introduction, the DPS was announced via a publicity campaign in all news media, and was included in the media agenda, giving rise to public debate (Novoa et al., 2010).

In an evaluation of the behavioural effects of the Spanish DPS, Gras et al. (2014) carried out a cross sectional survey amongst 1,452 young drivers (mean age 21.5; 52.8% female), all students at the same Spanish University. Most (84.9%) of the participants drove a car, rode a motorcycle or both in the six months before the introduction of the DPS. The study was conducted two years after the implementation of the point system. Students were asked how often they had engaged in the following five types of risky traffic behaviour, both before and after the introduction of the DPS:

1. drink-driving/riding,
2. driving/riding under the influence of drugs,
3. speeding,
4. use of safety equipment (front and rear seat belts, helmets), and
5. using a handheld mobile phone while driving/riding.

Researchers found the following (self-reported) behavioural effects of the point system:

- After the point system came into effect, self-reported risky behaviour decreased significantly, for both males and females and in all five risky behaviour categories.
- The highest self-reported reduction was for the use of a mobile phone while driving (8 to 9% decrease); the lowest was for speeding on urban roads (2 to 3% decrease).
- After the introduction of the DPS, the self-reported use of safety equipment increased significantly for both males and females, except for helmet use on the highway which did not increase.

- The self-reported behaviour that increased most was seat belt use in the rear seats on urban roads and highways (17 to 26% increase).

Basili et al., 2015 (Italy)

In Italy the DPS came into force in July 2003. Points are subtracted from a maximum of 20 points at the start. In order to get back 6 points, drivers have to attend a 12 (or 18) hour refresher course and to pay 190 (or 210) euros. Moreover, drivers with no traffic offences get 2 points every two years up to a maximum of 30 points.

Basili et al. analysed the demerit point changes of a sample of 50,000 Italian drivers in the period between 1 July 2003 and 20 May 2009, selected from all drivers included in the Italian Traffic Police's database. The drivers included in the sample all had the same (maximum) credit of 20 demerit points. The researchers found the following effects:

- The probability of committing violations decreased as the number of residual points decreased indicating a positive deterrent effect by the demerit point system.
- The larger the number of past violations, the higher the probability of new violations.
- Female drivers were more sensitive to a point reduction than the total sample average, resulting in a stronger decrease of the probability of committing a violation.
- Drivers of passenger cars with just a licence B were slightly more sensitive to a reduction of points than the total sample average, including drivers with (also) a licence A' (motorcycles) or licence C (motor vehicles ≥ 3.5 tonnes).

Abay, 2017 (Denmark)

Denmark introduced a Demerit Point System in September 2005. The DPS, among others, targeted drivers exceeding the speed limit beyond some threshold. The DPS in Denmark assigns a demerit point on driver's licence for each traffic violation committed, and three demerit points in three years lead to conditional suspension of driving licence. Since September 2005 speed offenders in Denmark have been subject to two types of punishments:

- If drivers exceed the speed limit by less than (or equal to) 30%, they receive a fine.
- If drivers exceed the speed limit by more than 30%, they receive a fine that is comparable to the fine for exceeding the limit by 30% plus a demerit point on their driving licence.

In addition, measures already in force before the introduction of the DPS apply: drivers exceeding the speed limit by more than 60% are subject to a conditional suspension of driving licence; those exceeding the speed limit by more than 100% are subject to an unconditional suspension of driving licence for a specified period.

With the use of an econometric analysis on a longitudinal offence database, Abay (2017) studied the impact of receiving one or more demerit points on the frequency of offending. His longitudinal database included 44265 licensed driver aged 25-59 whose driving offences were followed in a before period (January 2003 – August 2005: 32 months) and an after period (January 2007 – December 2009: 36 months). The treatment group (at least one point during the treatment assignment period August 2005-December 2006) comprised 33370 drivers. The control group (fine only, receiving no demerit points during treatment assignment period) comprised 10895 drivers.

He found that for speed offences, receiving one point, one point or more, or receiving two points versus one, reductions in frequency of such offences were observed to the extent of 9%, 11%, and 33% respectively. For traffic offences in general, receiving one point, one point or more, or receiving two points versus one was associated with reductions in the frequency of all traffic offences (including speeding) of respectively 7%, 8%, and 27%. The results also indicated that self-employed drivers and drivers living in rural areas were more responsive to each demerit point assigned to their

licence, possibly due to the larger expected costs for these drivers associated with losing their licence.

Modifying conditions

Repeating conclusions from earlier studies, Castillo-Manzano & Castro-Nuño (2012) mention the level of traffic enforcement and media coverage as the main determinant for (sustaining) the effectiveness of a DPS. If levels of traffic enforcement and media coverage are not maintained, drivers will realise that the chance of apprehension is low, and will return to previous levels of offending.

2.4 OVERVIEW OF MAIN FINDINGS

Based on the coded study we summarise the main findings as follows:

- A 2012 meta-analysis showed that the strong initial positive safety impact of a DPS – 15% to 20% reductions in accidents, fatalities and injuries - wears off in less than eighteen months.
- The wearing off effect of DPS is mainly attributed to the fact that the increased levels of enforcement and publicity associated with the start of the DPS are not maintained.
- An evaluation of the Spanish DPS, based on students' self-reports, found a stronger effect on mobile phone use and seat belt use offences than on speeding offences.
- An evaluation of the Italian DPS found evidence for a specific deterrent effect of a DPS, which was somewhat larger for female drivers and drivers of passenger cars.
- An evaluation of the Danish DPS found that speed-related offences receiving one point, one point or more, or receiving two points versus one were related to reductions in the frequency of speed-related offences of 9%, 11%, and 33% respectively. Slightly lower percentages were found for the analysis on general traffic violations.
- There is evidence that female drivers, self-employed drivers, and drivers living in rural areas are more strongly motivated to improve traffic behaviour upon receiving demerit points than the average driver.

3 Supporting document

This supporting document describes the literature search strategy (Section 3.1), it presents a schematic overview of study outcomes (Section 3.2) and it presents references on coded studies, and general literature (Section 3.3).

3.1 LITERATURE SEARCH STRATEGY

Literature on demerit point systems and traffic risk was searched for in the international database Scopus on 16 December 2016. Scopus is the largest international peer-reviewed database. A meta-analysis by Castillo-Manzano & Castro-Nuño in 2012 covered studies in the period 1995-2011. In view of this, relevant literature was searched over the period 2012-2016; the search terms were searched in title, abstract and keywords. Table 2 describes the search terms and logical operators and the resulting number of hits.

Table 2: Used search terms and logical operators

no	Search terms/logical operators/combined queries	hits
1	The search for point systems used the following combination of key words: (TITLE-ABS-KEY ("penalty point" OR "demerit point") AND TITLE-ABS-KEY (driver) AND TITLE-ABS-KEY (crash OR accident OR safety OR traffic OR effect)) AND PUBYEAR > 2011	24

This search resulted in 24 hits. In a first screening round, the 24 references were screened on potential relevance for coding based on title, abstract information. Also references were screened for further references (see Table 3). The criteria for not selecting publications were:

- no report on effects on accidents or behaviour
- general review-like text
- better or more complete results of the study were published earlier or later in another publication (duplication).
- written in non-English.

Many studies that had 'demerit point' or 'penalty point' mentioned in abstract or keyword examined the behaviour or personality characteristics of risky drivers or risky driving, or the relationship between penalty points and accidents. However, the questions and data from these studies did not look at the effects of a demerit or penalty point system as such.

Table 3: Initial selection of studies after the first screening round

Selection steps	Not selected first round	Selected first round
Excluded: No effects on accidents or violations reported	20	
Selected after initial screening		4
Added after screening references		1
Total selected		5

The five selected studies were further screened on relevance for coding in a second screening round (which also included the meta-analysis). In the second round the same criteria were used but were checked on full-text copies of the papers. Table 4 presents the results of the second screening round and describes the final decisions

Table 4: Selection of studies to be coded in second screening round

	Reference	Relevant	Coded
1	Basili, M. , Belloc, F. , & Nicita, A. (2015). Group attitude and hybrid sanctions: Micro-econometric evidence from traffic law. <i>Transportation Research Part A: Policy and Practice</i> , 78, pp. 325-336.	Yes	Yes
2	<i>Meta-analysis starting point:</i> Castillo-Manzano, J.I., & Castro-Nuño, M.(2012). Driver licences based on point systems: efficient road system strategy or latest fashion in global transport policy? A worldwide meta-analysis. <i>Transportation Policy</i> , 21, 191-201	Yes	Yes
3	Gras, M.-E. , Font-Mayolas, S. , Planes, M. , & Sullman, M.J.M. (2014). The impact of the penalty point system on the behaviour of young drivers and passengers in Spain. <i>Safety Science</i> , 70, 270-275.	Self-report study	Yes
4	Zámečník, P., Gabrhel, V., Kurečková, V., & Řezáč, P. (2017). 7 Years of experience with demerit point system in the Czech Republic: Is it effective? <i>Advances in Intelligent Systems and Computing</i> , 484, 269-278.	Paper presents some data but has no clear approach to data analysis	No
5.	Abay, K. A. (2017). How Effective Are Non-Monetary Instruments for Safe Driving? Panel Data Evidence on the Effect of the Demerit Point System in Denmark. <i>The Scandinavian Journal of Economics</i> , Accepted Author Manuscript. doi:10.1111/sjoe.12235	Yes	Yes

3.2 RESULTS

Table 5 presents an overview of results.

Table 5: Overview of studies and their (simplified) main outcomes (↗ = positive road safety effect; — = no or neutral effect on road safety).

Study	Indicator	Expected safety effect	Description of main outcomes
Castillo-Manzano & Castro-Nuño, 2012, international	Accidents, fatalities and injuries	↗	A 16% decrease
	Driving violations	↗	A 27% decrease
	Traffic-related health outcomes	↗	A 52% decrease
Gras et al., 2014, Spain	Self-reported Drinking and driving	↗	5 to 8% decrease
	Self-reported drugs and driving	↗	4% decrease
	Self-reported speeding on urban roads	↗	2% to 3% decrease

Study	Indicator	Expected safety effect	Description of main outcomes
	Self-reported speeding on highway	↗	2% to 5% decrease
	Self-reported Mobile phone use	↗	8% to 9% decrease
	Self-reported front seat belt urban roads	↗	9% to 10% increase
	Self-reported rear seat belt use urban roads	↗	19% to 26% increase
	Self-reported front seat belt highways	↗	3% increase
	Self-reported rear seat belt use highways	↗	17% to 24% increase
	Self-reported helmet use urban roads	↗	4% to 6% increase
	Self-reported helmet use highways	—	0 to 1 % increase (NS)
Basili et al., 2015, Italy	Probability of committing a traffic violation	↗	The probability of committing a violation decreased when the number of residual points decreased
	Sensitivity of driver groups to point reduction	—	Female drivers and Drivers of passenger cars with just a licence B were more sensitive to a point reduction than the total group average.
Abay, 2017, Denmark	Change in speed-related offences after 1 point	↗	9% reduction
	Change in speed-related offences after at least 1 points	↗	11% reduction
	Change in speed-related offences: 2 points vs. 1	↗	33% reduction
	Change in traffic offences general after 1 point	↗	7% reduction
	Change in traffic offences general after at least 1 point	↗	8% reduction
	Change in traffic offences general: 2 points v. 1	↗	27% reduction

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Red light cameras



Goldenbeld, Ch., SWOV, July 20th 2017

1 Summary



1.1 COLOUR CODE: LIGHT GREEN

Studies indicate that red light cameras decrease right-angle crashes but at the same time increase rear-end and other types of crashes. Since rear-end crashes are often associated with less severe injury than right-angle crashes, it may be assumed that the net effect on road safety is positive. Therefore this measure is probably effective (light green code).

1.2 KEY WORDS

Red light cameras, Signalised intersections, Red light running, motorised vehicles, crashes

1.3 ABSTRACT

Red light cameras (RLCs) are one of several possible countermeasures against red light running. Red light running is a risky traffic violation since it is associated with very serious, high injury crashes. Besides red light cameras, other countermeasures may include improving the driver's view of the intersection, converting intersection to roundabout, producing a raised intersection or improving the traffic signal phasing. A 2013 meta-analysis indicated that RLCs decrease right-angle injury collisions by 33%, but at the same time increase injury rear-end collisions by 19%. Several North-American studies after the meta-analysis, one European study and one Korean study, have confirmed that RLCs reduce right-angle crashes, but at the same time increase rear-end crashes and other types of crashes. Since rear-end crashes are often associated with less severe injury than right-angle crashes, it may be assumed that the net effect on road safety is positive. RLCs have been found to achieve larger road safety effects when red light violations are deliberate, when intersections have high proportion of right-angle crashes and lower proportion of rear-end crashes, when cameras are signposted, and when cameras are in continuous operation, rather than rotational.

1.4 BACKGROUND

What is a red light camera?

As part of general traffic enforcement strategy, red-light cameras (RLCs) are used to automatically detect and record red light running by vehicles at intersections. Frequently, RLCs combine speeding and red light detection.

How do red light cameras affect road safety?

The main purpose of RLCs is to prevent red light running and thus to prevent collisions that result from red light running. The combined speed/red light cameras may also serve to reduce speed in approaching an intersection. Basically red light running causes two main traffic conflicts that may result in a (serious) crash: right-angle and left turn-opposed conflicts (Bonneson & Zimmerman, 2004).

How do red light cameras work?

Red-light speed cameras detect and record the position and speed of a vehicle by using vehicle tracking radar or electronic detectors embedded in the road's surface. RLC systems typically include

at least one camera, at least one trigger, and a computer (Harris, 2001). The red-light detection function of the camera is connected to the traffic lights and is activated when a vehicle crosses the white stop line after the lights have turned red. Typically, the camera takes two photographs, one when the vehicle crosses the stop line and a second when the vehicle is in the intersection. The photographs include the date, time and place, vehicle speed, and elapsed time from the light turning red to the time the photograph was taken. The camera is not triggered by vehicles crossing the stop line on amber (yellow) or green lights. Digital cameras have improved the effectiveness of the systems and are the most common camera used for red light running detection.

When to use red light cameras?

RLCs are generally used if an intersection has a red light running problem. In that case there are several possible countermeasures of which the use of red light camera is only one. The red light running problem may be due to the view on the approach to the intersection or to the traffic light phasing. In such situations RLC enforcement is likely not to be the best solution, and other solutions should be considered first. When red light running is a deliberate violation, and is not caused by the view or the signal phasing, then RLCs may be considered as a viable countermeasure.

Which factors influence the effect of red light cameras on road safety?

RLCs have been found to achieve larger road safety effects when red light violations are deliberate, when intersections have a high proportion of right-angle crashes and lower proportion of rear-end crashes, when RLCs are signposted, and are in continuous operation, rather than rotational.

How is the effect of red light running on road safety measured?

The effectiveness of RLCs has been measured by the number or rate of collisions, right-angle crashes, rear-end crashes, crash severity measures, and the prevalence of red-light violations .

1.5 OVERVIEW OF RESULTS

- A 2013 meta-analysis concluded that red light cameras significantly reduced right-angle injury collisions (-33%) but at the same time significantly increased rear-end injury collisions (+19%).
- Several USA studies, one European and one Korean study, confirmed this pattern of results.
- Overall a positive safety effect of red light cameras is to be expected since rear-end crashes are often less serious than right-angle crashes.
- A positive safety effect of red light cameras can be expected especially at intersections where relatively many right-angle crashes related to deliberate red light running take place, and where relatively few rear-end crashes occur.
- The safety effects of red light cameras are greater when red light camera warning signs are posted at main entrances to areas with red light camera enforcement rather than when each camera-controlled intersection is signposted.
- Red light cameras are not a suitable measure for solving problems that arise from a bad view of the intersection, problems with unintentional red light running or problems with signal phasing.
- There is still a considerable lack of knowledge about the type of intersections where red light cameras are most effective.
- Most studies have been performed in the USA and results are not easily transferable to European intersections which have different designs, traffic volumes and traffic composition (e.g. larger share of cyclists and/or moped riders). However, two non-USA studies, one European and one Korean, show results that are in line with several American studies.

2 Scientific Overview



This scientific overview on the safety effect of red light cameras first describes knowledge on red light cameras and traffic safety from the general literature (Section 2.1), it then describes characteristics of coded studies on red light cameras (Section 2.2), major results of the coded studies (Section 2.3) and it ends with main conclusions (Section 2.4).

2.1 GENERAL LITERATURE

Red light cameras are a possible countermeasure against red light running. Studies show that the rate of red light violation per 1000 vehicles varies between 1.3 and 5.3 in USA and Australia (Attawi, 2014). Red-light violation frequency among car drivers is correlated with the following (intersection) factors: traffic volume, cycle length, advance detection for green extension, speed, signal coordination, approach grade, amber interval duration, proximity of other vehicles, presence of heavy vehicles, delay, intersection width, and signal visibility (Bonneson & Zimmerman, 2004).

If at an intersection there is a lot of red light running this may be due to the driver's view of the intersection or the traffic light phasing. In such cases camera enforcement may not be the best solution. Red light cameras are not the only countermeasure for reducing crashes at signalised intersections. Other solutions may work better. Converting traditional intersections to roundabouts eliminates the need for traffic signals as well as cameras. Raised intersections can reduce the approach speed and subsequent red light running (Fortuijn et al., 2005).

Red light running is an especially risky traffic violation since it is associated with very serious, high injury crashes (ATS, 2013; IIHS, 2014). Many of the victims are pedestrians, bicyclists and people in other vehicles who are hit by the red light runners. In European cities, the large number of red light cameras attest to the red light running problem. For example, in 2009 more than 850 red light and speed cameras were operational in London alone (ETSC, 2009).

Modifying conditions

According to Burkey (2005), traffic volume may affect the impact of red light cameras. At intersections with high traffic volumes he found less favourable effects than at intersections with low traffic volumes. Effects of red light cameras may change over time (Høye, 2013). For example, it is possible that drivers get used to both red light cameras and to other drivers braking at red (or amber) lights. As a consequence, rear-end collisions might therefore increase only initially, but decrease over time, while right-angle collisions continue to decrease.

Langland-Orban et al. (2011) specifically point out that red light cameras are not a solution to the problem of unintended red light running, i.e. when people unintentionally go through a red light. They advise that an analysis of the problem, which shows the cause of red light running at an intersection, is to be carried out before making a decision about deployment of a red light camera.

Council et al. (2005) performed an exploratory analysis and found that red light cameras were most effective when sites were highly publicised with public information programmes, when the detected violations were enforced with higher fines, when the traffic light had one or more left turn protected phases, shorter signal lengths and inter-green periods, when the intersection had a reduced speed

limit, a high proportion of traffic in the major road, and a high ratio of right-angle to rear-end crashes.

Pulugurtha et al. (2014) analysed red light camera data from thirty-two signalised intersections in the city of Charlotte, North Carolina. The empirical Bayes (EB) method was used to assess the effectiveness of a red light camera enforcement programme in reducing crashes. They estimated that the road safety benefits of red light cameras were higher if cameras are employed at signalised intersections with: 1. total entering vehicles per day less than 40,000; 2. fewer than 20 rear-end crashes per year, or 3. fewer than 5 sideswipe crashes per year.

Høye (2013) found that the safety effects of red light cameras are greater when red light camera warning signs are posted at main entrances to areas with red light camera enforcement rather than when each camera-controlled intersection is signposted.

In a Canadian study, Tay & de Barros (2011) compared red light running violation levels when cameras were either operating continuously or rotated amongst locations. The fixed camera scheme clearly produced lower violation levels than the two rotational schemes that were studied (cyclical and random).

2.2 METHODOLOGY

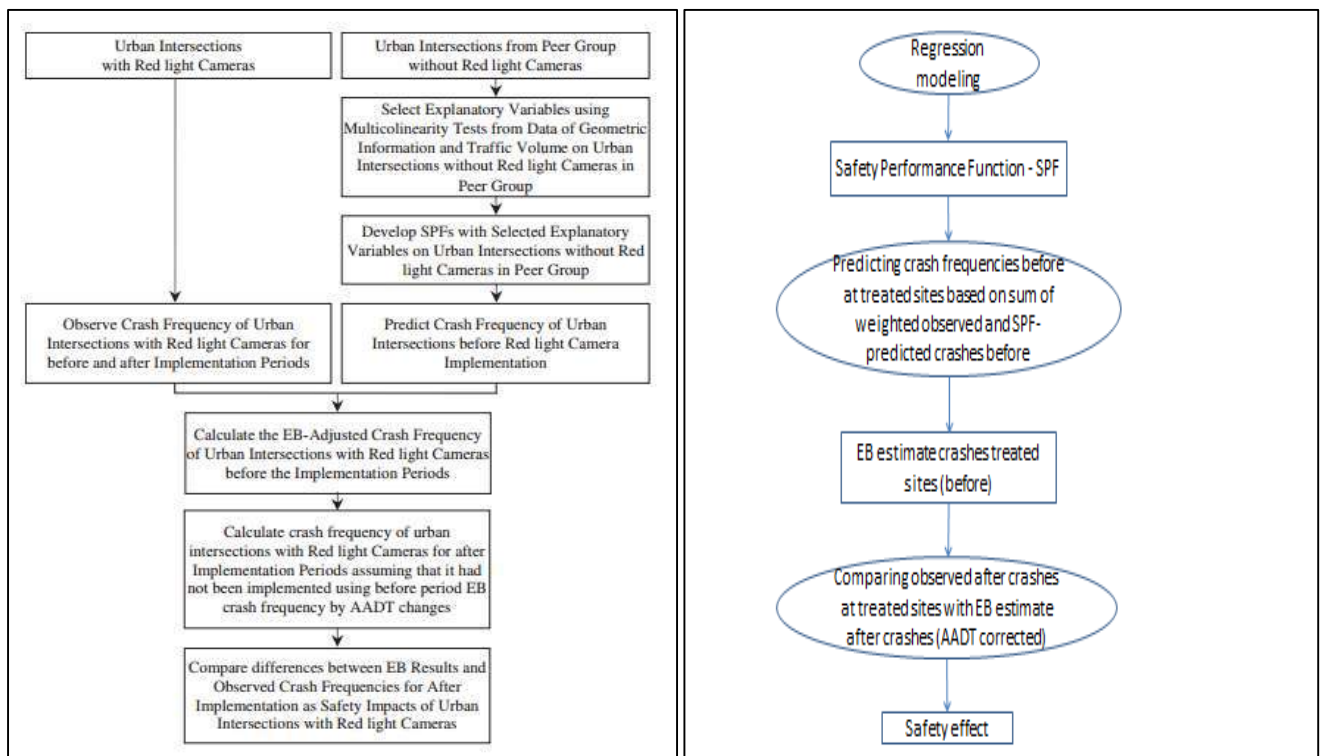
A systematic literature study was undertaken to identify scientific studies on the relationship between red light cameras and crashes. A total of 16 studies were identified and coded. Starting point was a 2013 meta-analysis (Høye, 2013). One relevant study previous to the meta-analysis was coded; the remaining 14 studies were published after the meta-analysis, and hence not included. It should be noted that most of the (coded) studies on red light cameras were done in the USA. The differences in intersection design and road user composition between USA and Europe prompt caution in generalising from these results to other parts of the world. Studies in Europe are scarce. Most of the USA red light camera studies did not assess the precise injury levels associated with red light running crashes and the expected road safety benefits from cameras, and most of them were not able to identify static or dynamic intersection characteristics that interact with camera effectiveness.

The main methodology for estimating the safety effects of red light cameras was a before-after Empirical Bayes with a reference (or control or peer) group. Several coded studies have used this method (Ahmed-Aty & Abdel-Aty, 2014; Ko et al., 2013; Lee et al., 2016; Llau et al., 2015; Pulugurtha & Otturu, 2014). The methodology basically consists of three steps (Lee et al., 2016):

1. Acquiring data from different sources and processing that data for treated and untreated (reference) intersections.
2. Modelling Safety Performance Functions using untreated intersection data, including geometric information, crash data, and traffic volume data.
3. Conducting Empirical Bayes analysis for safety impacts at intersections before and after the deployment of red light cameras.

In Figure 1, the left Panel presents a schematic, stepwise presentation of the method. The right Panel presents a simplified schematic representation of the method.

Figure 1: *Left panel*: Analysing safety impacts of urban intersections with red light cameras using Empirical Bayes approach (source: Lee et al., 2016); *Right panel*: alternative (simplified) representation of left panel (by synopsis author). (Abbreviations used: AADT = Annual Average Daily Traffic; EB = Empirical Bayes; SPF = Safety Performance Function)



For analysing the safety impact of red light cameras by the Empirical Bayes approach, a first step is the development of Safety Performance Functions (SPFs) based on data of untreated intersections (Lee et al., 2016). Lee et al. (2016) define SPFs as statistical and probabilistic models for the prediction and interpretation of vehicle crashes using variables that are related to vehicle crash frequencies. For SPF development, an appropriate set of dependent and independent variables is needed, as well as a statistical model that adequately accounts for the relationship between dependent and independent variables. Independent variables for modelling SPFs may include geometric information, vehicle crash data, and traffic volume data.

A few studies on red light cameras have used a distinct method for assessing their safety impact:

- Chai et al. (2015) used a cellular automata simulation model to estimate safety impacts of RLC.
- Chin & Haque (2012) used the quasi-induced exposure method to estimate the crash vulnerability and at-fault crash proneness of motorcyclists at intersections
- Polders et al. (2015) used a combination of video observations and driving simulator to better understand chances of and reasons for rear-end collisions at intersections
- Porter et al. (2013) used a design where effects of RLC were also studied after cameras were set off.

2.3 ANALYSIS AND RESULTS

16 studies on the effects of red light cameras on crashes or red light running were coded, including one meta-analysis.

Meta-analysis

Based on a meta-analysis on 29 international red light camera studies (of which 17 in USA), Høye (2013) found the following main results:

- A non-significant decrease of all injury crashes by 13% and a non-significant increase of all crashes by 6%.
- Right-angle collisions were found to decrease by 13% (NS) and rear-end collisions were found to increase by 39% (statistically significant).
- For right-angle injury collisions a far larger decrease was found (-33%, statistically significant) and for rear-end injury collisions a smaller increase was found (+19%, statistically significant).

Additional crash studies not covered by meta-analysis

After the meta-analysis by Høye several American studies have confirmed that red light cameras reduce right angle crashes but at the same time increase rear-end crashes and other types of crashes complicating the estimate of the net/total safety effect (Ahmed & Abdel-Aty, 2015; Claros et al., 2016; Lord & Geedipally, 2014; Pulugurtha & Otturu, 2014; Wong, 2014). One European study of safety effects of red light cameras (in Belgium) confirmed the pattern of results from American studies: a significant increase in rear-end crashes combined with significant decrease in severe side crashes (DePauw et al. 2014). An Asian study (South Korea) was partly in line with previous findings (Lee et al., 2016). This study indicated that red light cameras would reduce fatal injury angle crashes, but at the same time they would substantially increase injury crashes, both injury sideswipe and rear end crashes and angle injury crashes.

McCartt & Hu (2013) found some evidence for spill-over effect of red light cameras but the effects were observed only for nearby intersections on travel corridors with cameras and were not always significant.

A study by Chin et al. (2012) focused on effects of red light cameras on the exposure of motorcyclists to right-angle conflicts. They found that the presence of red light cameras reduced (observed) right angle conflicts of motorcyclist, and reduced the crash vulnerability of motorcyclists at right angle collision.

Additional studies on red light running

Studies on the effects of red light cameras on red light running indicate that the installation of red light cameras reduce red light running (McCartt & Hu, 2013; Polders et al., 2015), whereas the removal of red light cameras increase red light running (Porter et al., 2013). In several simulation and observational studies further evidence is found of how and the extent to which red light running violations lead to increased traffic conflict situations (Chai et al, 2014; Polders et al., 2015; Chin & Haque, 2012). For example, Chin & Haque (2012) based on video-observations found that motorcycles at RLC sites compared to non-RLC sites had a lower exposure to red light runners by about 10% during the first second of green and 13% in the first 2.5 seconds of green. This improvement was due to two behavioural mechanisms; first, at RLC sites, motorcyclists were less willing to queue beyond the stop line, thereby reducing the number of motorcycles discharging ahead of other vehicles; second, the motorcyclists were also less likely to jump start prior to gaining the right of way. Based on video-observations Polders et al. (2015) found evidence that red light cameras influence stopping behaviour of vehicles so that they stop earlier and also stop at the onset of yellow when they are closer to the stop line. Also, the influence on behaviour appeared stronger for truck driver than for other vehicles. Using a simulation model, Chai et al. (2014) found evidence that the safety impact of RLCs on right-turn conflicts was strongest for right angle conflicts (85% and 86% reduction for TTC < 2 s during peak and off-peak hours, respectively) and was more prominent during amber-red signal phases. Apparently, the installation of RLCs reduces red light running from opposing straight-through vehicles and thereby reduces the occurrence of this type of conflict.

2.4 CONCLUSIONS

From the coded studies and from the literature review the following conclusions can be derived:

- A 2013 meta-analysis concluded that red light cameras significantly reduced right-angle injury collisions (–33%) but at the same time significantly increased rear-end injury collisions (+19%).
- Several USA studies, one European and one Korean study, confirmed this pattern of results.
- Overall a positive safety effect of red light cameras is to be expected since rear-end crashes are often less serious than right-angle crashes.
- A positive safety effect of red light cameras can be expected especially at intersections where relatively many right-angle crashes related to deliberate red light running take place, and where relatively few rear-end crashes occur.
- The safety effects of red light cameras are larger when red light camera warning signs are posted at main entrances to areas with red light camera enforcement rather than when each camera-controlled intersection is signposted.
- Red light cameras are not a suitable measure for solving problems that arise from a bad view on the intersection, problems with unintentional red light running or problems with signal phasing.
- There is still a considerable lack of knowledge about the type of intersections where red light cameras are most effective.
- Most studies have been performed in the USA and results are not easily transferable to European intersections which have different designs, traffic volumes and traffic composition (e.g. larger share of cyclists and/or moped riders). However, two non-USA studies, one European and one Korean, show results that are in line with several American studies.

3 Supporting document



This supporting document describes the main characteristics of coded studies (Section 3.1), it presents a schematic overview of study outcomes (Section 3.2), it describes the literature search strategy, and it presents references on coded studies, and general literature (Section 3.4).

3.1 DESCRIPTION OF STUDIES

Table 1 presents information on the main characteristics of the coded studies.

Table 1: Overview of main characteristics of coded studies of the effects of red light cameras (RLC)

Author, Year, Country	Study type	Sample/Measurement	Analysis
1. Chin & Haque, 2012, Singapore	Crash analysis	This study evaluated the effectiveness of RLCs on motorcycle safety in Singapore by comparing their exposure, proneness of at-fault right-angle crashes as well as the resulting right-angle collisions at RLC with those at non-RLC sites. For this study, the Singapore crash data from 1998 to 2002 were used. During this 5-year period, there were 8880 2-vehicle crashes at intersections of which about 74.9% crashes were right-angle collisions. To simplify the assignment of fault in a crash, the analysis was restricted to two-vehicle collisions at intersections.	The researchers estimated relative right angle crash vulnerability and relative crash proneness for red light camera sites and non-camera sites to explore the effect of red light cameras for motorcyclists.
2. Høye, 2013 International	Meta-analysis	Total of 29 before-after studies (17 from USA, 6 from Australia, 3 from UK, 1 from Norway and 1 from Singapore). Studies were classified in 4 groups: <ul style="list-style-type: none"> - Studies that controlled neither for regression to the mean (RTM) nor for spill-over effects (8 studies) - Studies that controlled for spill-over effects, but not for RTM (7 studies) - Studies that controlled for RTM, but not for spill-over effects (5 studies). - Studies that controlled for both RTM and spill-over effects (9 studies) 	A meta-analysis was performed. A moderator analysis investigated effects of: <ul style="list-style-type: none"> - the approach to controlling for spill-over effects - the approach to controlling for RTM - the location of RLC warning signs (at intersections or main entrances to cities with RLC) - the unit of analysis (intersections with vs. without RLC or cities with vs. without RLC programme). Sensitivity analyses evaluated outlier bias, publication bias, statistical weighting.
3. Ko et al., 2013, USA, Texas	A before-after Empirical Bayes study with comparison group	The researchers collected crash data at 245 red light camera intersections in Texas. The data covered periods	To overcome a regression to the mean bias the Empirical Bayes method was used. Safety performance functions were

Author, Year, Country	Study type	Sample/Measurement	Analysis
		from 1 to 4 years before (516 intersection years) and after (663 intersection years) RLC installation.	developed by the use of crash, traffic, and geometric data from the reference sites and the negative binomial regression models for red light running crashes of all types and of right-angle and rear-end crashes.
4. McCartt & Hu, 2013, USA, Virginia	Observational study. The effects of the camera enforcement on red light violations were examined.	In June 2010, Arlington County, Virginia, installed red light cameras at four heavily travelled signalised intersections. Traffic was videotaped during a 1-month warning period and 1 month and 1 year after ticketing began at 4 camera intersections, 4 "spill-over" intersections without cameras, and 4 "control" intersections without cameras in an adjacent County.	At each intersection, the amount of red light running per 10,000 vehicles was calculated for each of the three observation periods by seconds elapsed after the signal light turned red (≥ 0.5 second, ≥ 1 second, and ≥ 1.5 seconds). Percentage changes were calculated for violation rates 1 month after ticketing began compared with the warning period and for rates 1 year after ticketing began compared with the warning period. Logistic regression models were used to estimate the effects of RLC on the probability of red light running at the camera intersections.
5. Porter et al., 2013, USA, Virginia	An observational study at treated and untreated intersections	Observations were done at 4 camera intersections, and 2 control non-camera intersections in one city (Virginia Beach). As a second control group 2 intersections in a nearby city were used (Newport News). Red light running was observed at intersections before (2 phases), during (5 phases) and after RLC enforcement (4 phases). The intersections in Virginia Beach varied from 4 x 4 lanes to 7 x 7 lanes; the two intersections in Newport News were chosen as control sites based on comparable size (6 x 2 lanes and 6 x 4 lanes). More than 2700 direct observations were made in these time periods.	The study was limited to behavioural data; no crash data provided. Relative risk estimates were based on frequencies of red light running before and after camera installation.
6. Chai et al. 2014, Singapore	A simulation study. In this study, a model was applied to estimate safety impacts of RLCs.	Using conflict occurrences generated in simulation allowed analysts to control regression to the mean and spill-over effects. Conflict occurrences were generated through simulating vehicular interactions based on a cellular automata (CA) model. The CA model was calibrated and validated against field observations at approaches with and without RLC. Simulation experiments were conducted for RLC and non-RLC intersections.	Average times-to-collision and post-encroachment times of 200 simulated conflicts were compared against 200 observed vehicle conflicts from video extraction at 4 approaches.
7. De Pauw et al., 2014, Belgium	Before-and-after Empirical Bayes comparison of the number of injury crashes	This study concerns combined speed/red light cameras (SRLC) in Flanders, Belgium. All crashes from 2000 until 2008 were included. As the first cameras were installed in	The effectiveness of the installation of SRLC was first calculated per intersection, and was expressed in an index of effectiveness. The database with all crashes in Flanders was selected as the

Author, Year, Country	Study type	Sample/Measurement	Analysis
		2002, for any location at least 2 years of data in the before period and 1 year of data in the after period were available. The before period amounted on average to 3.13 years, the after period to 3.7 years. The injury crashes in the treated group decreased from 800 in 2000 to 618 in 2008, with an average of 713 crashes per year. The severe crashes had a range from 144 in 2000 to 58 in 2008, with an average number of 90.	comparison group, as this gives a good estimation of the general trend. An Empirical Bayes estimation of regression-to-the-mean was executed, based on the crash frequencies in the treated group.
8. Lord & Geedipally, 2014, USA, Chicago	Before-after Empirical Bayes study with treatment and reference group. .	Crash, geometric and traffic flow data were collected at 90 4-legged signalised intersections for three years before and for three years after the installation of the cameras as well as at 59 intersections where no camera was installed. Three years of data were collected for the before (2005-2007) and after (2010-2012) periods (for both treatment and reference group).	Three types of before-after studies were conducted: 1) the naive or simple before-after; 2) the before-after study with reference group; and, 3) the before-after study with the Empirical Bayes method (these results most relevant and coded). For the Empirical Bayes method Safety Performance Functions were developed using Negative Binomial regression models.
9. Pulugurtha & Otturu, 2014 USA, North Carolina	Data from January 1997 to December 2010 for 32 signalised intersections in Charlotte, North Carolina, where RLCs were installed between August 1998 and August 2000 and terminated in fall 2006, were gathered, analysed, and compared for "before the installation", "after the installation", and "after the termination" periods.	Data from January 1997 to December 2010 for 32 signalised intersections in Charlotte, North Carolina, where RLCs were installed between August 1998 and August 2000 and terminated in fall 2006, were gathered, analysed, and compared for "before the installation", "after the installation", and "after the termination" periods.	Descriptive analysis and paired t-tests were performed using rear-end, sideswipe, left-turn, angle, and right-turn crashes as well as the number of total crashes. The expected number of total crashes, had RLC enforcement program not been implemented, was computed using the Empirical Bayes (EB) method and compared to the actual number of total crashes for "after the installation" and "after the termination" periods.
10. Vanlaar et al., 2014, Canada	A time-series analysis on red light running-related crashes	Crashes were grouped into right-angle and rear-end. First set of 12 cameras was installed Jan 2003, second 12 August 2003, third set July/August 2004; fourth set July/August 2005. The analysis covered crashes in the period 1994-2008 on 48 intersections in City Winnipeg.	Four dummy variables were created to indicate when each set of cameras was installed. ARIMA times series design was used to rule out regression to the mean. Data from the province of New Brunswick were used as a comparison group in the time series analysis. Monthly count data were used. % change in crashes was calculated from coefficient ω as: $100 \times (e^{\omega} - 1)$.
11. Wong, 2014, USA, Los Angeles	Before-after observation study with treatment and control sites.	The average number of months observed before a treated intersection received a RLC was 16.46 months, while the average number of months observed after a treated intersection received a camera was 42.53 months. For each	A Poisson panel data model with random coefficients was applied to these data and estimated using Bayesian methods. In the statistical model, the Poisson distribution was "mixed" with a log-normal distribution to form the Poisson-log-normal model. This mixing

Author, Year, Country	Study type	Sample/Measurement	Analysis
		<p>of the 32 treated intersections, the researcher selected 4 nearby intersections, one each to the north, south, east and west of the treated intersection as controls for that treated intersection. These control intersections were also selected by matching on three observable characteristics: type of intersection (i.e. four-way), presence of a traffic light, and number of lanes. If no intersection with a common street fulfilled the matching criteria, it was replaced with the closest intersection that does match the observable characteristics.</p>	<p>distribution relaxes the assumption of equidispersion and allows for error correlations across observations.</p>
<p>12. Ahmed & Abdel-Aty 2015 USA, Florida</p>	<p>A before-after Empirical Bayes crash analysis comparing treatment and control intersections</p>	<p>Intersections with active red-light cameras and at least three year of crash data in the before and after periods were considered for inclusion in the study. 25 RLC intersections were compared with 50 non camera intersections. Evaluation performed at 3 levels: 1. only target approaches where RLCs were installed, 2. all approaches on RLC intersections, and 3. non-RLC intersections located on the same travel corridors as the camera equipped intersections.</p>	<p>The observational Before-After EB method was applied on the 25 RLC intersections. The aggregate safety effectiveness over all RLC intersections was estimated and the Poisson test of significance was performed on all target approaches and all approaches combined.</p>
<p>13. LLau et al. 2015, USA, Florida</p>	<p>A before–after EB crash analysis using a comparison group along with traffic control correction</p>	<p>20 signalised intersections with RLC were matched to two comparison sites located at least 2 miles from camera sites (to minimize spill-over effect). Crashes were analysed for 3 years before (2008–2010) and 2 years after camera enforcement (2011 and 2012). Crashes at intervention and comparison sites were included if they occurred within 150 feet (\pm 46m) from the centre of an intersection.</p>	<p>An Empirical Bayes analysis was used to account for potential regression to the mean effects. An index of effectiveness along with 95% confidence intervals were calculated based on the comparison between the estimated and actual number of crashes in the after period.</p>
<p>14. Polders et al., 2015, Belgium</p>	<p>A combination of before-after observations and a driving simulator experiment (feeding into a Monte Carlo simulation)</p>	<p>Two signalised intersections where combined speed/red light cameras were about to be installed were selected for an on-field behavioural observation study in a before-and-after design. One of the intersections was rebuilt in a driving simulator where two test conditions (i.e., speed/red light cameras and speed/red light cameras with a warning sign) and one control condition (i.e., no speed/red light camera) were examined to provide input parameters for a Monte Carlo simulation of risk of rear-end collisions.</p>	<p>The odds of rear-end collisions for each condition are estimated by means of a Monte Carlo Simulation using a normal distribution. The Monte Carlo Simulation was performed with 100,000 iterations for each condition. The stopping distance was calculated for both the following and leading vehicle. A rear-end collision will occur when the sum of the stopping distance of the following vehicle and the distance headway is larger than the stopping distance of the leading vehicle</p>

Author, Year, Country	Study type	Sample/Measurement	Analysis
15. Claros et al., 2016, USA, Missouri	A before-after/treatment-control Empirical Bayes estimation	A total of 24 four-leg urban intersections were randomly selected from a list of RLC intersections in Missouri from 2006 to 2011. Additionally, 35 comparable non-treated intersections were selected for the analysis. The data collection included intersection geometry, signal control operation, traffic volume, surrounding features, and crash data.	The predicted crashes were obtained using Safety Performance Functions, Crash Modification Factors, Calibration factors, and crash type distribution by facility and severity type. All these functions and factors account for local site characteristics, refining the prediction of crashes. The comparison (unbiased odds ration) of expected and observed crash frequency for the after period formed the basis for deriving the safety effectiveness.
16. Lee et al., 2016, South Korea	A before-after Empirical Bayes method with treated and untreated intersections	In years 2008, 2009, 2010, 2011, 2012 there were 2, 18, 26, 40, 40 urban intersections with a RLC. In 2007, 2008, 2009, 2010, 2011, 2012, there were 101, 99, 83, 75, 61, 61 (untreated) intersections in the reference group.	The method for assessing the safety impact of RLC consisted of 3 steps: <ol style="list-style-type: none"> 1. Acquiring data from different resources and processing that data for treatment and reference intersections 2. Modelling Safety performance functions using untreated intersection data, including geometric information, vehicle crash data, and traffic volume data; 3. Conducting an Empirical Bayes analysis for assessing the safety impacts

3.2 STUDY OUTCOMES

Table 2 summarises the main results per study.

Table 2: Results of coded studies on the effects of red light cameras (RLC) on crashes or risk (↘ = expected decrease in road safety; ↗ = expected increase in road safety).

Author, Year, Country	Indicator	Expected effect on safety	Safety/Crash reduction percentage (type crash)
1. Chin, 2012, Singapore	The crash vulnerability or crash-involved exposure of motorcycles at right-angle collisions	↗	The crash-involved exposure of motorcycles at right-angle collisions was significantly reduced from non-RLC sites with relative crash vulnerability (RCV) = 0.532 to RLC sites with RCV = 0.414.
	Observed exposure of motorcycles to vehicles in conflicting stream (at intersection)	↗	Motorcycles at RLC sites compared to non-RLC sites had a lower exposure by about 10% during the first second of green and 13% in the first 2.5 seconds of green.
	Light motor cycles proneness of at-fault right -angle collisions (Odds Ratio)	↗	For light motor cycles, the Odds Ratio of at-fault right-angle collisions to collide with not-at-fault motorcycles was lowered from 9.14 at non-RLC sites to 4.03 at RLC sites.

Author, Year, Country	Indicator	Expected effect on safety	Safety/Crash reduction percentage (type crash)
	Heavy motor cycles proneness of at-fault right-angle collisions (Odds Ratio)	↗	The Odds Ratio for at-fault heavy motor cycles was lowered from 6.26 at non-RLC sites to 2.34 at RLC sites.
2. Høye, 2013 international	Right-angle injury crashes	↗	33% decrease
	Rear-end injury crashes	↘	19% increase
	Rear-end crashes	↘	39% increase
3. Ko, 2013, USA, Texas	Red light running crashes	↗	20% decrease
	Right-angle red light running crashes	↗	24% decrease
	Rear-end red light running crashes	↘	37% increase
4. McCartt, 2013, USA	Odds of red light running after 0.5 second red signal phase	↗	At the camera intersections, 1 year after the start of enforcement the odds of red light violations occurring at least 0.5 second into the red signal phase decreased by 39%.
	Odds of red light running after 1.5 seconds red signal phase	↗	The odds of red light violations occurring at least 1.5 seconds into the red signal phase decreased by 86 %, relative to what would have been expected without the cameras.
5. Porter, 2013, USA, Virginia	Relative risk (RR) of red light running at the camera locations	↗	In the immediate months after the cameras were turned off RR at the camera locations was 2.96 times higher than in the months before the law's expiration.
	Relative risk (RR) of red light running at the camera locations	↗	One year later , RR at former camera locations, that still had cameras turned off, had risen to 4.06 times higher than when cameras were last active.
6. Chai, 2014,	Right-angle conflicts	↗	40 to 80% decrease
	Rear-end conflicts	↘	10 to 45% increase
7. De Pauw, 2014, Belgium	Severe right-angle crashes	↗	24% decrease
	Rear-end crashes	↘	44% increase
8. Lord, 2014, USA, Chicago	Angle and turning injury crashes	↗	15% decrease
	Rear-end crashes	↘	22% increase
9. Pulugurtha, 2014, USA,	Total crashes	↗	50% decrease (contrasting "before the installation – after the installation")

Author, Year, Country	Indicator	Expected effect on safety	Safety/Crash reduction percentage (type crash)
North Carolina	Total crashes	↗	16% decrease (contrasting “before the installation – after the termination” scenario)
10. VanLaar, 2014, Canada	Right angle crashes	↗	46% decrease after installation of the second set of 12 cameras.
	Rear-end crashes	↘	42% increase in crashes after the installation of first set of cameras
11. Wong, 2014, USA, Los Angeles	Total crashes	↘	17% increase
	Injury crashes	↘	22% increase
	Red light running crashes	—	No significant effect
	Right-angle crashes	↘	24% increase
	Rear-end crashes	↘	34% increase
12. Ahmed 2015, Florida	Angle and left-turn crashes on target approaches	↗	24% decrease
	Angle and left-turn fatal and injury crashes on target approaches	↗	26% decrease
	Rear-end crashes on target approaches	↘	32% increase
	Rear-end fatal and injury crashes on target approaches	↘	41% increase
13. LLau, 2015	Injury crashes first yr.	↗	19% decrease
	Red light running related injury crashes 1st yr.	↗	24% decrease
	Red light running related injury crashes 2nd yr.	↗	17% decrease
	Rear-end crashes 1st yr.	↘	40% increase
	Rear-end crashes 2nd yr.	↘	51% increase
14. Polders, 2015, Belgium	Odds Ratio of compliance with red lights	↗	Odds Ratio compliance 1.2 times higher in the presence of a speed/red light camera.
	Odds Ratio of rear-end accident in camera condition	↘	Odds Ratio was 6.42 in the speed/red light camera condition compared to no-camera condition.
	Odds Ratio of rear-end accident in camera/sign condition	↘	Odds Ratio was 4.01 in the speed/red light camera + warning sign condition compared with no-camera condition

Author, Year, Country	Indicator	Expected effect on safety	Safety/Crash reduction percentage (type crash)
15. Claros, 2016, Missouri	Right-angle fatal and injury crashes	↗	14.5% decrease
	Rear-end crashes	↘	16.5% increase
	Rear-end fatal and injury crashes	↗	10.9% decrease
16. Lee, 2016, South Korea	Total crashes	↘	50.8% increase
	Injury sideswipe and rear-end crashes	↘	73.4% increase
	Sideswipe and rear-end crashes	↘	68.7% increase
	Injury crashes	↘	52.5% increase
	Fatal angle, sideswipe, rear-end and head-on crashes	↗	22.5% decrease

3-3 LITERATURE SEARCH

The literature on red light cameras and traffic risk was searched for in the international database Scopus on 16 December 2016. Scopus is the largest international peer-reviewed database. A meta-analysis by Høye in 2013 covered studies in the period 1995-2011. In view of this, the literature was searched over the period 2012-2016; the search terms were searched in title, abstract and keywords. Table 3 describes the search terms and logical operators and the number of hits for three searches on red light running and accidents.

Table 3: Used search terms and logical operators

no	Search terms/logical operators/combined queries	hits
1	The search for red light running and drivers used the following combination of key words: TITLE-ABS-KEY ("red light camera" AND (safety OR crash OR accident)) AND PUBYEAR > 2011	30

The search resulted in 30 hits. In a first screening round, these 30 references were screened on potential relevance for coding based on title and abstract. The main exclusion criteria were: no effects of red light camera studied, other than English language, duplication, general review like text instead of specific study. Also references were screened for additional studies. Table 4 shows the results.

Table 4: Initial selection of studies after the first screening round

Selection steps	Not selected first round	Selected first round
Excluded: No actual crash reduction studied	10	

Excluded : Duplication	1	
Excluded: General review-like text	3	
Selected after initial screening		16
Added after screening references (VanLaar, Lord, Porter)		3
Total selected after first round		19

The 19 selected studies were further screened on relevance for coding in a second screening round. In the second round the same criteria were used but now the full-text copies of the papers were checked. Table 5 presents the results of this second screening round and describes the final decisions.

Table 5: Selection of studies to be coded in second screening round

	Reference	Relevant	Coded
1	Ahmed, M.M. & Abdel-Aty, M. (2014). Evaluation and spatial analysis of automated red-light running enforcement cameras. Transportation Research Part C: Emerging Technologies. Article in Press.	Yes	1. Yes
2	Chai, C., Wong, Y.D., & Lum, K.M. (2015). Safety Impacts of Red Light Cameras at Signalized Intersections Based on Cellular Automata Models. Traffic Injury Prevention, 16, 374-379.	Yes	3. Yes
3	Chin, H.C. & Haque, Md.M.(2012). Effectiveness of red light cameras on the right-angle crash involvement of motorcycles. Journal of Advanced Transportation, 46 , 54-66.	Yes, but study in Singapore concentrating on motorcycles makes it hard to compare with any of the other studies	4. Yes
4	Claros, B., Sun, C. & Edara, P. (2017). Safety effectiveness and crash cost benefit of red light cameras in Missouri. Traffic Injury Prevention, 18, 70-76.	Yes	5. Yes
5	De Pauw, E., Daniels, S., Brijs, T., Hermans, E. & Wets, G. (2014). To brake or to accelerate? Safety effects of combined speed and red light cameras. Journal of Safety Research, 50, 59-65	Yes	2. Yes
6	<i>Meta-analysis starting point:</i> Høye, A. (2013). Still red light for red light cameras? An update. Accident Analysis and Prevention, 55, 77-89.	Yes	6. Yes
7	Ko, M., Geedipally, S. & Walden, T. (2012). Effectiveness and site selection criteria for red light camera systems. Transportation Research Record, 2327, 53-60.	Yes	7. Yes
8	Langland-Orban, B., Pracht, E.E., Large, J.T., Zhang, N. & Tepas, J.T. (2014). Explaining Differences in Crash and Injury Crash Outcomes in Red Light Camera Studies. Evaluation and the Health Professions, 39, 226-244.	This study is a brief methodological review of earlier studies (2000-2013) that analyses how findings are associated with data and method characteristics. Certainly relevant for understanding the research, but not suitable for coding.	No
9	Lee, S.H., Lee, Y.D. & Do, M. (2016). Analysis on safety impact of red	Yes	10. Yes

	Reference	Relevant	Coded
	light cameras using the Empirical Bayesian approach. <i>Transportation Letters</i> , 8, 241-249.		
10	Llau, A.F., Ahmed, N.U., Khan, H.M.R.U., Cevallos, F.G. & Pekovic, V. (2015). The Impact of Red Light Cameras on Crashes Within Miami-Dade County, Florida. <i>Traffic Injury Prevention</i> , 16, 773-780.	Yes	11. Yes
11	Lord, D. & Geedipally, S.R. (2014). Safety Effects of the Red-Light Camera Enforcement Program in Chicago, Illinois. Research report prepared for the Chicago Tribune, College Station, TX.	Yes	12. Yes
12	McCartt, A.T. & Hu, W. (2013). Effects of Red Light Camera Enforcement on Red Light Violations in Arlington County, Virginia. Insurance Institute for Highway Safety, Arlington.	Yes	8. Yes
13	Polders, E., Cornu, J., De Ceunynck, T., Daniels, S., Brijs, K., Brijs, T., Hermans & E., Wets, G. (2015). Drivers' behavioral responses to combined speed and red light cameras. <i>Accident Analysis and Prevention</i> , 81, 153-166.	Real-world observations and driving simulator-based observations are combined.	13. Yes
14	Porter, B.E., Johnson, K.L. & Bland, J.F. (2013). Turning off the cameras: Red light running characteristics and rates after photo enforcement legislation expired. <i>Accident Analysis & Prevention</i> , 50, 1104- 1111.	Yes	9. Yes
15	Pulugurtha, S.S. & Otturu, R. (2014). Effectiveness of red light running camera enforcement program in reducing crashes: Evaluation using "before the installation", "after the installation", and "after the termination" data . <i>Accident Analysis and Prevention</i> , 64, 9-17.	Yes	14. Yes
16	Stevenson, M., Faruque, S., Almajil, A., Farhan, M., Fildes, B, & Lawrence, B. (2016). An evaluation of the red-light camera programme in the city of Dammam, the Kingdom of Saudi Arabia. <i>International Journal of Injury Control and Safety Promotion</i> , 1-5. Article in Press.	Study in Saudi-Arabia. The small crash numbers observed prevented rigorous statistical analysis which is a limitation of the current study. Other limitations were: - insufficient details on the crash type (.e.g. whether crash was right angle type) - limited data available on the timing of the installation of the cameras, and the site of the cameras	No (too limited data quality)
17	Testerman, G.M., Al-Balbissi, L.A., & Quillen, O.D. (2013). Red light cameras reduce right-angle and rear-end crashes. <i>American Surgeon</i> , 79 (12), pp. E347-348.	Only 2 pages, perhaps letter or comment. Not relevant.	No
18	Vanlaar, W., Robertson, R. & Marcoux, K. (2014) An evaluation of Winnipeg's photo enforcement safety program: Results of time series analyses and an intersection camera experiment. <i>Accident Analysis and Prevention</i> , 62, 238-247.	Yes	15. Yes
19	Wong, T. (2014). Lights, camera, legal action! The effectiveness of red light cameras on collisions in Los Angeles (2014) <i>Transportation Research Part A: Policy and Practice</i> , 69, 165-182.	Yes	16. Yes

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Licence suspension



Goldenbeld, Ch., SWOV, July 20th 2017

1 Summary

1.1 COLOUR CODE

Green: Studies indicate that licence suspension (or licence revocation) is an effective measure for reducing violations and crashes of (repeat) offenders. It should be added that for drink- drivers, other sanction measures, in particular alcohol-interlock programs, will likely produce greater road safety benefits than licence suspension. Also, licence suspension in combination with other measures will likely perform better in reducing recidivism than licence suspension in isolation.

1.2 KEY WORDS

Licence suspension, licence revocation, licence disqualification, licence withdrawal, recidivism.

1.3 ABSTRACT

In most countries, a licence suspension means a temporary withdrawal of the privilege to drive a motorised vehicle. Most often after a fixed period of time and after fulfilling certain conditions (e.g. paying a fee, and/or participating in a rehabilitation program), the driving privileges will be restored. There are two basic ways in which licence suspension may improve road safety. First, the threat of licence suspension may motivate drivers to improve their traffic behaviour and to abstain from risky driving. Second, licence suspension temporarily removes risky drivers from traffic. Studies indicate that licence suspension (and also licence revocation) is effective in reducing crashes and violations of repeat offenders. A 2004 meta-analysis has estimated that licence suspension or revocation measures reduced crashes and violations of suspended offenders by 17% and 21% respectively. A 2009 meta-analysis indicated that administrative licence suspension laws reduced all fatal accidents by 4%. It should be added that for specific groups of offenders, such as drink- drivers, other sanction measures, in particular the alcohol-interlock measure, will likely produce larger road safety benefits than licence suspension. Also, the combination of licence suspension and other measures, such as rehabilitation programs, or vehicle impoundment, will likely perform better than licence suspension as a single measure.

1.4 BACKGROUND

What is licence suspension?

In most countries, a licence suspension means a temporary withdrawal of the privilege to drive a motorised vehicle. Most often after a fixed period of time and after fulfilling certain conditions (e.g. paying a fee, and/or participating in a rehabilitation program), the driving privileges will be restored. Licence suspension is distinct from licence revocation. Under licence revocation, the privilege to drive is factually ended. Revocation of the licence applies for a minimum period set by law, until the driver becomes eligible to apply for a new licence. In most countries the driver then needs to retake a driver's licence examination (or prove in some other way that he or she is competent to drive again).

How does licence suspension affect road safety?

There are two basic ways in which licence suspension (or revocation) may improve road safety. First, the threat of licence suspension may motivate drivers to improve their traffic behaviour and to abstain from risky driving. Second, the actual imposition of licence suspension temporarily removes risky drivers from traffic.

What are the reasons for having a suspended licence?

In most countries drivers will have their licence suspended after having once or repeatedly engaged in particularly risky driving behaviour such as drinking and driving, drugged driving, aggressive driving, high speed driving, and driving which leads to a crash. However, licence suspensions are not exclusive to traffic or driving offences. There may be also medical reasons for licence suspensions. In the USA, it is frequently the case that the suspension is not directly tied to a traffic conviction but to a failure to pay the costs associated with it.

Which factors influence the effect of licence suspension?

The effectiveness of licence suspension(or revocation) in reducing repeat violations depends upon:

- the perceived probability of detection of unlicensed driving: the higher the probability, the more effective licence suspension is,
- the presence of additional measures: licence suspension in combination with other motivating measures, such as rehabilitation programs or vehicle impoundment, is likely to perform better than licence suspension as a single measure,
- licence sanction certainty: for drinking/driving offenders increasing the certainty of licence suspension (or revocation) by implementing an administrative law procedure that automatically suspends or revokes a licence when certain conditions are fulfilled, has been shown to further reduce recidivism,
- licence sanction severity: there is some evidence that more severe licence suspensions/ revocations deliver worse recidivism results than less severe sanctions,
- social and economic conditions: drivers will be tempted to ignore licence suspension when social and economic conditions raise the need for driving.

Are there alternatives for licence suspension?

For drink- drivers, the alcohol interlock measure is an alternative that will outperform license suspension in terms of reduction of drinking and driving recidivism. The alcohol interlock measure requires convicted drink- drivers to install an alcohol interlock device in their car. This is an alcohol tester which is connected to the start-up mechanism of the car; it acts as a vehicle immobiliser if the driver has not passed the breath alcohol test. Various international studies show 65-90% fewer repeat offences for users of an alcohol interlock device than for drivers with a suspended or a revoked driving licence (Bax et al., 2001).

How is the effect of licence suspensions on road safety measured?

The effects of licence suspension(/revocation) on road safety have been measured in terms of change in:

- crash rates before/ after licence suspension, and
- violation rates before/ after licence suspension.

1.5 MAIN RESULTS

- A 2004 meta-analysis indicated that licence suspension/revocation measures reduced crashes and violations of suspended offenders by 17%, respectively, 21%.
- A 2009 meta- analysis indicated that administrative licence suspension laws reduced all fatal accidents by 4%
- Administrative licence suspension (or revocation) for drink-drivers where suspension (or revocation) follows automatically after an offence satisfies pre-established criteria performs better than the standard regulation (i.e. decision by court).

- Less severe forms of licence sanctioning (e.g. lower length of suspension period, suspension instead of revocation) have proved to perform better for certain groups of offenders.

1.6 NOTES ON RESEARCH METHODS AND TRANSFERABILITY

The research on license suspension includes one meta-analysis, and several studies on large databases containing national or state offence statistics. Most of the research has concentrated on drinking drivers. In almost all research the recidivism rate is the dependent measure. Most of the research has been done in the USA which means that in interpreting results and transferring knowledge account has to be taken of the peculiarities of the USA justice system.

2 Scientific Overview

This scientific overview on the safety effect of licence suspension first describes knowledge from the general literature (Section 2.1), it then describes characteristics of coded studies (Section 2.2), and major results of the coded studies (Section 2.3) and it presents major conclusions from the literature and coded studies (Section 2.4).

2.1 GENERAL LITERATURE

General reviews

Between 1976 and 2002 38 USA states passed laws that provide for immediate administrative (i.e., pre-conviction) licence suspension upon failure to pass an alcohol breath test (Wagenaar & Maldonado-Molina, 2007). These administrative licence suspension laws were expected to have larger effects than laws that provide for licence suspension much later after conviction by the courts. In a time-series analysis, Wagenaar & Maldonado-Molina (2007) investigated the effects of these administrative licence suspension laws on 4 outcome measures of monthly fatal alcohol-related crash involvement (fatal crashes: 1. single-vehicle night time; 2. breath or blood alcohol concentration (BAC) between 0.01 to 0.07; 3. BAC between 0.08 and 0.14; 4. BAC \geq 0.15 g/dL). In a time series analysis, it was estimated that the new administrative licence suspension laws resulted in reductions of 5% in low-BAC (BAC between 0.01 and 0.07) fatal crashes, 7% in medium-BAC fatal crashes (BAC between 0.08 and 0.14), and 4% in high-BAC fatal crashes (BAC \geq 0.15).

An evaluation study of administrative licence suspension in Canada, Ontario, confirmed the above positive USA findings (Asbridge et al. (2009). On 29 November 1996, Ontario introduced an Administrative Driver's Licence Suspension (ADLS) law. This law stipulated that any driver charged with driving with a Blood Alcohol Concentration (BAC) over the legal limit of 80 mg% or failing to provide a breath sample would have his or her licence suspended for a 90-day period. Using an interrupted time-series analysis, Asbridge et al. (2009) estimated that the introduction of the new licence suspension law was associated with a reduction of 14.5% in the numbers of fatally injured drivers.

Elvik et al. (2009) reported positive accident effects of licence suspension as a measure for all drivers (crash reductions ranging from 2% decrease to 82%) and as a measure for drinking-and-driving (crash reductions ranging from 16% to 65% decrease for specific types accidents). The positive accident effects concerned the drivers whose licence had been suspended. Although many studies have found that many drivers with a suspended licence continue driving, the observed decrease in crash involvement may be due to reduced exposure, to more cautious driving or a combination of both (Masten & Peck, 2004; Elvik et al, 2009).

Elvik et al. (2009) reviewed the literature on licence suspension. The studies on licence suspension as a general measure were very heterogeneous regarding the groups of drivers and the time periods included in the studies. The studies on the specific effects of licence suspension on the safety of suspended drivers also differed very much in terms of time periods studied and the proportions of study periods in which the licences were actually suspended. Due to the large heterogeneity for these two groups of studies no meta-analysis was done. However, Elvik et al (2009) did perform a meta-analysis on the general accident effects of administrative licence suspension studies. Administrative licence suspension laws allow the police to suspend the licence of drivers who do not pass a BAC test without involving a court (Elvik et al., 2009). The meta-analysis used 12 studies (11 USA, 1 Canada; 1991-2007). According to the meta-analysis, the introduction of administrative

licence suspensions led to a significant 4% reduction in fatal accidents and a 8% reduction in alcohol-related fatal accidents.

Modifying conditions

The effectiveness of licence suspension(/revocation) depends upon several factors such as:

- the perceived probability of detection of unlicensed driving,
- the presence of additional measures ,
- sanction certainty,
- sanction severity,
- social and economic conditions of drivers whose license has been suspended.

Perceived detection probability:

According to general deterrence theory, the effectiveness of a sanction depends upon the probability of detection (Zaal, 1994). Many suspended drivers choose to drive whilst unlicensed because they perceive the probability of detection as low (Lenton et al., 2010).

Sanction certainty:

For drink-drive offenders, increasing the certainty of licence suspension(or revocation) by implementing an administrative law procedure that automatically suspends or revokes a licence when certain conditions are fulfilled has been shown to further reduce drinking and driving recidivism (Ma et al., 2015; Fell & Scherer, 2017; further discussed in Sections 2.2 and 2.3)

Sanction severity:

The most severe sanction is not necessarily the best sanction in terms of motivation to comply. Reducing the severity of some punishments can serve as an effective incentive for deterring offenders from committing further offences (Smith et al., 2015). In South Korea, the less severe 'licence suspension'-sanction led to lesser traffic violations and lesser at-fault crashes than the more severe 'licence revocation'-sanction (Kim et al., 2009; further described in see Sections 2.2, and 2.3). In Australia, longer periods of licence suspension led to increased recidivism (Moffat & Poynton, 2007, further described in Sections 2.2 and 2.3)

Presence of additional measures:

There is evidence that certain measures may increase the effects of licence suspension. The DRUID-experts conclude that the combination of licence suspension or withdrawal and treatment/ rehabilitation is more effective in terms of deterrence than licence suspension or withdrawal alone (Schulze et al., 2012). This holds true especially for addicted drivers and in cases of medicines misuse (Schulze et al, 2012). In Canada, Byrne et al. (2016) found that: 1. impoundment, or its threat, improved compliance with drinking and driving licence suspensions, and 2. addition of impoundment to licence suspension reduced drinking and driving recidivism.

Social and economic conditions:

Drivers may choose to drive whilst unlicensed as the social and economic costs of not driving can be high. In an interview study among suspended drivers by Lenton et al. (2010), employment and social factors were key themes emerging in respondents' accounts of driving whilst under licence suspension.

2.2 DESCRIPTION OF CODED STUDIES

Five (5) studies on the effects of licence suspension were coded, one of which was an international meta-analysis.

2004 meta-analysis

In a fixed effects meta-analysis of 35 USA studies on driver offender sanctions, of which 7 were studies on licence suspension/revocation, Masten & Peck (2004) examined the effect of licence suspension on crash and violation rate. The researchers also compared the effects of licence suspension to other offender interventions (warning letters, group meetings, individual meeting, probation, educational information material, contingent point reduction, licence extension).

Additional studies

In Australia, Moffat & Poynton (2007) studied the effectiveness of financial penalties and the length of licence suspension in reducing recidivism rates of convicted offenders. The study examined the history and subsequent reoffending of approximately 70,000 persons who received a court imposed fine for a driving offence between 1998 and 2000. In an attempt to control for selection bias in recidivism analysis, the researchers used Heckman 2-Step Model to simultaneously estimate two regression equations: a selection equation and an outcome (or recidivism) equation.

A South-Korean study (Kim et al., 2011) examined the differences in traffic violations and crashes between two administrative sanctions, licence revocation and licence suspension. The study compared the traffic violation records and at-fault crash occurrences between the suspension and revocation groups at 6, 12, and 18 months after the offenders regained their driving privileges.

Traffic offenders who were sentenced to licence revocation and received either of two administrative sanctions (licence suspension or revocation) between July 1, 2002, and June 30, 2003, were selected for the study. The study data of about 154,000 driving records in the two study years represent about 8.5% of all suspension or revocation records. Among the offenders, about 10% received a reduced sanction - licence suspension with the total penalty point reset to 110 - and the others received the originally sentenced sanction of licence revocation. The study employed analysis of covariance (ANCOVA) and the t-test for stratified samples to control for influential factors and used the police profiles of approximately 154,000 drivers in South Korea. 6 covariates (gender, age, driving experience, licence classification, and prior traffic violations, prior traffic crashes) were controlled for in ANCOVA. Three ANCOVA models, one for each of the three follow up periods (6, 12, and 18 months), were estimated.

In Ontario, Canada, Ma et al. (2015) examined the effect of administrative licence suspensions for drink- drivers on drinking and driving recidivism. The study period, covering the time between November 28, 1991 and November 28, 2001 was divided into quarterly bins of three-month duration. Analysis was conducted using an interrupted time series approach based on segmented Poisson/negative binomial regression. In a first analysis, the researchers examined recidivism in the 90-days immediately after the initial offence. In a second analysis, they attempted to examine recidivism in the post 90-day suspension/ pre-conviction period when an offender was legally allowed to drive, but the data proved to be insufficient to perform the second analysis.

In an analysis covering USA states, Fell & Scherer (2017) set out to determine the relationship of the suspension length of Administrative Licence Revocation (ALR) law to the prevalence of drink-drivers relative to sober drivers in fatal crashes, and to estimate the extent to which the relationship is associated to the general deterrent effect, compared to the specific deterrent effect of the law. The researchers compared the impact of ALR law implementation and ALR law suspension periods with the use of structural equation modelling techniques on state data. Four main outcome measures were computed from the Fatal Accident Reporting System (FARS) data for each year by state:

1. to measure the impact of the ALR law and suspension length on drink-driver fatal crashes, the researchers used alcohol positive cases ($BAC \geq 0.01$) as the numerator and alcohol negative cases ($BAC = 0.00$) as the denominator.

2. to measure the effect of the ALR law and suspension length on intoxicated drivers in fatal crashes, the researchers used drivers with a BAC ≥ 0.08 as the numerator and drivers below a BAC < 0.08 as the denominator.
3. to measure the general deterrent effect of ALR suspension length, the researchers used alcohol positive cases in the numerator and alcohol negative cases as the denominator among drivers with no prior DWI convictions.
4. to measure the specific deterrent effect of the ALR suspension length, the researchers used cases in which alcohol positive drivers with a DWI conviction in the prior 3 years as the numerator and alcohol negative drivers with a prior DWI conviction in the prior 3 years as the denominator.

The analyses controlled for state mileage, state unemployment rate, state urban–rural mileage mix, state per-capita alcohol consumption, state population age distribution, and the presence of key alcohol safety laws and policies. According to the authors, no other prior study on administrative licence revocation has controlled for these specific factors.

2.3 RESULTS

5 studies on the effects of licence suspension were coded, one of which was an international meta-analysis. These studies provide evidence that licence suspension (and revocation) is an effective measure in reducing violation and crash rates.

Meta-analysis

In a meta-analysis on 7 USA studies, Masten & Peck found that licence suspension/revocation was significantly associated with a 17% decrease in crash rate and a 21% decrease in violation rate. Compared to other offender interventions (warning letters, group meetings, individual meeting, probation, educational information material, contingent point reduction, licence extension), licence suspension or revocation was by far the most effective strategy for reducing subsequent crash and violation rates. According to the authors, the major limitation of the meta-analysis concerned the existence of residual heterogeneity in the composite effect size clusters after stratifying the data by a number of significant moderator variables. Also, the study did not provide evidence on the effects of suspension beyond the term of the suspension. This latter issue was beyond the scope of the present meta-analysis.

Additional studies

In Australia, Moffat & Poynton (2007) examined whether the length of licence disqualification made any difference for recidivism. In 5 analyses (for 5 subgroups: low range, mid-range, high range alcohol offence, driving while disqualified, other driving offences) neither the length of licence disqualification nor the fine amount were significant predictors of the probability of returning to court. An exception to the above findings concerned persons convicted of speeding offences. For this offender group there was a significant, positive association between the length of licence disqualification and recidivism, indicating that a longer period of licence disqualification actually increased the probability of subsequent driving offending!

In South-Korea, Kim et al. (2011) compared traffic violation and at fault crashes between drivers under licence suspension and under licence revocation. They found that:

- the traffic violation rates of the revocation group were 7.2, 4.1, and 2.6 times higher than those of the suspension group for the follow-up at 6, 12, and 18 months respectively.
- for the three follow-up periods, the suspension group had significantly fewer recorded at-fault crashes.

In Canada, Ma et al. (2015) found administrative licence suspensions effective in reducing drinking and driving recidivism. Drinking and driving recidivism occurring within the first 90 days after a drinking and driving offence (in this study: the offence categories s.253 and s.254 under the Criminal Code Canada) decreased by 65% after implementation, from 2.45 to 0.82 re-offending drivers per 100 offending drivers.

In an analysis on USA state data, Fell & Scherer (2017) found the following effects of Administrative Licence Revocation (ALR):

- The implementation of any ALR law (with any suspension length) was associated with a 13.1% decrease in the drink-/ nondrink-driver FARS but only a 1.8% decrease in the intoxicated/ non-intoxicated FARS ratio. Thus, the ALR law affects drink-drivers (BAC ≥ 0.01) substantially, but not intoxicated drivers (BAC ≥ 0.08).
- With regard to ALR suspension length, even a short suspension period of 1 to 30 days had a significant effect ($p < 0.001$) compared to having no ALR law. However, suspension periods of 31 to 90 days proved to be no better than periods of 1 to 30 days. States with ALR suspension periods of 91 to 180 days were significantly better ($p < 0.001$) than states with suspension periods of 1 to 90 days, as were the three states with suspension periods greater than 180 days compared to states with lower suspension lengths of 1 to 180 days.
- Effects on deterrence: There was evidence for a strong general deterrent effect: ALR suspension length was associated with a 4.4% decrease in FARS ratios of drivers without prior DWIs; the specific deterrent effect however was non-significant.

Both findings from Moffat & Poynton (2007), and from Kim et al. (2011) suggest that a less severe licence sanction (e.g. a lower time period for licence disqualification; or a licence suspension instead of revocation) may be more effective at reducing recidivism than the more severe sanction.

2.4 MAIN CONCLUSIONS

On the basis of the reviewed evidence (general literature and coded studies) the following can be concluded:

- License suspension (or revocation) is an effective measure to reduce violations and crashes. A 2004 meta-analysis indicated that license suspension or revocation measures reduced crashes and violations by 17% and 21% respectively.
- Administrative licence suspension (or revocation) for drink-drivers where suspension (or revocation) follows automatically after an offence and satisfies pre-established criteria performs better than the standard regulation.
- Less severe forms of licence sanctioning (e.g. lower length of disqualification, suspension instead of revocation) have proved to perform better for certain groups of offenders.
- For drink-drivers, other measures such as an alcohol-interlock program will likely perform better in reducing recidivism than suspension.
- Although licence suspension is an effective measure there is no proof that its effects outlast the period of suspension itself.
- Licence suspension may perform better if it is combined with additional measures, such as rehabilitation and vehicle impoundment programs.

3 Supporting document

This Supporting Document on licence suspension describes the literature search strategy (Section 3.1), presents in tables the main characteristics and results of the 5 coded studies (Section 3.2) and presents references on coded studies and general references (Section 3.3).

3.1 LITERATURE SEARCH

The literature on licence suspension and traffic risk was searched for in the international database Scopus on May 31 2017. Scopus is the largest international peer-reviewed database. Table 1 describes the search terms and logical operators and the number of hits for the literature search.

Table 1: Used search terms and logical operators

No	Search terms/logical operators/combined queries	hits
1	(TITLE-ABS-KEY ("licence suspension" OR "licence revocation" OR "licence cancellation" OR "licence disqualification") AND TITLE-ABS-KEY (driver OR driving))	187

The search resulted in 187 hits. In a first screening round, these 187 references were screened on potential relevance for coding based on title. The main exclusion criteria were: no effects of licence suspension studied, not available in English language, duplication, general review like text instead of specific study. Also references were screened for additional studies. A lot of studies identified by keywords were not directly concerned with effects of licence suspension but were about suspension for age-related or medical reasons, about effectiveness of alcohol-interlock program, effectiveness of drink-driving enforcement or about effects of new BAC-laws. Table 2 shows the initial selection of studies after the first screening round.

Table 2: Initial selection of studies after the first screening round

Selection steps	Not selected first round	Selected first round
Excluded: No actual effect of licence suspension on safety-related outcome (violations/crashes) studied	163	
Excluded : Duplication	1	
Excluded: General review-like text	4	
Excluded: Non-English	6	
Selected after initial screening		13
Added after screening references (Moffat & Poynton)		1
Total selected after first round		14

The 14 selected studies were further screened on relevance for coding in a second screening round. In the second round the same criteria were used but now the full-text copies of the papers were

checked. Table 3 presents the results of this second screening round and describes the final decisions.

Table 3: Selection of studies to be coded in second screening round

	Reference	Relevant	Coded
1	Asbridge, M., Mann, R.E., Smart, R.G., Stoduto, G., Beirness, D., Lambie, R., & Vingilis, E. (2009). The effects of Ontario's administrative driver's licence suspension law on total driver fatalities: A multiple time series analysis. <i>Drugs: Education, Prevention and Policy</i> , 16, 140-151.	Yes but retrieved very late	No
2	Byrne, P.A., Ma, T., & Elzohairy, Y. (2016). Vehicle impoundments improve drinking and driving licence suspension outcomes: Large-scale evidence from Ontario. <i>Accident Analysis and Prevention</i> , 95, 125-131.	No licence suspension only outcome measure	No
3	Chang, H.-L., Woo, T.H., Tseng, C.-M., & Tseng, I.-Y. (2011). Driving behaviors and accident risk under lifetime license revocation. <i>Accident Analysis and Prevention</i> , 43, 1385-1391.	No	No
4	Fell, J.C., & Scherer, M. (2017). Administrative license suspension: Does length of suspension matter? <i>Traffic Injury Prevention</i> , DOI: 10.1080/15389588.2017.1293257	Yes	Yes
5	Kim, K.S., Myeong, M.H., & Kweon, Y.-J. (2011). Differences in traffic violations and at-fault crashes between license suspension and revocation. <i>Accident Analysis and Prevention</i> , 43, 755-761.	Yes	Yes
6	Lenton, S., Fetherston, J., & Cercarelli, R. (2010). Recidivist drink drivers' self-reported reasons for driving whilst unlicensed-A qualitative analysis. <i>Accident Analysis and Prevention</i> , 42, 637-644.	No direct effect of licence suspension studied	No
7	Ma, T., Byrne, P.A., Haya, M., & Elzohairy, Y. (2015). Working in tandem: The contribution of remedial programs and roadside licence suspensions to drinking and driving deterrence in Ontario (2015) <i>Accident Analysis and Prevention</i> , 85, 248-256.	Yes	Yes
8	Masten, S.V. & Peck, R.C. (2004). Problem driver remediation; A meta-analysis of the driver improvement literature. <i>Journal of Safety Research</i> , 35, 403-425.	Yes	Yes
9	Moffat, S., & Poynton, S (2007). The deterrent effect of higher fines on recidivism: Driving offenses. Sydney: The NSW Bureau of Crime Statistics.	Yes	Yes
10	Parrish, K.E., & Masten, S.V. (2015). The Problem of Suspended and Revoked Drivers Who Avoid Detection at Checkpoints. <i>Traffic Injury Prevention</i> , 16, 97-103.	No direct effects of licence suspension studied	No
11	Suo, Q. (2015). Investigation on Deterrence Effect of Legal Punishment Measures on Driving After Drinking in Chongqing, China (2015) <i>Traffic Injury Prevention</i> , 16, 540-544.	No direct effect of licence suspension studied	No
12	Tseng, C.-M., Chang, H.-L., & Woo, T.H. (2013). Modeling motivation and habit in driving behavior under lifetime driver's license revocation (2013) <i>Accident Analysis and Prevention</i> , 51, 260-267.	No direct effects of licence suspension studied	No
13	Williams, R.L., Hagen, R.E., & McConnell, E.J. (1984). A survey of	Study was concerned with continued	No

	suspension and revocation effects on the drinking-driving offender (1984) Accident Analysis and Prevention, 16, 339-350.	driving under suspension but it did not concern effects on recidivism	
14	Wagenaar, A.C., & Maldonado-Molina, M.M. (2007). Effects of drivers' license suspension policies on alcohol-related crash involvement: Long-term follow-up in forty-six states. Alcoholism: Clinical and Experimental Research, 31 (8), 1399-1406	Yes, but retrieved too late	No

3.2 CHARACTERISTICS AND RESULTS CODED STUDIES

Table 4 presents an overview of the main characteristics of the coded studies.

Table 4: Overview of main characteristics of coded studies of the effects of licence suspension(/revocation)

Author, Year, Country	Study type	Sample/Measurement	Analysis
Masten, 2004, USA	Meta-analysis	7 USA studies concerning licence suspension or revocation measures	Fixed effects meta-analysis
Moffat, 2007, Australia	Recidivism analysis on offender database	The study examined the history and subsequent reoffending of approx. 70,000 persons who received a court imposed fine for a driving offence between 1998 and 2000. This included drink-driving (low-range, mid-range and high-range prescribed concentration of alcohol offences), driving whilst disqualified, speeding and 'other driving' offences.	The study attempted to control for selection bias in recidivism analyses by simultaneously estimating 2 regression equations (a selection equation and an outcome (or recidivism) equation) by the Heckman 2-Step Model. The main outcome measure in the study was recidivism: a count variable indicating the number of reappearances before the court for any new driving offences within five years of their reference offence being determined.
Kim, 2011, South Korea	This study examined the differences in traffic violations and crashes between 2 administrative sanctions, licence revocation and licence suspension.	The study compared traffic violation records and at-fault crash occurrences between the suspension and revocation groups at 6, 12, and 18 months after the offenders regained their driving privileges. Offenders who were sentenced to licence revocation and received either of two administrative sanctions (licence suspension or revocation) between July 1, 2002, and June 30, 2003, were selected for the study. Traffic violation and crash records were extracted for the 18 months before the administrative sanctions were executed and for the 18 months after the licence of the offenders was restored. Other information such as age and gender of the offenders at the time of the sanctions; was also collected.	Two statistical methods were used to discern differences in the traffic violations and crashes between the suspension and revocation groups: ANCOVA and the t-test for stratified samples. In ANCOVA, gender, age, driving experience, licence type and prior traffic violations, prior traffic crashes were used as covariates. Both methods produced similar results.
Ma, 2017, Canada	Time-series analysis on effects of administrative licence suspensions for drink-drivers	This study examined the effect of administrative licence suspensions for drink-drivers on drinking and driving recidivism. The study period, covering the time between November 28, 1991 and November 28, 2001 was divided into quarterly bins of three-month duration.	Analysis was conducted using an interrupted time series approach based on segmented Poisson/negative binomial regression. The analysis examined recidivism in the 90-days immediately after the initial offence.
Fell, 2017, USA	Structural equation model study on state	4 main outcome measures were computed from FARS data for each year by state:	The researchers compared the impact of ALR law implementation and ALR

Author, Year, Country	Study type	Sample/Measurement	Analysis
	data	<ol style="list-style-type: none"> To measure the impact of the ALR law and suspension length on drinking driver fatal crashes, the researchers used alcohol positive cases (BAC \geq 0.01) as the numerator and alcohol negative cases (BAC = 0.00) as the denominator. To measure the effect of the ALR law and suspension length on intoxicated drivers in fatal crashes, the researchers used drivers with a BAC \geq 0.08 as the numerator and drivers below a BAC $<$ 0.08 as the denominator. To measure the general deterrent effect of ALR suspension length, the researchers used alcohol positive cases in the numerator and alcohol negative cases as the denominator among drivers with no prior DWI convictions. To measure the specific deterrent effect of the ALR suspension length, the researchers used cases in which alcohol positive drivers with a DWI conviction in the prior 3 years as the numerator and alcohol negative drivers with a prior DWI conviction in the prior 3 years as the denominator 	<p>law suspension periods with the use of structural equation modelling techniques on state data.</p> <p>The analyses controlled for state mileage, state unemployment rate, state urban–rural mileage mix, state per-capita alcohol consumption, state population age distribution, and the presence of key alcohol safety laws and policies. According to the authors, no other prior ALR study has controlled for these specific factors.</p>

Table 5 presents an overview of main results per coded study.

Table 5: Results of coded studies on licence suspension (\downarrow = expected decrease in road safety; \uparrow = expected increase in road safety; — = no expected effect on road safety).

Author, Year, Country	Measure	Offender group	Indicator	Expected effect on safety	Change indicator
Masten, 2004, USA	Licence suspension or revocation	All offenders	Crash rate	\uparrow	17% decrease
			Violation rate	\uparrow	21% decrease
Moffat 2007, Australia	Longer period of licence disqualification	Speed offenders	Probability of returning to court for a traffic offence	\downarrow	A longer period of licence disqualification increased the probability of subsequent driving offending.
Kim, 2011, South Korea	Licence suspension (compared to licence revocation)	All offenders	Traffic violations 6 month follow-up	\uparrow	7 times fewer violations
			Traffic violations 12 months follow-up	\uparrow	4 times fewer violations
			Traffic violations 18 months follow up	\uparrow	2.5 times fewer violations
			At-fault crashes 6 months follow-up	\uparrow	2.4 times fewer crashes
			At-fault crashes 12 months follow-up	\uparrow	2 times fewer crashes
			At fault-crashes 18 months follow-up	\uparrow	1.5 times fewer crashes

Author, Year, Country	Measure	Offender group	Indicator	Expected effect on safety	Change indicator
Ma, 2015, Canada	Administrative licence suspension	Drinking and driving offenders	Drinking and driving recidivism occurring within the first 90 days after an initial offence	↗	65% decrease recidivism rate
Fell, 2017, USA	Administrative licence revocation	Drink-drivers	Ratio drinking driver involved fatal crashes, operationalised as: alcohol positive cases (BAC \geq 0.01) (numerator)/alcohol negative cases (BAC = 0.00) (denominator).	↗	13.3% decrease
			Ratio intoxicated drivers in fatal crashes, operationalised as: drivers with a BAC \geq 0.08 (the numerator)/drivers below a BAC < 0.08 (denominator).	↗	1.8% decrease
	Higher length of licence suspension	Drink-drivers	Ratio drink-driver involved fatal crashes, operationalised as: alcohol positive cases (BAC \geq 0.01) (numerator)/alcohol negative cases (BAC = 0.00) (denominator).	↗	4.1% decrease
			Ratio intoxicated drivers in fatal crashes, operationalised as: drivers with a BAC \geq 0.08 (the numerator)/drivers below a BAC < 0.08 (denominator).	↗	0.7% decrease
			General deterrent effect operationalised as: alcohol positive cases (numerator)/alcohol negative cases (denominator) among drivers with no prior DWI convictions.	↗	4.4% decrease
			Specific deterrent effect operationalised as: cases in which alcohol positive drivers with a DWI conviction in the prior 3 years (numerator)/ alcohol negative drivers with a prior DWI conviction in the prior 3 years (denominator)	—	0.2% decrease (Not Significant)

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Education – Pedestrian skills training for children

Teaching children (<12 years) to cross the road

1 Summary

Talbot, R, May 2017



1.1 COLOUR CODE: LIGHT GREEN

There is some evidence, including a meta-analysis, that behaviour based education/training for children in pedestrian skills can improve the skills that children require to cross the road. However, some studies had mixed results and those with follow up results suggested that the benefit of training may reduce over time.

1.2 KEY WORDS

Training; Education; Pedestrian; Children; Child; School

1.3 ABSTRACT

There is some evidence, including a meta-analysis, that behaviour based education/training for children in pedestrian skills can improve the skills that children require to cross the road. However it is not clear how sustained this improvement is over time and the age of the children undertaking training may have an impact on its success. There may also be an increased risk when skills are beginning to be learned until children fully master them. Education/training has been linked to reduced numbers of accidents involving child pedestrians however this has not been studied recently and therefore link between education/training and accidents is unclear for more recent studies.

1.4 BACKGROUND

How is child pedestrian skills education/training defined?

Education and voluntary training is a broad topic area that includes many different methodologies and teaching styles. Child pedestrian education/training is defined here as any educational program/activity or training that aims to teach children pedestrian skills. For the purposes of this document, a child is classed as someone under the age of 12. The primary focus of pedestrian skills is those skills that allow a child to cross a road safely. That could be anything from looking left and right and judging gaps in traffic to encouraging children to enlist the help of an adult to cross the road. The focus here is assessing changes in children's behaviour and whether these are as a result of training/education. The link between behaviour change and road traffic crashes is not clear.

What type of education/training has been studied?

A number of different types of education/training designed for children have been used in the included studies, for example, classroom based teaching, practical activities in the playground, practising crossing the road on a virtual road in a simulator and viewing interactive video.

How are pedestrian skills assessed?

Pedestrian skills are assessed before and following training and the results are compared, preferably with a control that has not received training, to judge whether children's skills have improved because of the training they received. Studies measure pedestrian skills either by collecting self-report (questionnaire) data or conducting some kind of practical test. Practical tests are a more

accurate assessment of behaviour and so the majority of the studies included here were selected because they use a practical assessment either in a real world context or in a simulator.

How many Child pedestrians are killed in road traffic accidents?

In the EU in 2014, 4.1% (229) of the 5,729 pedestrian fatalities (countries included in the CARE statistics) were aged <15 years old (EC, 2016).

What is the relationship between training in pedestrian skills and accidents?

The majority of studies looking at the relationship between training and pedestrian skills only look at behaviour change and do not examine whether there is a link with accidents. No recent studies were found but a meta-analysis looking at the link between pedestrian training and accidents found 5 studies that were published before 1990. The meta-analysis indicated that training can reduce crashes however the link between changed behaviour and accidents is not clear.

1.5 OVERVIEW OF RESULTS

Out of the five studies examining changes in pedestrian skills/behaviour, three, including a meta-analysis (Schwebel et al., 2014; Hotz et al., 2004; Cross et al., 2000), found that education/training improved children's crossing skills although the two that included a follow up assessment found that this improvement was smaller a few months after training. Two studies (Hammond et al., 2005; Schwebel et al., 2016) were less clear with the first only finding an improvement with one element of crossing skills. The other study found that children were quicker to make decisions but these decisions were more risky following training.

Two of the studies (Schwebel et al., 2016; Hotz et al., 2004) did not have a control group which could weaken the findings. The age of the child when receiving training may also be a factor in their ability to learn pedestrian skills. Children are unlikely to have the more advanced cognitive skills to fully master pedestrian tasks such as mid-block crossing before the age of 7/8 and then will take several years to master them.

One meta-analysis study found that training/education reduced the number of child pedestrian injury accidents but all the studies were pre 1990, so it is not clear what effect training/education in pedestrian skills has on accidents today.

More generally, evidence that training/education has a significant impact on real-world behaviour is weak. It is also difficult to compare one education/training study with another as the types of education/training and the study methodologies vary greatly. However the studies examined here suggest that when the focus is on behaviour i.e. practical pedestrian skills, specifically targeted education/training may have some positive effect. The majority of studies identified here were from the UK or USA. This may limit the applicability of findings to other countries.

2 Scientific Overview



2.1 INTRODUCTION

Crossing the road safely involves multiple cognitive-perceptual tasks that require the child to choose an appropriate place to cross, judge the location and speed of oncoming traffic and cross in an appropriate manner (Schwebel et al., 2014). Children develop cognitive skills at different rates and ages however teaching pedestrian skills may be more successful in children of a certain age. For example (Whitebread & Neilson, 2000) found that children had made clear developments in their visual search strategy by ages 7-8 allowing them a greater ability to employ a quick checking strategy before a crossing decision – something that the study found was associated with effective pedestrian skills.

2.2 METHODOLOGY

A systematic literature review was undertaken to identify peer-reviewed journal papers that show a measurable relationship between child-focused education and voluntary training and the acquisition of pedestrian skills. Studies with some element of practical assessment were the primary focus and five of the most recent studies will be discussed here. In addition a meta-analysis examining the effect of road crossing training on injury traffic accidents was identified and the results of this will also be discussed.

The research methodologies used in the studies looking at education/training and crossing behaviour were diverse. One study was a meta-analysis of randomised control trials (Schwebel et al., 2014). Out of the four individual studies, two used technology as training tools - semi-immersive simulation (Schwebel et al., 2016) and interactive video (Hammond et al., 2015) and two used education that could be taught in the classroom (Hotz et al., 2004; Cross et al., 2000). All the studies assessed crossing behaviour at base line and following training and two studies also assessed crossing behaviour several months following training (Hotz et al., 2004; Schwebel et al., 2014). All studies used a practical assessment of pedestrian safety except Cross et al. (2000) who used self-reported pedestrian behaviour. Cross et al. (2000) also conducted a smaller scale observational study to validate results and suggested that there was a moderate correlation (about 0.5) between the self-report responses and the observed behaviour. Schwebel et al. (2014), Hammond et al. (2015) and Cross et al (2000) included a non-intervention control group but (Schwebel et al., 2016) and Hotz (2004) just compared pre and post intervention scores/observations respectively.

Table 1 gives an overview of the methodologies and samples for the six studies discussed here.

Table 1: Overview of study methodologies

Author(s), year, country	Study Methodology	Sample	Analysis method/ Effect measure
Schwebel et al., 2014, various (14 out of the 25 studies were conducted in the UK)	Meta-analysis of randomised controlled trials. Studies were separated according to whether the effect size was calculated using a continuous or dichotomous measure. Both immediate and follow up (several months post training/education) effects were calculated.	Children (aged 3-11) assigned to 2 or more conditions with a non- contact control. Continuous = 10 studies immediate, and 5 studies follow up. Dichotomous = 16 studies immediate, 8 studies follow up.	Random effects meta-analysis. Continuous measure: standardised mean differences. Dichotomous measure: Risk Ratios (RR)
Akhtar and Høye, 2011, USA/UK	Meta-analysis of studies looking at the effect of education in school about crossing of roads on injury accidents with children	Accidents involving child pedestrians aged 6-12 in areas where children received education about crossing of roads	Meta-analysis resulting in best estimate percentage change in injury accidents
Schwebel et al., 2016, USA	Repeated measures/before and after design with training conducted in a virtual reality environment in community. Pedestrian skills assessed in laboratory simulator. No control group.	44 7-8 year olds from 2 schools and a community centre	An Independent mixed effects repeated measures regression model and Regression model using ordinary least squares with subject level clustering. Effect measure: Slope
Hammond et al., 2015, UK	Repeated measures/before and after design with training via an interactive hazard identification video. Pedestrian skills assessed during an on-road 'test'.	2 classes of 6-7 year olds from 1 school. 1 class received training (n=22) and 1 was the control (n=21)	Wilcoxon signed ranks tests
Hotz et al. 2004, USA	Real world observational before and after design. Observations were made before pedestrian skills education, immediately after and 3 months following education. No control group.	Children (5-11) crossing the road at a busy intersection at each of the 4 sampled primary schools.	Logistic regression (safe vs unsafe behaviour) was the main analysis method and Odds ratios were calculated.
Cross et al. 2000, Australia	Repeated measures, longitudinal design. Pedestrian safety education was provided for three years. Assessment by questionnaire was conducted before education and following education for three years.	6-9 year olds from 3 different communities, 1 of which was a control.	Repeated measure ANOVA; F-test.

2.3 ANALYSIS AND RESULTS

Due to the diversity of the assessment methodologies and effect measures used in the included studies, a review analysis was the most appropriate see Table 2 for a summary of results.

The meta-analysis by Schwebel et al.(2014) gives a good overview of studies that focus on behavioural interventions aimed at child pedestrian safety. Their results suggest that that education/training can increase safe crossing behaviour immediately following training and also this increase is also evident, albeit to a lesser extent, several months later. Hotz et al. (2004) in their observational study also found that safe crossing behaviour (looking left-right-left and stopping at the kerb) was increased and unsafe behaviour (unsafe crossing place/darting out) decreased immediately following education but no statistically significant changes in behaviour were observed 3 months following education. Cross et al. (2000) measured low risk behaviour such as walking and crossing the road with an adult. Their self-report results also showed an overall decrease in risky behaviour for their 3 year longitudinal study, despite the tendency for children to take more risks, in terms of not walking with adults, as they get older.

The remaining two studies focusing on pedestrian skills had more mixed results. Schwebel et al. (2016) found that following training, children made quicker decisions but also paid less attention to the traffic before crossing and allowed shorter time gaps between themselves and oncoming traffic. The authors suggest that this indicates that the children were beginning to learn skills (greater confidence and judgement speed) but that the number of sessions provided did not allow these skills to be developed sufficiently. Hammond et al (2005) examined whether training increased children’s pedestrian skills when crossing between parked cars. The training group only showed a significant skill increase when compared to control for checking whether parked cars were about to move for all other skills, both the training and control group had improved suggesting changes were not due to training.

Akhtar and Høye’s (2011) meta-analysis focused on accident reduction rather than pedestrian behaviour. The included studies examined a variety of education methodologies including TV programmes to assess their impact on the numbers of child-involved pedestrian road traffic accidents. However the most recent study included in the meta-analysis was published in 1988 and no other studies examining the link between road crossing skills education/training and crashes were identified in the systematic review. The results of this meta-analysis therefore can only be indicative and cannot be used to draw conclusions about the effect in terms of accident reduction of the behavioural changes reported in the more recent studies.

Table 2: Summary of measures and results

Author(s), Year, Country	Independent / Exposure variable	Dependant / outcome type	Effects on Road Safety	Main outcome - Description
Schwebel et al. 2014, various (14/25 studies UK)	Pedestrian safety training/education	Safe behaviour, continuous measurement – immediate	↑ p=0.001 (small to medium effect size)	Training/education was associated with an improvement in pedestrian safety behaviour immediately following training with a small to medium effect size.
		Safe behaviour, continuous measurement – follow up	↑ p=0.05 (small effect size)	Training/education was associated with an improvement in pedestrian safety behaviour immediately following training with a small effect size.
		Safe behaviour, dichotomous measurement – immediate	↑ RR = 3.44 (95% CI 2.05-5.75) p<0.00001	Training/education in safe pedestrian behaviour increased the likelihood of safe behaviour immediately following training

		Safe behaviour, dichotomous measurement – follow up	↗	RR = 2.88 (95% CI 1.89-4.39) p<0.00001	Training/education in safe pedestrian behaviour increased the likelihood of safe behaviour several months following training
Akhtar and Høye, 2011, USA/UK	Education for children about crossing the road	Injury accidents involving child pedestrians (aged 6-9)	↗	Best estimate percentage change = -11; 95% CI -15 - -7	Training children in road crossing skills appears to result in fewer accidents when crossing the road
		Injury accidents involving child pedestrians (aged 9-12)	↗	Best estimate percentage change = -20; 95% CI -32 - -7	Training children in road crossing skills appears to result in fewer accidents when crossing the road
Schwebel et al., 2016, USA	Virtual environment training - 6 x 15 minute sessions (25 virtual crossings)designed for children	Attention to traffic	✓	Coefficient = -0.06, SE = 0.03; p<0.05	This result implies a greater risk of injury following training
		Start delay	↗	Coefficient = -0.14, SE = 0.03; p<0.01	Training reduced the time it took children to decide to cross the road suggesting more rapid decision-making about the safety of traffic gaps. This indicates an increase in confidence.
		Time to contact	✓	Coefficient = -0.26, SE = 0.11; p<0.05	This result implies a greater risk of injury following training
		Unsafe crossing	—	Coefficient = 2.87, SE = 2.07	No association between training and the number of unsafe crossings was found
Hammond et al., 2015, UK	1 x 20-30 minute session spent playing with the interactive hazard-identification video	Checking parked cars were not about to move –	↗	Training: Z = -3.071; p ≥ 0.05; Control: Z = -3.071; p ≤ 0.05	The training group's assessment score was significantly higher following training for this skill. No difference was observed in the pre and post scores for the control group. These results suggest that training improved children's ability to check whether parked cars were about to move.
		All other pedestrian skills	—	No figures available	Both the training and control group's assessment scores were higher in the post test than they were in the pre-test suggesting the training made no difference to pedestrian skills.
Hotz et al. 2004, USA	Educational program, 'WalkSafe' school-based injury prevention program using a mixture of classroom education, videos and outside activities	Safe behaviour (stop at kerb and/or look left-right-left): immediate	↗	OR = 1.7037; 95% CI 1.093-2.656	Children were more likely to be observed engaging in safe road crossing behaviour following education than before the education took place.
		Safe behaviour (stop at kerb and/or look left-right-left): 3 month follow up	—	OR = 1.46; 95% CI 0.72-1.87	No significant differences were observed at the three month follow up however there were no significant differences between the immediate and 3 month follow up suggesting that the change of behaviour was

					sustained overtime.
		Unsafe behaviour (unsafe crossing place and/or darting out): immediate	↗	OR = 0.6561; 95% CI 0.45-0.9376	Children were less likely to be observed engaging in unsafe road crossing behaviour following education than before the education took place.
		Unsafe behaviour (unsafe crossing place and/or darting out): 3 month follow up	—	OR = 0.81; 95% CI 0.56-1.16	No significant differences were observed at the three month follow up however there were no significant differences between the immediate and 3 month follow up suggesting that the change of behaviour was sustained overtime.
Cross et al., 2000, Australia	Pedestrian safety education: 3 classroom and 3 homework activities per school term for 3 years.	Road crossing behaviour (self-report): walking and crossing roads with adults	↗	P=0.0130	Children who received pedestrian safety education were more likely to walk with adults and receive help crossing roads than the control over the three study years.
		Pedestrian safety knowledge	—	P=0.0840	No statistical differences in pedestrian safety knowledge were observed between the education and control groups across the three study years.

Key: ↗ = measure increases road safety (significant effect); ↘ = measure decreases road safety (significant effect) — = none significant result. Abbreviations: RR = Relative Risk; OR = Odds ratio; CI = confidence interval; SE = standard error

2.4 CONCLUSION

Training/Educating children in pedestrian skills appears to increase skill level to some extent – especially where training is practical behaviour based. However the age of children when receiving training may relate to its success. Schwebel et al.(2014) suggest that there is a need to consider pedestrian safety from the perspective of child development. They concluded that dash out behaviour was successfully reduced with basic intervention strategies but that the skills needed for mid-block crossing are difficult to improve with behavioural interventions. Children need to judge speeds distances and acceleration of vehicles and distance across road and own walking speed. 5-6 year olds from a developmental perspective would find this very difficult even with training – for 7-8 year olds, training may help develop this but a typical child is unlikely to develop the cognitive ability for this type of crossing until 10 or older.

3 Supporting Documents



3.1 DESCRIPTION OF STUDIES

The following paragraphs give an overview of the five papers addressing the effect of training/education on pedestrian skill changes with a summary of the relevant findings.

Schwebel et al. (2014) report on random effects meta-analyses examining the relationship between pedestrian safety education for children and safe pedestrian behaviour. A systematic literature review was undertaken to identify studies and had the following inclusion criteria: randomised trials where children were assigned to two or more conditions, including a no-contact control group, for training in one or more components of pedestrian safety. 25 studies were suitable for the meta-analyses from eight countries (14 from UK) studying children with the age range 3-11. The results were reported separately for behavioural assessments immediately post training and those that occurred several months after training. Studies using a continuous measure were grouped and the effect size was calculated using standardised mean differences, as were those using a dichotomous measure where risk ratios were calculated. Overall the four meta-analyses reported here showed that pedestrian safety behaviour was improved as a result of training. Results were also reported in the paper according to the target behaviour (Mid-block crossing, crossing at junctions, speed judgment, selecting safe routes, crossing at parked cars, preventing dash outs) and by training type (Individual or small group, classroom, computer based or virtual reality, board games or peer group activities, film or video based or multiple strategies).

Schwebel et al. (2016) aimed to test whether training in a semi-immersive virtual pedestrian environment at schools and community centres could increase children's pedestrian skills. Forty four (44) 7-8 year old children from 2 primary schools and 1 youth centre took part in the study. 52% were African-American and 48% Caucasian. 52% were female. There was no control group. A portable semi-immersive virtual reality environment was used to train the children. Children were asked to stand on a simulated curb, 3 feet from the virtual reality monitors. They stepped off the curb when they thought it was safe onto a pressure pad. This triggered a change from immersive view to 3rd person and the child then watched their own crossing. Traffic density and volume were adjusted to be more challenging as the children's skills improved. A cartoon character gave feedback as to whether safe crossing was successful or how to improve if not. The children took part in six training sessions lasting 15 mins which involved 25 virtual crossings. Pedestrian skills were assessed before and after the training in a laboratory based virtual environment. 30 virtual crossings were completed for three different traffic densities (randomised across participants) with all traffic travelling at 30 miles per hour. Four measures were used to assess pedestrian skills: Attention to traffic - looks to left/right while deciding to cross divided by waiting time in seconds (average across trials of each difficulty); Start delay - Time in seconds between safe crossing gap appearing and the child stepping down to enter the road (average across trials of each difficulty); Time to Contact - Shortest time (in seconds) between oncoming vehicle and the child's presence on the road. (average across trials of each difficulty); and Unsafe crossing - number of times when child was hit or within 1 second of being hit by a virtual vehicle (Recorded as percentage of crossings attempted that were unsafe). An Independent mixed effects repeated measures regression model controlling for crossing difficulty, walking speed and gender was used to assess differences in attention to traffic, start delay and time to contact. A regression model using ordinary least squares with subject level clustering was used to assess differences in unsafe crossings. Results showed a statistically significant ($p < 0.05$) reduction in attention to traffic and time to contact which implies that a greater

risk of injury was associated with training. There was also a statistically significant ($p < 0.001$) reduction in start delay indicating more rapid decision making as a result of training. No training effect on unsafe crossings was found. The authors thought that following the training children may have chosen equally safe but tighter gaps rather than waiting for obviously safe gaps. Post hoc analysis of raw time waiting to cross data supports this as it showed that this decreased significantly by nearly a second (0.96s, p -value < 0.001). The authors suggested that the training children received (six 15-minute sessions) may have helped the children to become more confident and efficient pedestrians, but that it was insufficient to achieve full pedestrian safety

Hammond et al. (2015) aimed to assess the effectiveness of an interactive hazard-identification video in teaching children to cross safely between parked cars. Two classes from the same primary school (6-7 year olds) took part. One received training and the other acted as the control. 21 were in the control class, 9 females and 12 males and 22 were in the training class, 14 females and 8 males. All children took part in a pre-training skill assessment. Groups of three were taken (walking) to a quiet road with parked cars. They were asked to lead the assessor across the road. Skills were assessed on a three point scale (good (2 points) satisfactory (1 point) and poor (0 points)). The skills assessed were: stopping at the kerb, checking parked cars are not about to move, stopping at a safe location at the outside edge of cars, looking all around for traffic, crossing sensibly, remaining aware while crossing. Waiting children were not allowed to view previous children crossing. The training class had a 20-30 minutes session playing with video. Video footage showing undesirable on-street crossing behaviour designed to train children in a safer technique for crossing between parked cars. This consisted of an introduction, a tutorial of how to interact with the video, the video itself, a practice section breaking the desired behaviour down into small steps and finally reinforcement - playing the whole of the safe crossing sequence. The skills assessment test was then repeated for all children the day after training. Wilcoxon signed ranks tests were used to assess whether test scores had changed for each skill element. The only difference found between the training and control group was for "Checking the parked cars were not about to move" where the difference in test score pre and post intervention was statistically significant for the training group ($Z = -3.071$, $p \leq 0.05$) but not for the control ($Z = -1.732$, p -value ≥ 0.05). For all other skill scores, both training and control groups showed an improvement in the second test (no statistics provided). The authors suggest that this could have been due to unintended learning of the children en route to the test site as two busy roads had to be crossed to get to it.

The aim of Hotz et al. (2004) was to evaluate the effectiveness of the child pedestrian education program WalkSafe. WalkSafe is a US school-based injury prevention program that uses a mixture of classroom education, videos and outside simulation activities (road drawn on school playground) to teach children about pedestrian safety. This is delivered by the children's class teachers during one half an hour session per day for a week (2.5 hours in total). Sixteen schools took part in the study and four of these were randomly selected to be sites for pedestrian behaviour observations. Observations took place via a static video camera at a busy intersection at each of the four schools. Children's pedestrian behaviour was observed for a 20 minute period at the same time of day, day of the week and traffic conditions. Observations took place pre-intervention, post intervention and 3 months following intervention. The video was then analysed and for each crossing event the presence / absence of safe crossing behaviour was recorded. Safe behaviour was recorded if the child stopped at kerb and/or looked left-right-left before crossing. Unsafe behaviour was recorded if the child crossed mid-street crossing (not at safe place) and/or stepped into the road without stopping or looking (darted out). Logistic regression (desired behaviour versus undesired behaviour) was used to analyse these results and Odds Ratios (OR) were calculated. When pre-intervention observations were compared to post - intervention observations, children's safe behaviour had increased (OR=1.7037, 95% Confidence Intervals [CI]=(1.0930-2.6560)) and unsafe behaviour had reduced (OR=0.6561, 95%CI= (0.45-0.9376)). No significant differences were found between post intervention and 3 months post intervention observations suggesting learning was sustained

overtime. The difference between the pre-intervention and 3 month post interventions observations suggested a benefit from the education however these findings were not statistically significant. Knowledge tests scores and the differences between them for pre, post and 3 months post intervention were also reported in the paper but are not recorded here.

Cross et al. (2000) aimed to evaluate a pedestrian safety intervention for primary school children. Participants were recruited from three different communities in Perth, Western Australia. 1 community received 'high' intervention (school and home based pedestrian safety as well as community and environmental intervention); while the second received 'moderate' intervention (school and home based pedestrian safety only). The third acted as a control and received a nutritional education programme and standard Western Australia health education that includes road-safety related activities. For each study year, 3 classroom and 3 home activities were delivered at the beginning of each of the 3 school terms (9 classroom and 9 home activities per year). Knowledge and behaviour questionnaires were administered at baseline (May 1995) and as a post-test measure in November for three years (1995-97). A random subsample was also selected for unobtrusive observations of crossing behaviour of children who walked to school and where parental permission for observations was granted. The observations were used to validate the self-reported behaviour. 80 children were observed during their walk to school and then interviewed when they got to the classroom (asked whether they walked with an adult and whether an adult helped them cross the road). The correlation for observed and interview data for walking with an adult and being helped to cross the road by an adult were 0.83 and 0.8 respectively. The correlation for observed and self-reported questionnaire data for walking with an adult and being helped to cross the road by an adult were 0.5 and 0.52 respectively (moderate correlation). Results for Pedestrian safety knowledge and self-reported crossing behaviour were pooled for high and moderate communities as no statistical difference between their scores were found. Time by group interactions were analysed using a repeated measures ANOVA and statistical significance was tested using an F test. Children in the intervention groups were significantly more likely to cross the road with adult supervision (p -value = 0.013) than the comparison group. No differences were detected in children's pedestrian safety knowledge between the intervention and comparison groups

3.2 LITERATURE SEARCH

A systematic literature search was undertaken to identify papers that examined the effectiveness of education and/or training in improving road safety. The initial search was general and was then refined to focus on education/training that focused on teaching children (<12 years old) pedestrian skills. This section describes the search terms, screening and eligibility selection processes that were used to identify relevant papers.

The following criteria were applied to a key word search in the database Scopus. See

Table 3 for full results:

- Search field: TITLE-ABS-KEY
- published: year > 2000
- Document Type: "Review" and "Article"
- Source Type "Journal"
- Language: "English"

Table 3: Scopus search terms and results

Database: Scopus

Date: 7 Dec 2016

search no.	search terms / operators / combined queries	hits
#1	"Education" OR "Training"	891777
#2	"road safety" OR "traffic safety" OR "driv*" OR "road" OR "transport" OR "traffic" OR "Pedestrian" OR "Rider"	1381363
#3	"collision*" OR "crash*" OR "accident*" OR "incident*" OR "casualt*" OR "fatalit*" OR "injur*"	1023558
#4	#1 and #2 and #3	5274

Due to the large number of search results, the search was limited to papers originating in the following countries: Europe, Israel, North America, Australia, New Zealand and Japan and excluded those in the subject areas: health professions, nursing, biochemistry, genetics and molecular biology and chemical engineering. This reduced the number of papers to be screened to **3327**.

Screening

A screening process then took place where titles and if necessary abstracts were quickly assessed to eliminate papers that were not relevant (Table 4). During this process, the relevant Education and Voluntary Training subtopic(s) that the paper related to was identified.

Table 4: Title and abstract screening for relevance

Total number of studies to screen title/ abstract – 1 st screening	3327
-De-duplication	15
-Exclusion: not relevant (not focusing on Education/training in relation to road safety)	3159
Remaining studies to obtain full texts	168

Eligibility

The final stage was to identify the papers for which a full text could be obtained based on paper availability and which of these were eligible to be included in the SafetyCube Decision Support System (DSS) for the topic Education and Voluntary training in pedestrian skills for children. (Table 5).

Table 5: Eligible papers

Total number of studies to screen full-text for subtopics 'children' and 'Pedestrian'	20
Full-text could be obtained	19
Additional relevant studies identified from reference lists/other sources	1
Exclude: included in meta-analysis	6
Exclude: not relevant	2

Exclude: not suitable for inclusion in DSS	1
Total number of eligible papers	11

Prioritisation

Once the full papers had been evaluated as eligible, they were assessed as to their suitability to be included in this synopsis based on the following prioritisation criteria:

- Prioritising Step A: Meta-analysis;
 - Prioritising Step B: Studies assessing behaviour change via a practical test;
 - Prioritising Step C: Studies assessing behaviour change via self-reported behaviour ;
- For each prioritisation step, the most recent papers were coded first.

Exclusion decisions

The full list of 11 eligible papers and the reasons why they were coded or not are shown in Table 6.

Table 6: Inclusion decisions

No.	Publication	Coded Y/N	Reason
1.	Schwebel, D. C., Barton, B. K., Shen, J., Wells, H. L., Bogar, A., Heath, G., & McCullough, D. (2014). Systematic review and meta-analysis of behavioral interventions to improve child pedestrian safety. <i>Journal of Pediatric Psychology</i> , 39(8), 826–845. article. http://doi.org/10.1093/jpepsy/jsu024	Y	Prioritising Step A
2.	Schwebel, D. C., Combs, T., Rodriguez, D., Severson, J., & Sisiopiku, V. (2016). Community-based pedestrian safety training in virtual reality: A pragmatic trial. <i>Accident Analysis and Prevention</i> , 86, 9–15. article. http://doi.org/10.1016/j.aap.2015.10.002	Y	Prioritising Step B
3.	Schwebel, D. C., Shen, J., & McClure, L. A. (2016). How do children learn to cross the street? The process of pedestrian safety training. <i>Traffic Injury Prevention</i> , 17(6), 573–579. article. http://doi.org/10.1080/15389588.2015.1125478	N	Unclear how results differed from paper included in meta-analysis
4.	Hammond, J., Cherrett, T., & Waterson, B. (2015). Making in-class skills training more effective: The scope for interactive videos to complement the delivery of practical pedestrian training. <i>British Journal of Educational Technology</i> , 46(6). http://doi.org/10.1111/bjet.12205	Y	Prioritising Step B
5.	Livingston, D. H., Suber, I., Snyder, D., Clancy, S. F., Passannante, M. R., & Lavery, R. F. (2011). Annual pediatric pedestrian education does not improve pedestrian behavior. <i>Journal of Trauma - Injury, Infection and Critical Care</i> , 71(5), 1120–1124. article. http://doi.org/10.1097/TA.0b013e31822dd03c	N	Knowledge only
6.	Hotz, G., de Marcilla, A. G., Lutfi, K., Kennedy, A., Castellon, P., & Duncan, R. (2009). The WalkSafe Program: developing and evaluating the educational component. <i>The Journal of Trauma</i> , 66(3 Suppl). article. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-65249111053&partnerID=40&md5=70a2d620acaec814fa135eb7f7448728	Y	Prioritising Step B
7.	Hotz, G. A.,c, Cohn, S. M. , Castelblanco, A. , Colston, S. , Thomas, M. , Weiss, A. , ... Duncan, R. (2004). WalkSafe: A school-based pedestrian safety intervention program. <i>Traffic Injury Prevention</i> , 5(4), 382–389. article.	N	Knowledge only

	http://doi.org/10.1080/15389580490510507		
8.	Zeedyk, M. S. , & Wallace, L. (2003). Tackling children's road safety through education: An evaluation of effectiveness. <i>Health Education Research</i> , 18(4), 493–505. article. http://doi.org/10.1093/her/cyfo33	N	Knowledge only
9.	Luria, J. W.,c, Smith, G. A. , & Chapman, J. I. (2000). An evaluation of a safety education program for kindergarten and elementary school children. <i>Archives of Pediatrics and Adolescent Medicine</i> , 154(3), 227–231. article. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-0034008059&partnerID=40&md5=4359d39b344d351f50540fa765576771	N	Knowledge only
10.	Cross, D. , Stevenson, M. , Hall, M. , Burns, S. , Laughlin, D. , Officer, J. , & Howat, P. (2000). Child pedestrian injury prevention project: Student results. <i>Preventive Medicine</i> , 30(3), 179–187. article. http://doi.org/10.1006/pmed.1999.0622	Y	Prioritising Step C
11.	Akhtar, J. and Høye, A. (2011), USA/UK Education in schools The Handbook of Road Safety Measures, Norwegian (online) version, accessed April 2017 at http://tsh.toi.no/index.html?22935	Y	Prioritising Step A

3.3 REFERENCES

Coded studies

Akhtar, J and Høye, A (2011), USA/UK Education in schools The Handbook of Road Safety Measures, Norwegian (online) version, accessed April 2017 at <http://tsh.toi.no/index.html?22935>

Cross, D., Stevenson, M., Hall, M., Burns, S., Laughlin, D., Officer, J., & Howat, P. (2000). Child pedestrian injury prevention project: Student results. *Preventive Medicine*, 30(3), 179–187. article. <http://doi.org/10.1006/pmed.1999.0622>

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Schwebel, D. C., Barton, B. K., Shen, J., Wells, H. L., Bogar, A., Heath, G., & McCullough, D. (2014). Systematic review and meta-analysis of behavioral interventions to improve child pedestrian safety. *Journal of Pediatric Psychology*, 39(8), 826–845. article. <http://doi.org/10.1093/jpepsy/jsuo24>

Schwebel, D. C., Shen, J., & McClure, L. A. (2016). How do children learn to cross the street? The process of pedestrian safety training. *Traffic Injury Prevention*, 17(6), 573–579. article. <http://doi.org/10.1080/15389588.2015.1125478>

Additional references

European Commission (2016) Annual Accident Report 2016. Accessed at:

http://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/statistics/dacota/asr2016.pdf on 17th May 2017

Whitebread, D. , b, & Neilson, K. (2000). The contribution of visual search strategies to the development of pedestrian skills by 4-11 year-old children. *British Journal of Educational Psychology*, 70(4), 539–557. article. Retrieved from <https://www.scopus.com/inward/record.uri?eid=2-s2.0-0041684420&partnerID=40&md5=3506e9d64362c5679eb2a7e4642e01do>

Education – non-statutory training for novice drivers

Training/education for novice (inexperienced) or young (<25 years) drivers



Talbot, R. June 2017

1 Summary

1.1 COLOUR CODE:

Grey: The 5 selected studies report a mixture of significant and none significant results and differences in methodologies prevent the comparison of results. There was not enough evidence in the selected studies to establish a link between education and voluntary training aimed at novice drivers and skills improvement or risky behaviour reduction.

1.2 KEY WORDS

Novice; young; driver; education; training; risk taking; speeding; alcohol

1.3 ABSTRACT

The crash risk of young (aged <25 years old) and novice drivers is greater than that of the general driving population. Five studies focusing on education and voluntary training for young/novice drivers were examined. Their focus was on skills improvement (cognitive and vehicle handling) and on reducing risky behaviour such as speeding and driving under the influence of alcohol. Training was a mixture of on road and simulator training as well as classroom based training. Skills/behaviour/attitudes were assessed using on-road or simulated driving tests or questionnaires. Not all results were compared with an independent control group and self-assessed behaviour/attitudes may not represent actual behaviour. Results showed a mixture of significant and non-significant findings for both driving skills and reducing risky behaviour. There was insufficient evidence to establish a link between the education/training reported here and improved skills and reduced risky behaviour.

1.4 BACKGROUND

How is novice education/training defined?

The term 'novice driver's as used here refers to those who have limited driving experience either because have not obtained their full driving licence or because they have held a licence for only a short period of time (approximately 3 years or fewer). This group of drivers are often also 'young' drivers (<25 years old); therefore coded studies include either young and/or novice drivers. Voluntary training for this group includes any type of training that is aimed at novice drivers and is neither part of formal pre-licence training nor part of a Graduated Licencing (GDL) program.

What type of education/training has been studied?

Training for novice drivers focuses on skills acquisition, such as vehicle handling, on decision making while driving or on risk mitigation. Risk mitigation tends to focus on reducing speeding or driving under the influence. A variety of methodologies are used, from classroom based teaching and discussions to on-road or simulated driver training and performance feedback.

How are improvements in road safety assessed?

Driving skills are most often assessed by a practical assessment either in a driving simulator or during an on-road test. It is ethically difficult to assess risky behaviour such as speeding or driving under the influence by on-road tests, so changes to these are usually assessed via simulator or self-report methods such as questionnaires.

How many novice/young drivers are killed in road traffic accidents?

In Europe, road traffic crashes are the most common single cause of death for 15-24 year olds. Drivers between the ages of 16-24 are over-represented by 2-3 times in crash and fatality statistics and such crashes are associated with greater numbers of fatalities of other road users than crashes involving more experienced drivers (DaCoTA, 2012).

What is the relationship between training for novice/young drivers and accidents?

The majority of studies looking at the relationship between training and driver skills/risky behaviour only examine behaviour change and do not investigate whether there is a link with accidents. Improving driver skills is likely to lead to fewer mistakes and therefore crashes, but the studies examined did not provide evidence for this. However the increased risk of crashes resulting from driving at increased speed and driving under the influence of alcohol is well documented.

1.5 OVERVIEW OF RESULTS

The studies included here focus on skills training and reducing risk taking behaviour such as speeding and driving under the influence of alcohol. The results were mixed and there was not sufficient evidence to conclude that education and voluntary training increases novice driver skills and reduces the likelihood that they engage in risk taking behaviour.

This topic has an overlap with driver licencing and training and to some extent campaigns. The topic novice driver training is much more widely researched in relation to formal pre-licence training and graduated driving licence programmes and so should be read alongside the document(s) dealing with these subjects.

2 Scientific overview

2.1 INTRODUCTION

The five studies included here evaluate a wide variety of different education/ training types. These range from classroom-based to on-road and simulated driving. The majority focus on reducing risky behaviour such as speeding or driving under the influence of alcohol or drugs (Ker et al., 2005; Brijs et al., 2014, Prabhakaran and Molesworth, 2011; Molia et al., 2007), while one study focuses on improving driver performance (Isler et al., 2011).

2.2 METHODOLOGY

Ker et al. (2005) applied a meta-analysis methodology to investigate the crash risk of drivers who had attended remedial educational courses; therefore all the studies included in the meta-analysis had participants who had committed a driving offence, such as speeding or driving under the influence of alcohol. Although these participants were not necessarily young, they were included in the investigation as novice driver training often focuses on the reduction of such risky behaviour.

The individual studies assess the effect of the education/ training in a number of different ways. Prabhakaran and Molesworth (2011) used a simulated driving task to measure the number of times and duration that participants drove over the speed limit and Isler et al (2011) used an on-road assessment to assess driving skills. In contrast Brijs et al (2014) and Molia et al. (2007) both used questionnaires to record self-reported behaviour with regards to speeding and drink driving and risk taking and driving habits respectively.

Table 1 gives an overview of each of the study's methodology.

Table 1: Overview of study methodologies

Author(s), year, country	Study Methodology	Sample	Analysis method/ Effect measure
Ker et al. (2005), USA	Meta-analysis of randomised controlled trials examining the effect of remedial education and advanced driver education on road traffic crashes	Valid driving licence holders including motorcyclists of all ages and driving experience. Remedial education = 13 studies; advanced driver education = 2 studies	Random effects meta-analysis/ Relative risk
Brijs et al. (2014), Belgium	Quasi-experimental study evaluating an education program aiming to reduce risky driving behaviour. Evaluation via questionnaire (self-reported behaviour)	Young (<25 years old) drivers: 150 filled in pre-training questionnaire, 216 filled in post training questionnaire and 104 filled in questionnaire 2 months post training (no control group)	Multivariate/univariate ANCOVA; Cohen's d

Author(s), year, country	Study Methodology	Sample	Analysis method/ Effect measure
Prabhakaran and Molesworth (2011), Australia	Experiment assessing the effect of a variety of training tasks on speeding and rule violations, including a control. Assessment via simulated driving task.	58 young drivers (16-24 years)	Bonferroni adjusted planned comparisons
Isler et al. (2011), New Zealand	Experimental study assessing whether training in higher order driving or vehicle handling skills improves on road driving performance and hazard perception. Assessment via on road test and providing commentary to video based hazard perception test.	35 young (aged 15-18) drivers with a restricted licence or within 2 months of gaining a full licence. Higher order skills group = 11, vehicle handling skills group = 12, control = 12.	Wilcoxon signed rank and repeated measures ANOVA
Molina et al. (2007), Spain	Quasi- experimental study examining the effect of the RACC training program (track experience, on road driving with feedback and group discussion) on self-reported behaviour and attitudes via questionnaire	Novice drivers (18-24 years) with 3 years or fewer driving experience. 124 in training group, 114 in control group.	Univariate ANOVA and ANCOVA (when ANOVA = statistically significant)

2.3 ANALYSIS AND RESULTS

The differences in the educational/ training focused upon and the methodologies used to assess effectiveness make it very hard to draw comparisons between the five studies focused upon here. Also results were mixed with all studies reporting a mixture of significant and insignificant results. **Table 2** gives a full summary of results.

Ker et al.'s (2005) meta-analysis did not identify any significant relationship between remedial education and road traffic crashes. Isler et al. (2011) found that training in higher order driving skills and vehicle handling significantly increased on road driving performance between baseline and post-test but this was not compared with the none intervention control. No significant improvements in hazard perception were found when the two training groups were compared with the control. Molia et al. (2007) found that self-reported 'skills for careful driving' improved following training (track, on road and group discussion) but that self-reported careless driving habits and showing off and situational reactions did not.

For speeding behaviour, Prabhakaran and Molesworth (2011) found that simulator based driving training reduced speeding behaviour but just reading accounts of road traffic crashes as a result of speeding with or without reference to the legal consequences did not. Brijs et al. (2014) found that a mixture of classroom, test track and on-road driving reduced self-reported speeding; however the effect did not last and was not identified during the follow-up two months after the training. Finally, Molia et al.'s (2007) results for self-reported 'driving habits – high speed' were not significant.

For driving under the influence, Molia et al (2007) reported that they found no significant differences in self-reported 'driving habits – improper state'. In addition Brijs et al. (2014) reported that self-

reported drink driving significantly increased immediately following training although this result was non-significant two months later.

Table 2: Summary of measures and results

Author(s), Year, Country	Independent / Exposure variable	Dependant / outcome type	Effects on Road Safety	Main outcome - Description
Ker et al (2005), USA	Remedial education	Crash in 12-24 month follow up period	— RR = 0.98, 95% CI = 0.96-1.01	No effect of remedial education on road traffic crashes was found.
	Advanced driver education (post licence)		— RR = 0.99, 95% CI = 0.93-1.05	No effect of remedial education on road traffic crashes was found.
Brijs et al. (2014), Belgium	Training course: classroom, test track, road driving and group discussion (3.5 hours)	Self-reported: Speeding, immediate	↗ F(11,350) = 2.63, p=0.0030	Responses following training were more positive in relation to road safety than before training.
		Self-reported: Speeding, 2 month follow up	— F(11,60) = 1.29, p=0.26	No differences were observed between questionnaire responses pre and post training
		Self-reported: Drink driving, immediate	✓ F(9,352) = 2.40, p=0.012	Young drivers who had received training showed less safe attitude/behaviour in relation drinking and driving (self-report)
		Self-reported: Drink driving, 2 month follow up	— F(9,610)=0.90, p=0.53	No differences were observed between questionnaire responses pre and post training
		Risk detection (identification of risk in pictures) – immediate	— F(1,364) = 1.02, p=0.31	No differences were observed between questionnaire responses pre and post training
		Risk detection (identification of risk in pictures) – 2 month follow up	— F(1,71)=0.18, p=0.67	No differences were observed between questionnaire responses pre and post training
Prabhakaran and Molesworth (2011), Australia	Reading three accounts of road traffic crashes	Percentage of 21km drive spent speeding	— F(1,54)=0.02 0.89	No significant effect of training on % of drive spent speeding
		Frequency of zone violations	— F(1,54)=0.40 0.53	No significant effect of training on frequency of zone violations
	Reading three accounts of road traffic crashes, associated road rule violations and legal consequences	Percentage of 21km drive spent speeding	— F=(1,54)=0.20 0.66	No significant effect of training on % of drive spent speeding
		Frequency of zone violations	— F(1,54)=0.07 0.8	No significant effect of training on frequency of zone violations
	Simulator based driving session with personalised	Percentage of 21km drive spent speeding	↗ F(1,54)=8.68 0.01	Simulator training significantly reduced the percentage of drive spent speeding

	feedback with regards to speeding and legal implications	Frequency of zone violations	↗	F(1,54)=10.77 0	Simulator training significantly reduced the number of zone violations
Isler et al. (2011), New Zealand	Training in higher order driving skills (situational awareness, visual search, hazard anticipation)	On road driving assessment score (pre test vs. post test)	↗	z=-2.046, p <0.05	Higher order driving skills training significantly improved on road driving performance
	Vehicle handling training		↗	z=-2.708, p <0.01	Vehicle handling skills training significantly improved on road driving performance
	Control		—	No figures reported	No significant difference between driving test scores
	Higher order or vehicle handling training	Percentage of hazards detected	—	F(2,32)=1.13, p>0.5	No significant differences in % of hazards detected for the higher order skills or vehicle handling training groups when compared with the control
		Percentage of actions in response to hazards	—	F(2,32)=1.20, p>0.31	No significant differences in % of actions in response to hazards for the higher order skills or vehicle handling training groups when compared with the control
Molina et al. (2007), Spain	Training: track, on road and group discussion	Internal risks – careless driving habits (self-report)	—	F(1227)=0.27, P=0.6	Compared with the control, training had no effect on score for careless driving
		Internal risks – showing off and situational reactions (self-report)	—	F(1229)=0.64, P=0.42	Compared with the control, training had no effect on score for showing of and situational awareness
		Skills for careful driving (self-report)	↗	F(1.228)=5.07, P=0.025	Training significantly improved the score for careful driving
		Driving habits – improper state (self-report)	—	F(1227)=2.27, P=0.13	Compared with the control, training had no effect on score for driving in an improper state
		Driving habits – high speed (self-report)	—	F(1227)=0.13, P=0.71	Compared with the control, training had no effect on score for driving at high speed

Key: ↗ = measure increases road safety (significant effect); ↘ = measure reduces road safety (significant effect); — = none significant result

2.4 CONCLUSION

The mixture of significant improvements, one significant reduction in desired behaviour and non-significant results along with the variety of education/training and assessment methodologies makes it challenging to draw clear conclusions. In addition, not all results were compared directly

with a non-intervention control and self-reported intended behaviour is not necessarily indicative of actual behaviour.

The studies reported here do not provide sufficient evidence that education/training improves road safety for novice/young drivers either in terms of driving skills or reduction in risky behaviour.

3 Supporting Document

3.1 DESCRIPTION OF STUDIES

In the following paragraphs, an overview of each coded study is provided along with a summary of the relevant findings.

3.2 LITERATURE SEARCH

A systematic literature search was undertaken to identify studies that examined the effectiveness of education and/ or training in improving road safety. The initial search was general and was then refined to focus on education/training that focused on novice drivers. This section describes the search terms, screening and eligibility selection processes that were used to identify relevant papers.

The following criteria were applied to a key word search in the database Scopus. See **Table 3** for full results.:

- Search field: TITLE-ABS-KEY
- published: year > 2000
- Document Type: "Review" and "Article"
- Source Type "Journal"
- Language: "English"

Table 3: Scopus search terms and results

search no.	search terms / operators / combined queries	hits
#1	"Education" OR "Training"	891,777
#2	"road safety" OR "traffic safety" OR "driv*" OR "road" OR "transport" OR "traffic" OR "Pedestrian" OR "Rider"	1,381,363
#3	"collision*" OR "crash*" OR "accident*" OR "incident*" OR "casualt*" OR "fatalit*" OR "injur*"	1,023,558
#4	#1 and #2 and #3	5,274

Due to the large number of search results, the search was limited to papers originating in the following countries: Europe, Israel, North America, Australia, New Zealand and Japan and excluded those in the subject areas: health professions, nursing, biochemistry, genetics and molecular biology and chemical engineering. This reduced the number of papers to be screened to **3,327**.

Screening

A screening process then took place where titles and if necessary abstracts were quickly assessed to eliminate papers that were not relevant (**Table 4**). During this process, the relevant Education and Voluntary Training subtopic(s) that the paper related to was identified.

Table 4: Title and abstract screening for relevance

Total number of studies to screen title/ abstract – 1 st screening	3,327
- De-duplication	15
- Exclusion: not relevant (not focusing on Education/training in relation to road safety)	3,159
Remaining studies to obtain full texts	168

Eligibility

The final stage was to identify the papers for which a full text could be obtained based on paper availability and which of these were eligible to be included in the SafetyCube Decision Support System (DSS) for the topic education or voluntary training for novice drivers. (Table 5).

Table 5: Eligible papers

Total number of studies to screen full-text for subtopics 'Novice' and 'Driver'	29
Full-text could be obtained	6
Additional relevant studies identified from reference lists/other sources	3
Exclude: included in meta-analysis	0
Exclude: not relevant	9
Exclude: not suitable for inclusion in DSS	8
Total number of eligible papers	9

Prioritisation

Once the full papers had been evaluated as eligible, they were assessed as to their suitability to be included in this synopsis based on the following prioritisation criteria:

- Prioritizing Step A: Meta-analysis;
- Prioritizing Step B: Studies assessing behaviour change via a practical test;
- Prioritizing Step C: Studies assessing behaviour change via self-reported behaviour ;
- Prioritizing Step D: Studies assessing knowledge change

For this synopsis, Step D papers were excluded.

Exclusion decisions

The full list of 9 eligible papers and the reasons why they were coded or not are shown in Table 6.

Table 6: Inclusion decisions

No.	Publication	Coded Y/N	Reason
1.	Ker, K., Roberts, I., Collier, T., Beyer, F., Bunn, F., & Frost, C. (2005). Post-	Y	Prioritisation step A

	licence driver education for the prevention of road traffic crashes: a systematic review of randomised controlled trials. <i>Accident; Analysis and Prevention</i> , 37(2), 305–313. Journal Article. http://doi.org/10.1016/j.aap.2004.09.004		
2.	Rosenbloom, T., & Eldror, E. (2014). Effectiveness evaluation of simulative workshops for newly licensed drivers. <i>Accident Analysis and Prevention</i> , 63, 30–36. article. http://doi.org/10.1016/j.aap.2013.09.018	N	Included in DSS under Formal Pre-licencing training
3.	Brijs, K., Cuenen, A., Brijs, T., Ruiter, R. A. C., & Wets, G. (2014). Evaluating the effectiveness of a post-license education program for young novice drivers in Belgium. <i>Accident Analysis and Prevention</i> , 66, 62–71. article. http://doi.org/10.1016/j.aap.2014.01.015	Y	Prioritisation step C
4.	Petzoldt, T., Weiß, T., Franke, T., Krems, J. F. F., & Bannert, M. (2013). Can driver education be improved by computer based training of cognitive skills? <i>Accident Analysis and Prevention</i> , 50, 1185–1192. article. http://doi.org/10.1016/j.aap.2012.09.016	N	Included in DSS under Formal Pre-licencing training / Hazard Perception
5.	Prabhakaran, P., & Molesworth, B. R. C. (2011). Repairing faulty scripts to reduce speeding behaviour in young drivers. <i>Accident Analysis and Prevention</i> , 43(5), 1696–1702. article. http://doi.org/10.1016/j.aap.2011.03.028	Y	Prioritisation step B
6.	Isler, R. B. B., Starkey, N. J. J., & Sheppard, P. (2011). Effects of higher-order driving skill training on young, inexperienced drivers' on-road driving performance. <i>Accident Analysis and Prevention</i> , 43(5), 1818–1827. article. http://doi.org/10.1016/j.aap.2011.04.017	Y	Prioritisation step B
7.	Molina, J. G., Sanmartín, J., & Keskinen, E. (2013). Driver training interests of a Spanish sample of young drivers and its relationship with their self-assessment skills concerning risky driving behavior. <i>Accident Analysis and Prevention</i> , 52, 118–124. article. http://doi.org/10.1016/j.aap.2012.12.035	Y	Prioritisation step C
8.	Toledo, T., Lotan, T., Taubman-Ben-Ari, O., & Grimberg, E. (2012). Evaluation of a program to enhance young drivers' safety in Israel. <i>Accident Analysis and Prevention</i> , 45, 705–710. article. http://doi.org/10.1016/j.aap.2011.09.041	N	Excluded as part of Graduate driving programme
9.	Peek-Asa, C., Cavanaugh, J. E., Yang, J., Chande, V., Young, T., & Ramirez, M. (2014). Steering teens safe: A randomized trial of a parent-based intervention to improve safe teen driving. <i>BMC Public Health</i> , 14(1). article. http://doi.org/10.1186/1471-2458-14-777	N	Education aimed at parents not the drivers themselves

3.3 REFERENCES

Coded studies

Brijs, K., Cuenen, A., Brijs, T., Ruiter, R. A. C., & Wets, G. (2014). Evaluating the effectiveness of a post-license education program for young novice drivers in Belgium. *Accident Analysis and Prevention*, 66, 62–71. article. <http://doi.org/10.1016/j.aap.2014.01.015>

Isler, R. B. B., Starkey, N. J. J., & Sheppard, P. (2011). Effects of higher-order driving skill training on young, inexperienced drivers' on-road driving performance. *Accident Analysis and Prevention*, 43(5), 1818–1827. article. <http://doi.org/10.1016/j.aap.2011.04.017>

Ker, K., Roberts, I., Collier, T., Beyer, F., Bunn, F., & Frost, C. (2005). Post-licence driver education for the prevention of road traffic crashes: a systematic review of randomised controlled trials.

Accident; Analysis and Prevention, 37(2), 305–313. Journal Article.
<http://doi.org/10.1016/j.aap.2004.09.004>


Molina, J. G., Sanmartín, J., & Keskinen, E. (2013). Driver training interests of a Spanish sample of young drivers and its relationship with their self-assessment skills concerning risky driving behavior. *Accident Analysis and Prevention*, 52, 118–124. article.
<http://doi.org/10.1016/j.aap.2012.12.035>

Prabhakaran, P., & Molesworth, B. R. C. (2011). Repairing faulty scripts to reduce speeding behaviour in young drivers. *Accident Analysis and Prevention*, 43(5), 1696–1702. article.
<http://doi.org/10.1016/j.aap.2011.03.028>

Additional references

DaCoTA (2012) Novice Drivers, Deliverable 4.8j of the EC FP7 project DaCoTA. Available at: https://ec.europa.eu/transport/road_safety/specialist/knowledge/young_en, accessed 27 June 2017.

Driver training and Licensing: formal pre-license training, graduated driver licensing and probation



Marion Hay, Virginie Etienne, Laurence Paire-Ficout, May 2017

1 Summary

1.1 COLOUR CODE:

Light green: Graduated driver licensing (GDL) seems to be effective in improving road safety for 16 and 17 year old drivers but the results are more inconsistent for those aged 18 to 20 years. In the majority of the coded studies, the implementation of a strict GDL results in a reduction of the crash rate (overall, fatal, or injury-related). However, in a few studies, the effect is not significant, and sometimes is the opposite. Regarding the formal pre-license training, where only a few number of studies have been coded, it seems that completing a mandatory specific training or a computer-based training improved road safety and simulated driving performances. However, it has also been shown that an intensive driving course and time-discount were detrimental for novice drivers' road safety.

1.2 KEYWORDS

Graduated driver licensing; GDL; decal; novice drivers; learner drivers; formal pre-license training; night-time driving restriction; passenger restriction; road safety; simulator-based driver training.

1.3 ABSTRACT

Young drivers are disproportionately represented in motor vehicle collisions. Graduated driver licensing (GDL) programs and probationary licenses were progressively introduced in several countries worldwide since the early 1970s in order to reduce fatal crashes and high-risk behaviours in teen drivers. The 34 reviewed studies focused on the effect of the GDL and formal pre-license training (FPLT) on learner and novice drivers' road safety (four meta-analyses and thirty original papers). Before-after studies or time series analyses (21), cohort studies (4), longitudinal or observational studies (2), and quasi-experimental or experimental studies (3) were used to investigate the effect of GDL and FPLT on crash rate (overall, fatal, leading to severe injury, occurring during the night, or in presence of passengers) and traffic violations. Most of the studies were conducted on car drivers from the United States ($n = 21$). The results tend to indicate that GDL and FPLT have a global positive effect on road safety, but some inconsistent results were noted regarding drivers aged 18 and above. More specifically, GDL and FPLT appear to reduce crash rates and, to a small extent, improve driving behaviour. However, these effects are sometimes reversed for older drivers (>18 years).

1.4 BACKGROUND

1.4.1 Definitions

Most formal pre-license training (FPLT) focuses on procedural skills relating to vehicle control. They cover many formats, including professional driving instruction and school-based driver education etc. The graduated driver licensing (GDL) is a licensing system designed to provide learners with driving experience and skills, gradually over time, in low-risk environments. The GDL system involves different steps (usually 3) through which new drivers pass. They begin by acquiring a learner's permit which is related to the FPLT they received and then progress to a restricted, provisional or probationary license, followed by receipt of a full driver's license. The GDL generally restricts night-time driving, carrying passengers, expressway, and unsupervised driving during initial stages. It gradually lifts these restrictions with time and/or with testing, eventually concluding with a full driver's license. The GDL is a risk management system which allows novice drivers to gain experience by progressively facing riskier driving situations (see Shope & Molnar, 2003; Simpson, 2003; Williams, McCartt, & Sims, 2016 for reviews).

1.4.2 Measures of effect

The effect of GDL on road safety is usually measured as a change in crash rate, crash involvement, or crash incidence before and after the GDL implementation. Regarding the effect of FPLT, it can be measured as a difference in driving performance between drivers who did not complete the same training.

1.4.3 Study methods

The effect of the GDL is usually investigated using police-reported or self-reported crash data. Several types of crashes are considered: fatal crashes, injury crashes, crashes occurring during the night or those involving passengers. The effect of the FPLT can be investigated using driving evaluation, performed either on road or with a driving simulator.

1.5 OVERVIEW OF THE RESULTS

Thirty four papers were examined for this literature review. Amongst these coded papers, there were four meta-analyses (two related to FPLT and two related to GDL) and thirty original papers (six related to FPLT and twenty four related to GDL). The authors mainly conducted before-after studies or time series analyses (21). The other studies were cohort studies (4), longitudinal or observational studies (2), and quasi-experimental or experimental studies (3). Most of the studies were conducted in the United States (21), the others in: Europe (4), Oceania (4) and Asia (1). The main outcome considered was the crash rate (overall, fatal, leading to severe injury, occurring during the night, or in the presence of passengers).

FPLT based on mandatory driver education or computer-based training focused on cognitive driving skills are effective overall in improving novice drivers' road safety (reduction in the crash rate and improvement of the glance behaviour assessed during a simulated driving evaluation). Nevertheless, FPLT which allows drivers to have a time discount on their learner license (stage 1 of the GDL), or those which are based on an intensive driving course, tend to have a negative effect on road safety by increasing crash involvement and the risk of traffic offenses (particularly for speeding). Hence, these results indicate that the FPLT should be long enough to allow the driver to acquire solid experience and better road safety practices.

Implementation or revision of GDL programs are effective in reducing the crash rate for 16 to 17 year old drivers in the majority of the coded studies. Moreover, the stricter the GDL, the more it reduces fatal and injury crash incidence. The strictness of the GDL is based on the duration of the learner permit holding period (stage 1), the night-time driving restriction, and the passenger restriction (stage 2). In addition, the implementation of a decal law also has a positive effect on road safety as it decreases the crash rate amongst young probationary drivers. However, the results are less clear for drivers older than 18 years. In fact, some studies showed an increased crash and traffic violation rate after the GDL or decal law implementation.

1.6 NOTES ON ANALYSIS METHODS

The majority of the coded studies have been conducted in the United States. Hence, the results should be considered with caution for other countries, since FPLT and GDL systems may be considerably different. Moreover, further investigation is needed to understand why there is a negative effect of GDL on older novice drivers (aged 18 and over).

Furthermore, only two studies focused on powered two-wheelers. Further investigation should be performed to address the lack of information regarding riders' license training and probation.

2 Scientific overview

2.1 LITERATURE REVIEW

According to OECD, road crashes are the largest single cause of death amongst 15 to 24 year old people (Stacey, 2006). This review focuses on the effect of graduated driver licensing (GDL) on novice drivers' road safety, and on the quality of their formal pre-license training (FPLT). The GDL is a risk management system which allows novice drivers to gain experience by progressively facing riskier driving situations (see Shope & Molnar, 2003; Simpson, 2003; Williams, McCartt, & Sims, 2016 for reviews). GDL programs consist of three stages: i) a learner phase, related to the FPLT which generally includes two parts: a theoretical training which consists in the road rules learning; and a practical training in which a driving instructor teaches vehicle handling and safe driving procedures (Williams et al 2008); ii) an intermediate phase which is a restricted period (night restriction/ passenger restriction), and iii) an unrestricted period.

Three international databases have been examined to conduct the literature review on the effect of the FPLT and GDL on road safety. A total of 34 studies has been coded: 4 meta-analyses (two have examined the effect of the FPLT and two others the effect of the GDL) and 30 original articles (6 focused on the FPLT and 24 on the GDL). Amongst these original papers, 16 were before-after studies, 5 were time-series analyses, 4 were cohort studies, 3 were experimental or quasi-experimental studies, and the 2 others were longitudinal and observational studies. Most of the research took place in the United States (21 coded studies); four studies have been conducted in Europe (more precisely in Germany, Netherlands, Sweden, and Finland); four other studies have been conducted in Oceania (three in New Zealand and one in Australia), and the last one in Israel. In addition to these 34 coded studies, 33 papers could not be examined. Only the most recent and relevant studies were coded.

2.2 DESCRIPTION OF THE ANALYSIS CARRIED OUT

A review-type analysis has been performed to investigate the effect of GDL and FPLT on road safety. First, **four meta-analyses** have been coded for this literature review on driver training and licensing: two focused on the effect of GDL programs (Høye & Vaa, 2012; Zhu, Cummings, Chu, Coben, & Li, 2013), and two focused on the effect of the FPLT on novice drivers' road safety (Amundsen, 2011a, 2011b). Concerning **GDL**, the two coded meta-analyses revealed a general positive impact of GDL on road safety. GDL implementation was associated with a 22% reduction in crash rates amongst 16 year olds, but only a 6% reduction in rates among 17 year olds and was unrelated to crash rates among 18 year olds (Zhu et al., 2013). Moreover, the meta-analysis conducted by Høye & Vaa (2012), based on 14 studies, indicated that night-time driving restriction and driving license with a test period have a good impact on crashes and / or injuries reduction. The authors concluded that GDL programs have a positive effect in reducing crash rates among novice drivers. Concerning **FPLT**, two meta-analyses were coded, one on the effect of formal driver training versus informal driver training (Amundsen, 2011a) and one on the effects of different types of testing (Amundsen, 2011b). Regarding driver training, results remain uncertain but tend to show that drivers who have completed formal training have fewer accidents per driver and per kilometre (during first 1-2 years after the driving test) than drivers who have not completed formal training. Then, regarding the effects of a driving test, results show that (1) a formal training with a preliminary examination, (2) a voluntary advanced driving test and (3) a professional drivers commercial driving license test for heavy vehicles have all a positive effect on crash rates, with respectively 7%, 25% and 11% less accidents for those who passed the test compared to those who failed the test.

Second, **thirty other original papers** have been coded. The summary of the results is presented in the two tables below, the first one (Table 1) relates to the effect of FPLT and the second (Table 2) of GDL.

Table 1. Summary of the effects of the formal pre-license training on road safety (based on the five coded studies)

Road safety indicators	Effect	Main outcomes
Crash prevalence / Crash rate	↘	Significant reduction in the crash prevalence and of the injury and fatal crash rate for novice drivers who obtained their provisional operators permit after completing a specific mandatory driver education compared to those who obtained their license after 50h of adult supervised driving (Shell et al., 2015)
Crash involvement	↗	Significant increase of crash involvement for novice drivers who obtained their license through an intensive driving course than those who obtained it through a traditional driving education (de Craen & Vlakveld, 2013)
Citation / Traffic violation rate	↘	Significant drivers traffic violations for those who obtained their provisional operators permit after completing a specific mandatory driver education than for those who obtained their license after 50h of adult supervised driving (Shell et al., 2015)
	↗	Significant increase in the risk of traffic offenses (speeding) for drivers who received a time-discount in their first years of unrestricted driving than those who did not (Begg & Brookland, 2015)
Global driving performance	NS	Non-significant effect of a driving simulator-based training on newly licensed drivers global driving performances, assessed both on-road and on a simulator (Rosenbloom & Eldror, 2014)
Glance behaviour (simulated driving)	↘	Participants who completed the computer-based training were faster at detecting and fixating the hazard indicator and in completing a critical glance sequence than participants from the other two control groups, in near and far transfer situations (Petzoldt et al., 2013)

↘: positive effect; ↗: negative effect; NS: non-significant

Table 2. Summary of the effects of the graduated driver licensing on road safety (based on the five coded studies)

Road safety indicators	Driver's age (years)	Effect	Main outcomes
Crash incidence or crash rate	< 18	↘	<p>Significant reduction in the overall, injury, or fatal crashes amongst young drivers after the implementation of a strict GDL program or revision of the existing one (Chapman, Sargent-Cox, Horswill, & Anstey, 2014; Cheng et al., 2012; Conner & Smith, 2016; Ehsani, Bingham, & Shope, 2013; Ehsani, Bingham, & Shope, 2013; Fell, Jones, Romano, & Voas, 2011; Fell, Todd, & Voas, 2011; Jiang & Lyles, 2011; Kaafarani et al., 2015; Lyon, Pan, & Li, 2012; Masten, Foss, & Marshall, 2011, 2013; Rajaratnam et al., 2015; Rogers et al., 2011; Rouse et al., 2013; Scott-Parker, Bates, Watson, King, & Hyde, 2011; Williams, Chaudhary, Tefft, & Tison, 2010)</p> <p>Significant reduction in the police-reported crash rate among young probationary drivers during the first year after the implementation of the decal law (Curry, Pfeiffer, Localio, & Durbin, 2013), which was still observed 2 years after (Curry, Elliott, Pfeiffer, Kim, & Durbin, 2015)</p> <p>Significant reduction in fatal crashes amongst 16 year old drivers after the implementation of a medium or strict GDL program, but the effect is not significant for 17 year-old drivers (Zhu, Zhao, Long, & Curry, 2016)</p>

		NS	Non-significant effect of the passenger restriction (Williams et al., 2010) nor of the introduction of a minimum number of required supervised driving hours (Ehsani et al., 2013)
		↗	Significant increase of injury crash rate after night-time driving and passenger restrictions (GDL stage 2, intermediate licensing phase, Lyon et al., 2012)
	> 18	↘	Significant reduction of the fatal crash rate among 18-to-20-year-old drivers after the implementation of a stricter GDL program (Conner & Smith, 2016)
		NS	Non-significant change in crash rate among 18-year-old drivers after the implementation or revision of GDL programs (Ehsani et al., 2013; Rouse et al., 2013; Williams et al., 2010)
		↗	Significant increase in crashes incidence after strict or lenient GDL implementation (Conner & Smith, 2016; Masten et al., 2011)
Citation / Traffic violation rate / Offence	<18	↘	Significant reduction in the self-reported offence rate among learner drivers (men in particular) after the revision of the GDL program (Scott-Parker et al., 2011)
		NS	Non-significant change in GDL citations after GDL decal provision (Curry, Pfeiffer, Elliott, & Durbin, 2015)
		↗	Significant increase in the traffic violation rate during the first year of unsupervised driving (Chapman et al., 2014), and during the first year after the implementation of the decal law (Curry et al., 2013)

↘: positive effect; ↗: negative effect; NS: non-significant

Modifying conditions

The conditions that might modify the effect of GDL and FPLT on drivers' road safety could be personal factors such as age (<18 versus >18 years old), gender, personality traits, or compliance with the GDL (Williams & Mayhew, 2008).

2.3 CONCLUSION

Analysis indicates that generally GDL and FPLT both have a positive effect on road safety; however, some inconsistent results were noted, particularly regarding drivers aged 18 years and older. More specifically, GDL and FPLT appear to reduce crash rates and, to a small extent, improve driving behaviour. The results also indicate that the FPLT should be long enough to allow the driver to acquire solid experience and better road safety practices.

Bias and transferability

Due to the difference that may exist between countries driver licensing and probation, the findings have to be considered with caution. Indeed, as indicated above, the coded studies were mainly conducted in the United States.

In addition, the results cannot be generalized to all road users, as the coded studies were mainly focused on novice drivers (only two coded papers investigated the effect of GDL and FPLT on powered two-wheelers).

3 Supporting document

This section starts with a detailed presentation of the literature search methodology carried out, and we subsequently give a summary of the main results presented in the coded studies.

3.1 METHODOLOGY

Below is the literature search strategy (part 3.1.1), the study design of each coded study (part 3.1.2) and the detailed results of coded studies (part 3.1.3).

3.1.1 Literature search strategy

The literature search was conducted in January 2017. Three international databases have been explored for the identification of the relevant studies which have investigated the effects of formal pre-license training (FPLT) and graduated driver licensing (GDL), two sub-topics of the "driving training and licensing" countermeasure, on road safety:

- **Sciadirect** (part of Elsevier databases), which hosts over 12 million pieces of content from 3,500 academic journals;
- **Web of science** (previously known as ISI Web of Knowledge), which hosts over 37 million from 9,000 sources;
- and **Pubmed**, a free search engine accessing primarily the MEDLINE database of references and abstracts on life sciences and biomedical topics.

In the tables below, are described the combination of search terms in each of these three databases and the number of articles found in each case (see Table 3, Table 4, and Table 5).

Table 3. Results from Sciadirect database (date: 3rd January 2017)

search no.	search terms / operators / combined queries	hits
#1	"training" OR "licensing" OR "driver education" OR "graduated driver licensing"	113.336
#2	"road safety" OR "traffic safety" OR "crash" OR "accident"	5.147
#3	"driver" OR "motorcyclist" OR "powered two wheeler" OR "bus" OR "truck" OR "lorry" OR "car" OR "biker"	50.690
#4	#1 AND #2 AND #3	386

Limitations/ Exclusions:

- Search field: TITLE-ABS-KEY
- published: 1990 to current
- Source Type: „Journal“

Table 4. Results from Web of Science database (date:3rd January 2017)

search no.	search terms / operators / combined queries	hits
#1	TS=(training OR licensing OR driver education OR graduated driver licensing)	416.444
#2	TS=(road safety OR traffic safety OR crash OR accident)	82.487
#3	TS=(driver OR motorcyclist OR powered two wheeler OR bus OR truck OR lorry OR car OR biker)	147.266
#4	#1 AND #2 AND #3	2374

Limitations/ Exclusions:

- Search field: TS = Topic (title, abstract, key words, authors keywords)
- published: 1990 to current
- Source Type: „Journal“
- Language: English

Table 5. Results from Pubmed database (date: 3rd January 2017)

search no.	search terms / operators / combined queries	hits
#1	"training" OR "licensing" OR "driver education" OR "graduated driver licensing"	268.579
#2	"road safety" OR "traffic safety" OR "crash" OR "accident"	40.615
#3	"driver" OR "motorcyclist" OR "powered two wheeler" OR "bus" OR "truck" OR "lorry" OR "car" OR "biker"	38.181
#4	#1 AND #2 AND #3	463

Limitations/ Exclusions:

- Search field: TS = Topic (title, abstract, key words, authors keywords)
- published: 1990 to current
- Source Type: „Journal“
- Language: English

This search strategy resulted in **289 studies to screen** (Table 6).

Table 6. Results of the literature search

Database	Hits
Scopus (after exclusions of irrelevant papers)	57
Web of Science (after exclusions of irrelevant papers)	96
Pubmed(after exclusions of irrelevant papers)	136
Total number of studies to screen title/ abstract	289

Among these 289 studies, 165 have been excluded. The exclusion criteria are presented in Table 7.

Table 7. Results from the first screening

Total number of studies to screen title/ abstract	289
-exclusion criteria: duplicate	108 (remaining: 181)
-exclusion criteria: review	34 (remaining: 147)
-exclusion criteria: research not conducted in OECD countries	23
Remaining studies	124
Not clear (full-text is needed)	52
Studies to obtain full-texts	124

Among the 124 remaining studies, 123 full texts were obtained and eligible to be coded (Table 8).

Table 8. Eligibility

Total number of studies to screen full-text	124
Full-text could be obtained	123
Reference list examined Y/N	N
Eligible papers	123

The 123 references were screened on potential relevance for coding (Table 9). The inspection of abstracts and/or full texts provided further information on whether the article was relevant for coding. Among the 123 references, 59 were not coded either because articles were part of a meta-analysis (15 articles) or because the data were not codable or not relevant for the topic (44 articles). Hence, it remained 64 articles to code. However, 33 articles were not screened due to insufficient time. Then, 31 have been finally coded. In addition, three meta-analyses published in a Norwegian

handbook on traffic safety have been coded by Norwegian speaker colleagues. In the end, the total number of coded studies was raised at 34.

The prioritizing coding steps were:

- Prioritizing Step A (meta-analysis first);
- Prioritizing Step B (best fitting in coding scheme);
- Prioritizing Step C (published more recently);
- Prioritizing Step D (Central-European countries before others).

Table 9. Screening of the full texts

Total number of eligible papers	123
Exclusion criteria: "part of a meta-analysis"	15
Exclusion criteria: "Not relevant for the topic"	17
Exclusion criteria: "No codable data"	24
Exclusion criteria: "No objective driving safety outcome"	3
Remaining studies	64

The detailed list of the eligible papers and the reasons why the articles have been included or excluded on the global analysis are presented in the Table 10.

Table 10. List of references resulting from search strategy (sorted by year of publication and meta-analysis first)

No.	Publication	Coded	Reason
1.	Curry, A. E., Pfeiffer, M. R., & Elliott, M. R. (2017). Compliance With and Enforcement of Graduated Driver Licensing Restrictions. <i>American Journal of Preventive Medicine</i> , 52(1), 47-54.	N	Not relevant
2.	Conner, K. A., & Smith, G. A. (2016). An evaluation of the effect of Ohio's graduated driver licensing law on motor vehicle crashes and crash outcomes involving drivers 16 to 20 years of age. <i>Traffic injury prevention</i> , DOI: 10.1080/15389588.2016.1209493.	Y	Prioritizing Step B Graduated driver licensing and probation
3.	Deza, M., & Litwok, D. (2016). Do Night-time Driving Restrictions Reduce Criminal Participation Among Teenagers? Evidence From Graduated Driver Licensing. <i>Journal of Policy Analysis and Management</i> , 35(2), 306-332.	N	Not relevant
4.	Kosola, S., Salminen, P., & Kallio, P. (2016). Driver's education may reduce annual incidence and severity of moped and scooter accidents. A population-based study. <i>Injury</i> , 47(1), 239-243.	Y	Prioritizing Step B Formal pre-license training
5.	Shults, R. A., Williams, A. F. (2016). Graduated Driver Licensing Night Driving Restrictions and Drivers Aged 16 or 17 Years Involved in Fatal Night Crashes—United States, 2009–2014. <i>MMWR. Morbidity and Mortality Weekly Report</i> , 65(29), 725-730.	N	No codable data
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7.	Begg, D., & Brookland, R. (2015). Participation in driver education/training courses during graduated driver licensing, and the effect of a time-discount on subsequent traffic offenses: Findings from the New Zealand Drivers Study. <i>Journal of safety research</i> , 55, 13-20.	Y	Prioritizing Step B Formal pre-license training
8.	Bonander, C., Andersson, R., & Nilson, F. (2015). The effect of stricter licensing on road traffic injury events involving 15 to 17-year-old moped drivers in Sweden: A time series intervention study. <i>Accident Analysis & Prevention</i> , 83, 154-161.	Y	Prioritizing Step B Graduated driver licensing and probation

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10.	Curry, A. E., Pfeiffer, M. R., Durbin, D. R., & Elliott, M. R. (2015). Young driver crash rates by licensing age, driving experience, and license phase. <i>Accident Analysis & Prevention</i> , 80, 243-250.	N	Not relevant
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13.	Kaafarani, H. M., Lee, J., Cropano, C., Chang, Y., Raybould, T., Klein, E., ... & Velmahos, G. C. (2015). The impact and sustainability of the graduated driver licensing program in preventing motor vehicle crashes in Massachusetts. <i>Journal of trauma and acute care surgery</i> , 78(2), 265-271.	Y	Prioritizing Step B Graduated driver licensing and probation
14.	McCartt, A. T., & Teoh, E. R. (2015). Tracking progress in teenage driver crash risk in the United States since the advent of graduated driver licensing programs. <i>Journal of safety research</i> , 53, 1-9.	N	No codable data
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16.	Rajaratnam, S. M., Landrigan, C. P., Wang, W., Kaprielian, R., Moore, R. T., & Czeisler, C. A. (2015). Teen crashes declined after Massachusetts raised penalties for graduated licensing law restricting night driving. <i>Health Affairs</i> , 34(6), 963-970.	Y	Prioritizing Step B Graduated driver licensing and probation
17.	Shell, D. F., Newman, I. M., Córdova-Cazar, A. L., & Heese, J. M. (2015). Driver education and teen crashes and traffic violations in the first two years of driving in a graduated licensing system. <i>Accident Analysis & Prevention</i> , 82, 45-52.	Y	Prioritizing Step B Formal-pre-license training
18.	Winston, F. K., Mirman, J. H., Curry, A. E., Pfeiffer, M. R., Elliott, M. R., & Durbin, D. R. (2015). Engagement with the TeenDrivingPlan and diversity of teens' supervised practice driving: lessons for internet-based learner driver interventions. <i>Injury Prevention</i> , 21(1), 4-9.	N	No codable data
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20.	Begg, D. J., Langley, J. D., Brookland, R. L., Ameratunga, S., & Gulliver, P. (2014). Pre-licensed driving experience and car crash involvement during the learner and restricted, licence stages of graduated driver licensing: Findings from the New Zealand Drivers Study. <i>Accident Analysis & Prevention</i> , 62, 153-160.	N	Not relevant
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22.	Chen, Y., Berrocal, V. J., Bingham, C. R., & Song, P. X. (2014). Analysis of spatial variations in the effectiveness of graduated driver's licensing (GDL) program in the state of Michigan. <i>Spatial and spatio-temporal epidemiology</i> , 8, 11-22.	N	No codable data
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24.	Glendon, A. I., McNally, B., Jarvis, A., Chalmers, S. L., & Salisbury, R. L. (2014). Evaluating a novice driver and pre-driver road safety intervention. <i>Accident Analysis & Prevention</i> , 64, 100-110.	N	No objective driving safety outcome
25.	Rosenbloom, T., & Eldror, E. (2014). Effectiveness evaluation of simulative workshops for newly licensed drivers. <i>Accident Analysis & Prevention</i> , 63, 30-36.	Y	Prioritizing Step B Formal pre-license training
26.	Steadman, M., Bush, J. K., Thygerson, S. M., & Barnes, M. D. (2014). Graduated driver licensing provisions: an analysis of state policies and what works. <i>Traffic injury prevention</i> , 15(4), 343-348.	N	No codable data
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28.	Zhu, M., Cummings, P., Chu, H., Coben, J. H., & Li, G. (2013). Graduated driver licensing and motor vehicle crashes involving teenage drivers: an exploratory age-stratified meta-analysis. <i>Injury prevention</i> , 19(1), 49-57.	Y	Prioritizing Step A Graduated driver licensing and probation
29.	Aupetit, S., Riff, J., Buttelli, O., & Espié, S. (2013). Naturalistic study of rider's behaviour in initial training in France: Evidence of limitations in the educational content. <i>Accident Analysis & Prevention</i> , 58, 206-217.	N	No codable data
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33.	Ehsani, J. P., Bingham, C. R., & Shope, J. T. (2013). The effect of the learner license Graduated Driver Licensing components on teen drivers' crashes. <i>Accident Analysis & Prevention</i> , 59, 327-336.	Y	Prioritizing Step B Graduated driver licensing and probation
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37.	Masten, S. V., Foss, R. D., & Marshall, S. W. (2013). Graduated driver licensing program component calibrations and their association with fatal crash involvement. <i>Accident Analysis & Prevention</i> , 57, 105-113.	Y	Prioritizing Step B Graduated driver licensing and probation
38.	O'Brien, N. P., Foss, R. D., Goodwin, A. H., & Masten, S. V. (2013). Supervised hours requirements in graduated driver licensing: Effectiveness and parental awareness. <i>Accident Analysis & Prevention</i> , 50, 330-335.	N	Not relevant

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41.	Høye, A. & Vaa, T. (2012). Graduated driver's license and driving restrictions. <i>The handbook of Road Safety Measures, Norwegian</i> (online) version. tsh.toi.no/index.html?22047	Y	Prioritizing Step A Graduated driver licensing and probation
42.	Castillo-Manzano, J. I., & Castro-Nuño, M. (2012). Driving licenses based on points systems: Efficient road safety strategy or latest fashion in global transport policy? A worldwide meta-analysis. <i>Transport Policy</i> , 21, 191-201.	N	No codable data
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44.	Langley, J., Begg, D., Brookland, R., Ameratunga, S., McDowell, A., & Broughton, J. (2012). Establishment of the New Zealand drivers study. <i>The New Zealand Medical Journal</i> (Online), 125(1357).	N	No codable data
45.	Lyon, J. D., Pan, R., & Li, J. (2012). National evaluation of the effect of graduated driver licensing laws on teenager fatality and injury crashes. <i>Journal of safety research</i> , 43(1), 29-37.	Y	Prioritizing Step B Graduated driver licensing and probation
46.	Amundsen, A. (2011). Basic driver training. <i>The Handbook of Road Safety Measures, Norwegian</i> (online) version. tsh.toi.no/index.html?22047	Y	Prioritizing Step A Formal pre-license training
47.	Amundsen, A. (2011). The driving test. <i>The Handbook of Road Safety Measures, Norwegian</i> (online) version. tsh.toi.no/index.html?22743	Y	Prioritizing Step A Formal pre-license training
48.	Damm, L., Nachtergaële, C., Meskali, M., & Berthelon, C. (2011). The evaluation of traditional and early driver training with simulated accident scenarios. <i>Human Factors: The Journal of the Human Factors and Ergonomics Society</i> , 53(4), 323-337.	N	Not examined
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50.	Fell, J. C., Todd, M., & Voas, R. B. (2011). A national evaluation of the night-time and passenger restriction components of graduated driver licensing. <i>Journal of safety research</i> , 42(4), 283-290.	Y	Prioritizing Step B Graduated driver licensing and probation
51.	Isler, R. B., Starkey, N. J., & Sheppard, P. (2011). Effects of higher-order driving skill training on young, inexperienced drivers' on-road driving performance. <i>Accident Analysis & Prevention</i> , 43(5), 1818-1827.	N	Not examined
52.	Jiang, X., & Lyles, R. W. (2011). Exposure-based assessment of the effectiveness of Michigan's graduated driver licensing night-time driving restriction. <i>Safety Science</i> , 49(3), 484-490.	Y	Prioritizing Step B Graduated driver licensing and probation
53.	Masten, S. V., Foss, R. D., & Marshall, S. W. (2011). Graduated driver licensing and fatal crashes involving 16-to 19-year-old drivers. <i>Jama</i> , 306(10), 1098-1103.	Y	Prioritizing Step B Graduated driver licensing and probation

54.	McCartt, A. T., & Teoh, E. R. (2011). Strengthening driver licensing systems for teenaged drivers. <i>JAMA</i> , 306(10), 1142-1143.	N	No codable data
55.	Peck, R. C. (2011). Do driver training programs reduce crashes and traffic violations? A critical examination of the literature. <i>IATSS research</i> , 34(2), 63-71.	N	No codable data
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57.	Russell, K. F., Vandermeer, B., & Hartling, L. (2011). Graduated driver licensing for reducing motor vehicle crashes among young drivers. <i>Cochrane Database Syst Rev</i> , 10.	N	Not examined
58.	Scott-Parker, B. J., Bates, L., Watson, B. C., King, M. J., & Hyde, M. K. (2011). The impact of changes to the graduated driver licensing program in Queensland, Australia on the experiences of Learner drivers. <i>Accident Analysis & Prevention</i> , 43(4), 1301-1308.	Y	Prioritizing Step B Graduated driver licensing and probation
59.	Bates, L., Watson, B., & King, M. (2010). Required hours of practice for learner drivers: A comparison between two Australian jurisdictions. <i>Journal of safety research</i> , 41(2), 93-97.	N	Not examined
60.	Castillo-Manzano, J. I., Castro-Nuño, M., & Pedregal, D. J. (2010). An econometric analysis of the effects of the penalty points system driver's license in Spain. <i>Accident Analysis & Prevention</i> , 42(4), 1310-1319.	N	Not relevant
61.	Karaca-Mandic, P., & Ridgeway, G. (2010). Behavioral impact of graduated driver licensing on teenage driving risk and exposure. <i>Journal of health economics</i> , 29(1), 48-61.	N	Not examined
62.	Kardamanidis, K., Martiniuk, A., Ivers, R. Q., Stevenson, M. R., & Thistlethwaite, K. (2010). Motorcycle rider training for the prevention of road traffic crashes: review. <i>Cochrane Database of Systematic Reviews</i> 2010, Issue 10. Art. No.: CD005240. DOI: 10.1002/14651858.CD005240.pub2	N	Not examined
63.	Lewis-Evans, B. (2010). Crash involvement during the different phases of the New Zealand Graduated Driver Licensing System (GDLS). <i>Journal of Safety Research</i> , 41(4), 359-365.	N	Not examined
64.	Masten, S. V., & Foss, R. D. Long-term effect of the North Carolina graduated driver licensing system on licensed driver crash incidence: A 5-year survival analysis. 2010 <i>Accident Analysis & Prevention</i> , 42(6), 1647-1652.	N	Not examined
65.	McCartt, A. T., Teoh, E. R., Fields, M., Braitman, K. A., & Hellinga, L. A. Graduated licensing laws and fatal crashes of teenage drivers: a national study. 2010 <i>Traffic injury prevention</i> , 11(3), 240-248.	N	Not examined
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69.	Begg, D., & Langley, J. (2009). A critical examination of the arguments against raising the car driver licensing age in New Zealand. <i>Traffic injury prevention</i> , 10(1), 1-8.	N	Not relevant
70.	Corden, T. E., Tonellato, D. J., Frisch, K. B., & Laud, P. W. (2009). Graduated driver licensing policy in the Great Lakes states: current benefits and future potential. <i>Wisconsin Medical Journal (WMJ)</i> , 108(8), 393.	N	No codable data

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72.	Senserrick, T., Ivers, R., Boufous, S., Chen, H. Y., Norton, R., Stevenson, M., ... & Zask, A. (2009). Young driver education programs that build resilience have potential to reduce road crashes. <i>Pediatrics</i> , 124(5), 1287-1292.	N	Not examined
73.	Vanlaar, W., Mayhew, D., Marcoux, K., Wets, G., Brijs, T., & Shope, J. (2009). An evaluation of graduated driver licensing programs in North America using a meta-analytic approach. <i>Accident Analysis & Prevention</i> , 41(5), 1104-1111.	N	Not examined
74.	Zhu, M., Chu, H., & Li, G. (2009). Effects of graduated driver licensing on licensure and traffic injury rates in Upstate New York. <i>Accident Analysis & Prevention</i> , 41(3), 531-535.	N	Already included in a meta-analysis
75.	Andreff, M., Bancel-Charensol, L., & Dessertaine, A. (2008). Controlling the driving and road safety training sector through the driving test success rate? <i>The Service Industries Journal</i> , 28(3), 355-373.	N	Not relevant
76.	Blackman, R., Cheffins, T., Veitch, C., & O'Connor, T. (2008). Young driver restrictions: Does the evidence support them? <i>Australian journal of rural health</i> , 16(6), 332-337.	N	Not relevant
77.	Hallmark, S. L., Veneziano, D. A., Falb, S., Pawlovich, M., & Witt, D. (2008). Evaluation of Iowa's graduated driver's licensing program. <i>Accident Analysis & Prevention</i> , 40(4), 1401-1405.	N	Not examined
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80.	Neyens, D. M., Donmez, B., & Boyle, L. N. (2008). The Iowa graduated driver licensing program: effectiveness in reducing crashes of teenage drivers. <i>Journal of safety research</i> , 39(4), 383-390.	N	No codable data
81.	Bourgeon, J. M., & Picard, P. (2007). Point-record driving licence and road safety: an economic approach. <i>Journal of Public Economics</i> , 91(1), 235-258.	N	No codable data
82.	Foss, R. D. (2007). Improving graduated driver licensing systems: a conceptual approach and its implications. <i>Journal of Safety Research</i> , 38(2), 185-192.	N	No codable data
83.	Males, M. (2007). California's graduated driver license law: Effect on teenage drivers' deaths through 2005. <i>Journal of Safety Research</i> , 38(6), 651-659.	N	Already included in a meta-analysis
84.	Margolis, L. H., Masten, S. V., & Foss, R. D. (2007). The effects of graduated driver licensing on hospitalization rates and charges for 16-and 17-year-olds in North Carolina. <i>Traffic injury prevention</i> , 8(1), 35-38.	N	Not examined
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86.	Nyberg, A., & Gregersen, N. P. (2007). Practicing for and performance on drivers' license tests in relation to gender differences in crash involvement among novice drivers. <i>Journal of safety research</i> , 38(1), 71-80.	N	Not examined
87.	O'connor, R. E., Lin, L., Tinkoff, G. H., & Ellis, H. (2007). Effect of a Graduated Licensing System on Motor Vehicle Crashes and Associated Injuries Involving Drivers Less Than 18 Years-of-Age. <i>Prehospital emergency care</i> , 11(4), 389-393.	N	Not examined
88.	Chen, L. H., Baker, S. P., & Li, G. (2007). Graduated driver licensing programs and fatal crashes of 16-year-old drivers: a national evaluation. <i>Pediatrics</i> , 118(1), 56-62.	N	Not examined
89.	Hirsch, P., Maag, U., & Laberge-Nadeau, C. (2006). The role of driver education in the licensing process in Quebec. <i>Traffic injury prevention</i> , 7(2), 130-142.	N	Not examined

90.	Morrisey, M. A., & Grabowski, D. C. (2006). Graduated drivers license programs and rural teenage motor vehicle fatalities. <i>The Journal of Rural Health</i> , 22(4), 300-307.	N	Not examined
91.	Simons-Morton, B., Hartos, J. L., Leaf, W. A., & Preusser, D. F. (2006). Do recommended driving limits affect teen-reported traffic violations and crashes during the first 12 months of independent driving? <i>Traffic injury prevention</i> , 7(3), 238-247.	N	Not relevant
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93.	Adams, C. (2005). Probationary and non-probationary drivers' night-time crashes in Western Australia, 1996–2000. <i>Journal of safety research</i> , 36(1), 33-37.	N	Not examined
94.	Baldi, S., Baer, J. D., & Cook, A. L. (2005). Identifying best practices states in motorcycle rider education and licensing. <i>Journal of Safety Research</i> , 36(1), 19-32.	N	Not relevant
95.	Dee, T. S., Grabowski, D. C., & Morrisey, M. A. (2005). Graduated driver licensing and teen traffic fatalities. <i>Journal of Health Economics</i> , 24(3), 571-589.	N	No codable data
96.	Fohr, S. A., Layde, P. M., & Guse, C. E. (2005). Graduated driver licensing in Wisconsin: does it create safer drivers? <i>Wisconsin Medical Journal</i> , 104(7), 31-36.	N	Already included in a meta-analysis
97.	Hyde, L. K., Cook, L. J., Knight, S., & Olson, L. M. (2005). Graduated driver licensing in Utah: Is it effective? <i>Annals of Emergency Medicine</i> , 45(2), 147-154.	N	Not examined
98.	McIntosh, G. (2005). Wisconsin's experience with the Graduated Driver Licensing Law. <i>WMJ: official publication of the State Medical Society of Wisconsin</i> , 104(1), 52-56.	N	No objective driving safety outcome
99.	Hartling, L., Wiebe, N., Russell, K., Petruk, J., Spinola, C., & Klassen, T. P. (2004). Graduated driver licensing for reducing motor vehicle crashes among young drivers. <i>Cochrane Database Syst Rev</i> , 2(2).	N	Not examined
100.	Masten, S. V., & Hagge, R. A. (2004). Evaluation of California's graduated driver licensing program. <i>Journal of Safety Research</i> , 35(5), 523-535.	N	Not examined
101.	McGwin Jr, G., Whatley, J., Metzger, J., Valent, F., Barbone, F., & Rue III, L. W. (2004). The effect of state motorcycle licensing laws on motorcycle driver mortality rates. <i>Journal of Trauma and Acute Care Surgery</i> , 56(2), 415-419.	N	Not examined
102.	Rice, T. M., Peek-Asa, C., & Kraus, J. F. (2004). Effects of the California graduated driver licensing program. <i>Journal of Safety Research</i> , 35(4), 375-381.	N	Already included in a meta-analysis
103.	Shope, J. T., & Molnar, L. J. (2004). Michigan's graduated driver licensing program: evaluation of the first four years. <i>Journal of Safety Research</i> , 35(3), 337-344.	N	Already included in a meta-analysis
104.	Wolming, S., & Wiberg, M. (2004). The Swedish driver licensure examination: exploration of a two-stage model. <i>Journal of Safety Research</i> , 35(5), 491-495.	N	Not relevant
105.	Mayhew, D. R., Simpson, H. M., Desmond, K., & Williams, A. F. (2003). Specific and long-term effects of Nova Scotia's graduated licensing program. <i>Traffic Injury Prevention</i> , 4(2), 91-97.	N	Not examined
106.	Shope, J. T., & Molnar, L. J. (2003). Graduated driver licensing in the United States: evaluation results from the early programs. <i>Journal of Safety Research</i> , 34(1), 63-69.	N	No codable data
107.	Simpson, H. M. (2003). The evolution and effectiveness of graduated licensing. <i>Journal of Safety Research</i> , 34(1), 25-34.	N	No codable data
108.	Carstensen, G. (2002). The effect on accident risk of a change in driver education in Denmark. <i>Accident Analysis & Prevention</i> , 34(1), 111-121.	N	Not examined
109.	Begg, D. J., Stephenson, S., Alsop, J., & Langley, J. (2001). Impact of graduated driver licensing restrictions on crashes involving young drivers in New Zealand. <i>Injury prevention</i> , 7(4), 292-296.	N	Not examined
110.	Foss, R. D., Feaganes, J. R., & Rodgman, E. A. (2001). Initial effects of graduated driver licensing on 16-year-old driver crashes in North Carolina. <i>Jama</i> , 286(13), 1588-1592.	N	Already included in a meta-analysis

111.	McCartt, A. T. (2001). Graduated driver licensing systems: reducing crashes among teenage drivers. <i>JAMA</i> , 286(13), 1631-1632.	N	No codable data
112.	Shope, J. T., Molnar, L. J., Elliott, M. R., & Waller, P. F. (2001). Graduated driver licensing in Michigan: early impact on motor vehicle crashes among 16-year-old drivers. <i>Jama</i> , 286(13), 1593-1598.	N	Already included in a meta-analysis
113.	Ulmer, R. G., Ferguson, S. A., Williams, A. F., & Preusser, D. F. (2001). Teenage crash reduction associated with delayed licensure in Connecticut. <i>Journal of Safety Research</i> , 32(1), 31-41.	N	Already included in a meta-analysis
114.	Dussault, C. (2000). Le nouveau système d'accès graduel à la conduite au Québec fondements et résultats préliminaires. <i>Recherche-Transports-Sécurité</i> , 67, 7-18.	N	No codable data
115.	Foss, R. D. (2000). Reducing fatal crash risk among teenaged drivers: Structuring an effective graduated licensing system. <i>JAMA</i> , 283(12), 1617-1618.	N	No codable data
116.	Gregersen, N. P., Berg, H. Y., Engström, I., Nolén, S., Nyberg, A., & Rimmö, P. A. (2000). Sixteen years age limit for learner drivers in Sweden—an evaluation of safety effects. <i>Accident Analysis & Prevention</i> , 32(1), 25-35.	N	Already included in a meta-analysis
117.	Ulmer, R. G., Preusser, D. F., Williams, A. F., Ferguson, S. A., & Farmer, C. M. (2000). Effect of Florida's graduated licensing program on the crash rate of teenage drivers. <i>Accident Analysis & Prevention</i> , 32(4), 527-532.	N	Already included in a meta-analysis
118.	Foss, R., & Evenson, K. (1999). Effectiveness of graduated driver licensing in reducing motor vehicle crashes. <i>American journal of preventive medicine</i> , 16(1), 47-56.	N	Not examined
119.	Reeder, A. I., Alsop, J. C., Langley, J. D., & Wagenaar, A. C. (1999). An evaluation of the general effect of the New Zealand graduated driver licensing system on motorcycle traffic crash hospitalisations. <i>Accident Analysis & Prevention</i> , 31(6), 651-661.	N	Not examined
120.	Ulmer, R. G., Preusser, D. F., Ferguson, S. A., & Williams, A. F. (1999). Teenage crash reduction associated with delayed licensure in Louisiana. <i>Journal of Safety Research</i> , 30(1), 31-38.	N	Already included in a meta-analysis
121.	Doherty, S. T., & Andrey, J. C. (1997). Young drivers and graduated licensing: the Ontario case. <i>Transportation</i> , 24(3), 227-251.	N	Not examined
122.	Ferguson, S. A., Leaf, W. A., Williams, A. F., & Preusser, D. F. (1996). Differences in young driver crash involvement in states with varying licensure practices. <i>Accident Analysis & Prevention</i> , 28(2), 171-180.	N	Not examined
123.	Hagge, R. A., & Romanowicz, P. A. (1996). Evaluation of California's commercial driver license program. <i>Accident Analysis & Prevention</i> , 28(5), 547-559.	N	Already included in a meta-analysis
124.	Langley, J. D., Wagenaar, A. C., & Begg, D. J. (1996). An evaluation of the New Zealand graduated driver licensing system. <i>Accident Analysis & Prevention</i> , 28(2), 139-146.	N	Already included in a meta-analysis
125.	Jones, B. (1994). The effectiveness of provisional licensing in Oregon: an analysis of traffic safety benefits. <i>Journal of Safety Research</i> , 25(1), 33-46.	N	Already included in a meta-analysis
126.	Laberge-Nadeau, C., Maag, U., & Bourbeau, R. (1992). The effects of age and experience on accidents with injuries: should the licensing age be raised? <i>Accident Analysis & Prevention</i> , 24(2), 107-116.	N	Not relevant

3.1.2 Detailed analysis of study designs and methods

In the table below are presented the study designs and group characteristics of each coded study Table 11.

Table 11. Characteristics of coded studies

Author, Year, Country	Sample, method/design and analysis type	Period covered	Test group	Control group	Research conditions / Control variables
Conner & Smith, 2016, United States	Before-after study Poisson regression models Relative risk (adjusted rate ratios, aRR)	Pre-GDL: Jan 2004 – Dec 2006 Post-GDL: Jan 2008 – Dec 2010	Exposed to GDL (Post-GDL)	Non-exposed to GDL (Pre-GDL)	Ohio annual gasoline prices; Ohio highway fuel use; and Ohio annual vehicle-miles of travel
Kosola et al., 2016, Finland	Before-after study Fisher's exact test or Chi-square test Absolute proportion	Pre-law amendment: Jan 2008 – Dec 2010 Post-law amendment: Jan 2012 – Dec 2013	After the law amendment (n = 110)	Before the law amendment (n = 308)	–
Zhu et al., 2016, United States	Before-after study Poisson regression models Relative risk (Adjusted rate ratios, aRR)	1995 – 2012	Exposed to GDL (presence / weak / medium / strong)	Non-exposed to GDL	Repeated measures within each state with generalized estimating equation; year; quarter; age; traffic laws; state economic factors
Begg & Brookland, 2015, New Zealand	Prospective cohort study Poisson regression models Relative risk	–	Exposed to the 3-month-time-discount n = 868	Non-exposed to the 3-month-time-discount n = 895	Model 1: no control variable Model 2: Driving related variables Model 3: Driving related variables and demographic variables Model 4: Driving related variables, demographic variables, and the year of full license
Bonander et al., 2015, Sweden	Before-after study Segmented generalized additive models for location, shape and scale (GAMLSS model) Relative risk (Incidence Rate Ratio)	Pre-AM driving license: Jan 2007 – Sept 2009 Post-AM driving license: Immediate (Oct 2009 – Dec 2013); 1-year delay (Oct 2010 – Dec 2013); 2-year delay (Oct 2011 – Dec 2013)	Exposed to AM driving license (Post-AM driving license)	Non-exposed to AM driving license (Pre-AM driving license)	Trend; seasonality; number of registered mopeds in traffic
Curry, Elliott, et al., 2015, United States	Before-after study Negative binomial model. Relative risk (Adjusted rate ratios, aRR) and difference in slopes	Pre-GDL ecal provision: Jan 2006 – Jan 2010 Post-GDL decal provision: May 2010 – June 2012	Exposed to GDL decal (Post-decal period)	Non-exposed to GDL decal (Pre-decal period)	–
Curry, Pfeiffer, et al., 2015, United States	Before-after study Negative binomial model.	Pre-GDL decal provision: Jan 2006 – Dec 2010	Exposed to GDL decal (Post-decal period)	Non-exposed to GDL decal (Pre-decal period)	Gender; age; calendar month; gas price; crash rates among licensed drivers aged 21 to 24 years

Author, Year, Country	Sample, method/design and analysis type	Period covered	Test group	Control group	Research conditions / Control variables
	Relative risk (Adjusted rate ratios, aRR)	Post-GDL decal provision: May 2010 – June 2012			
Kaafarani et al., 2015, United States	Before-after study Poisson regression model Percent change	Pre-GDL period: 01/01/2002 – 31/12/2006 Post-GDL period: 01/01/2007 – 31/12/2011	Exposed to GDL (Post-GDL period)	Non-exposed to GDL (Pre-GDL period)	–
Rajaratnam et al., 2015, United States	Before-after study Poisson regression model. Percent change Incidence rate ratio	April 2006 – March 2012	Exposed to GDL (Five year after the GDL law revision)	Non-exposed to GDL (One year before the GDL law revision)	–
Shell et al., 2015, United States	Cohort study Absolute proportion Chi-square test	Jan 2003 – Dec 2009	Certified driver education course, n = 80,685	50h of supervised driving documented on a certification form; n = 71,195	–
Chapman et al., 2014, United States	Before-after study Poisson regression models Relative risk (Adjusted Rate Ratio, aRR)	Jan 2001 – Dec 2007	Drivers licensed under GDL (Pre-licensure, 1-3 months, 4-6 months, 7-12 months, 13-24 months, 25-36 months)	Drivers not licensed under GDL, aged 25-35 years old.	Gender; calendar month of licensure; calendar year of licensure; interaction between calendar year and month of licensure
Rosenbloom & Eldror, 2014, Israel	Quasi experimental study MANOVA, t-tests, and Poisson regression models Absolute differences and Relative Risk (Odds Ratio)	June 2010 – Dec 2011	Learner drivers who completed the driving simulator-based training in addition to the standard driving lessons	Learner drivers who only had standard driving lessons	–
Zhu et al., 2013, United States	Meta-analysis Poisson regression Relative Risk (Adjusted Rate Ratio, aRR)	Jan 1991 – Dec 2011	Exposed to GDL	Non-exposed to GDL	Time; Age
Curry et al., 2013, United States	Before-after study Negative binomial regression models Relative risk (Adjusted Rate Ratio, aRR)	Pre-decal period: Jan 2008 – Dec 2010 Post-decal period: May 2010 – May 2011	Exposed to the decal law	Non-exposed to the decal law	Gender; seasonal trends
de Craen & Vlakveld, 2013, Netherlands	Longitudinal study Absolute proportion Chi-square test	Sept 2008 – Aug 2007	Novice drivers exposed to the intensive driving course (n = 35)	Novice drivers who followed the traditional driving education (n = 351)	–

Author, Year, Country	Sample, method/design and analysis type	Period covered	Test group	Control group	Research conditions / Control variables
Ehsani et al., 2013, United States (AJPM)	Time-series analysis Auto-Regressive Integrated Moving Average (ARIMA) interrupted time-series analysis Percent change	Florida: Jan 1990 – Dec 2009 Michigan: Jan 1992 – Dec 2009 Maryland: Jan 1998 – Dec 2009	Exposed to GDL	Non-exposed to GDL	Adult crash rates (25-54 years) gasoline prices; GDL effective dates; trend; seasonality
Ehsani et al., 2013, United States (AAP)	Time-series analysis Random effects meta-analytic model Percent change	Jan 1990 – Dec 207	Duration of the learner license Number of required supervised hours	–	Adult crash rate; gasoline prices; trend; seasonality
Gulliver et al., 2013, New Zealand	Cohort study Poisson regression model Relative Risk (adjusted Rate Ratio, aRR)	Baseline interviews: Feb 2006 – Aug 2008 1 st follow-up interview: 17 th Jan 2010 2 nd follow-up interview: 30 th May 2011	Drivers who drove unsupervised at the learner license stage	Drivers who did not drive unsupervised at the learner license stage	Age; gender; residential location; sensation seeking; impulsivity; aggression; hazardous alcohol consumption; distance driven on restricted licence; days on restricted licence
Langley et al., 2013, New Zealand	Prospective cohort study Modified Poisson model Relative risk (Adjusted Risk Ratio, aRR)	–	Medium or non-adherence to the supervisory driving restriction	Full-adherence to the supervisory driving restriction	Sex, age at learner licence, herbal high use, agreement to the requirement of having a supervisor, estimated km driven as a learner, and months to progress to restricted licence
Masten et al., 2013, United States	Before-after study Poisson regression models Relative risk (Adjusted Risk Ratio, aRR)	Jan 1986 – Dec 2007	Exposed to GDL: Learner permit holding period (from less than 3 months to 12 months) Nighttime driving restriction Passenger restriction	Non-exposed to GDL: no learner permit holding period, neither nighttime driving restriction, nor passenger restriction	State; annual state highway fuel use per capita; changes in state traffic-safety related laws (e.g., seat belt laws); quarterly state unemployment rate; state linear trend and seasonality; and state contemporaneous age 20–24, 25–39, 40–59; and 60-or-older driver fatal crash involvement rates
Pertzoldt et al., 2013, Germany	Experimental study ANOVAs and pairwise comparisons Absolute difference	–	Computer based training group (CBT, n = 12) Paper based training group (PBT, n = 13)	Passive control group (n = 11)	–
Rouse et al., 2013, United States	Before-after study Chi-square test Percent change	Pre-GDL period: Jan 2008 – Dec 2008 Post-GDL period: Jan 2010 – Dec 2010	Exposed to GDL (Post-GDL)	Non-exposed to GDL (Pre-GDL)	–

Author, Year, Country	Sample, method/design and analysis type	Period covered	Test group	Control group	Research conditions / Control variables
Høye & Vaa, 2012, United States, Germany, Austria, New Zealand, Canada & Sweden	Meta-analysis Percent change	–	Exposed to GDL	Non-exposed to GDL	–
Cheng et al., 2012, United States	Before-after study Chi-square Absolute proportion	Pre-GDL period: Jan 2001 – Dec 2003 Post-GDL period 1: Jan 2004 – Dec 2006 Period 2: Jan 2007 – Dec 2009	Exposed to GDL, two periods post-GDL	Non-exposed to GDL (Pre-GDL)	Motor fuel tax receipts by the NYS Comptroller's Office
Lyon et al., 2012, United States	Observational study Negative binomial generalized linear model Relative risk (Incidence rate ratio)	Jan 1995 – Dec 2009	Strict or medium GDL	Lenient GDL	–
Amundsen, A., 2011 Australia, New Zealand, Norway, Finland, United Kingdom, United States, Sweden	Meta-analysis Percent change	–	Drives who received formal training	Drives who received informal training	–
Amundsen, A., 2011, United States, United Kingdom	Meta-analysis Percent change	–	Exposed to mandatory theoretical driving license test, or to the rigorous theoretical and driving tests for heavy goods vehicles, or drivers who passed the optional commercial driving license test	Non-exposed to mandatory theoretical driving license test, or to the rigorous theoretical and driving tests for heavy goods vehicles, or drivers who failed the optional commercial driving license test	–
Fell, Jones, et al., 2011, United States	Cross-sectional study Time-series analysis Percent change (Coefficient from time-series regression models)	Jan 1990 – Dec 2007	Exposed to GDL (16-17-year-old drivers) GDL quality: good, less than good, or any (all GDL laws, regardless of rating)	Non-exposed to GDL exposed but exposed to drinking law (19-20_year-old drivers) Non-exposed to GDL nor	Primary seat belt law; Zero tolerance law; 0.08 BAC limit law; Use and lose law

Author, Year, Country	Sample, method/design and analysis type	Period covered	Test group	Control group	Research conditions / Control variables
				drinking laws (21-25-year-old drivers)	
Fell, Todd, et al., 2011, United States	Before-after study Relative difference	–	Exposed to GDL nighttime driving restriction or passenger restriction	Non-exposed to GDL nighttime driving restriction or passenger restriction	–
Jiang & Lyles, 2011, United States	Before-after study Two-tailed difference of proportion test and Chi-square test	Pre-GDL period: Jan 1994 – Dec 1996 Post-GDL period: Jan 2000 – Dec 2002	Exposed to GDL nighttime driving restriction (post-GDL period)	Non-exposed to GDL nighttime driving restriction (pre-GDL period)	–
Masten et al., 2011, United States	Cross-sectional study Time-series analyses Poisson regression models Relative risk (Adjusted Rate Ratio, aRR)	Jan 1986 – Dec 2007	Exposed to GDL	Non-exposed to GDL	State; annual state highway fuel use per capita; changes in state traffic safety-related laws (eg, seat belt laws); quarterly state unemployment rate; state linear trend and seasonality; and state contemporaneous age 20 through 24, 25 through 39, 40 through 59, and 60 years or older driver fatal crash involvement rates
Rogers et al., 2011, United States	Before-after study Time-series analyses Linear regression Percent change	Pre-GDL period: 1999, 1999 – 2004, or 1999 – 2005 Post-GDL period: 2008, or 2005 – 2008, or 2006 – 2008	Exposed to GDL (Post-GDL)	Non-exposed to GDL (Pre-GDL)	–
Scott-Parker et al., 2011, Australia	Quasi-experimental study design Chi square test Absolute proportion	–	Exposed to the revised-GDL (after July 1 st 2007)	Non-exposed to the revised-GDL (before July 1 st 2007)	–
Williams et al., 2010, United States	Before-after study Differences in rate ratios Percent change	Pre-GDL period: Jan 1995 – Dec 2000 Post-GDL period: Jan 2002 – Dec 2007	Exposed to GDL (Post-GDL period)	Non-exposed to GDL (Pre-GDL period)	–

3.2 SUMMARISING THE RESULTS

3.2.1 Meta-analyses

Four meta-analyses have been coded for this literature review. They were conducted in the United States, Canada, Germany, Austria, Sweden Norway, Finland, United Kingdom, Australia, and New

Zealand, amongst drivers and were focused on both the FPLT and the effect of the GDL on road users' safety.

Concerning GDL, the two-meta-analyses coded (Høye & Vaa, 2012; Zhu et al., 2013) showed that GDL has a global positive impact on road safety. First, Zhu et al. showed that the GDL implementation has effects for the youngest drivers. Indeed, GDL implementation was associated with a 22% reduction in traffic crash rates among 16 year olds, but only a 6% reduction in rates among 17 year olds and was unrelated to crash rates among 18 year olds. However, these results must be treated with caution, as the study was based on a small sample of four jurisdictions (Zhu et al., 2013). Second, the meta-analysis conducted by Høye & Vaa (2012) took into account multiple factors in the analysis of the effects. They estimated the effects on three types of accidents (injuries, fatal and unspecified), with three types of measures (night-time driving restriction, driving license with test period and global graduated driver license). Moreover, the GDL program was classified as good, fair, marginal or poor. The results showed that the three types of measures have a good impact on accidents and / or injuries reduction. In the night restriction period, the number of injuries significantly decreased by 36%. Moreover, adding a test period to the driving license has a positive effect on all types of crashes with the largest effect on the more serious ones (diminution of 14% for personal injuries and diminution of 26% for fatal crashes). GDL programs also have a positive effect in reducing crash rates, with the largest effect on night crashes (reduction of 31%), single crashes (21%) and alcohol-related crashes (23% but not significant).

Concerning the FPLT, two meta-analyses were coded, one on the effect of formal driver training versus informal driver training (Amundsen, 2011a) and one on the effects of different types of testing (Amundsen, 2011b). Regarding the driver training, results remain uncertain. After considering only studies with the strongest methodology, the authors have not shown any effect of the formal training on the number of accidents per driver. Moreover, they have shown a negative effect on accident per kilometre with an increase of 11% for accidents per kilometer driven for drivers who received a formal training compared to those who did not receive the formal training. When the results of all studies are considered altogether, regardless of the methodological quality, results show that drivers who completed the formal training have fewer accidents per driver and per kilometre (during first 1-2 years after the driving test) compared to drivers who have not completed it. Then, regarding the effects of a driving test, Amundsen (2011b) showed that (1) a formal training with a preliminary examination, (2) a voluntary advanced driving test and (3) a professional drivers commercial driving license test for heavy vehicles have all a positive effect on accident rates, with respectively 7%, 25% and 11% less accidents for those who passed the test compared to those who failed the test.

In addition to these meta-analyses, the results of additional original coded studies are summarised below.

3.2.2 Additional studies

Among the 30 remaining coded studies, only two were focused on powered two-wheelers. These studies were conducted in Finland and in Sweden and were both before-after studies. Considering this few number of studies, we cannot conclude on this point but studies globally showed a positive effect of the measures implemented for riders' road safety. More precisely, Kosola and collaborators showed positive changes in crash patterns and helmet use and a decrease of the injury incidence per PTW license (Kosola, Salminen, & Kallio, 2016). Bonander and collaborators reported a significant reduction of the injury crash rate involving teen moped drivers after the introduction of the AM license (Bonander, Andersson, & Nilson, 2015).

On the twenty-eight remaining coded studies focused on novice drivers' safety, five were focused on FPLT and 23 on GDL effects. A review-type analysis was conducted to investigate the effects of

these two countermeasures on road safety. The results are summarized in Table 12 for FPLT and Table 13 for GDL.

Table 12. Summary of the effects of the formal pre-license training on road safety (based on the five coded studies)

Road safety indicators	Effect	Main outcomes
Crash prevalence / Crash rate	↘	Significant reduction in the crash prevalence and of the injury and fatal crash rate for novice drivers who obtained their provisional operators permit after completing a specific mandatory driver education compared to those who obtained their license after 50h of adult supervised driving (Shell et al., 2015)
Crash involvement	↗	Significant increase in crash involvement for novice drivers who obtained their license through an intensive driving course than those who obtained it through a traditional driving education (de Craen & Vlakoveld, 2013)
Citation / Traffic violation rate	↘	Significant reduction in novice drivers traffic violations for those who obtained their provisional operators permit after completing a specific mandatory driver education than for those who obtained their license after 50h of adult supervised driving (Shell et al., 2015)
	↗	Significant increase in the risk of traffic offenses (speeding) for drivers who received a time-discount in their first years of unrestricted driving than those who did not (Begg & Brookland, 2015)
Global driving performance	NS	Non-significant effect of a driving simulator-based training on newly licensed drivers global driving performances, assessed both on-road and on a simulator (Rosenbloom & Eldror, 2014)
Glance behaviour (simulated driving)	↘	Participants who completed the computer-based training were faster at noticing the hazard indicator and in completing a critical glance sequence than participants from the two other control groups, in near and far transfer situations (Petzoldt et al., 2013)

↘: positive effect; ↗: negative effect; NS: non-significant

Table 13. Summary of the effects of the graduated driver licensing on road safety (based on the five coded studies)

Road safety indicators	Age of the driver	Effect	Main outcomes
Crash incidence or crash rate	< 18	↘	Significant reduction in the overall or injury or fatal crashes among young drivers after the implementation of a strict GDL program or revision of the existing one (Chapman, Sargent-Cox, Horswill, & Anstey, 2014; Cheng et al., 2012; Conner & Smith, 2016; Ehsani, Bingham, & Shope, 2013; Ehsani, Bingham, & Shope, 2013; Fell, Jones, Romano, & Voas, 2011; Fell, Todd, & Voas, 2011; Jiang & Lyles, 2011; Kaafarani et al., 2015; Lyon, Pan, & Li, 2012; Masten, Foss, & Marshall, 2011, 2013; Rajaratnam et al., 2015; Rogers et al., 2011; Rouse et al., 2013; Scott-Parker, Bates, Watson, King, & Hyde, 2011; Williams, Chaudhary, Tefft, & Tison, 2010)
			Significant reduction in the police-reported crash rate among young probationary drivers during the first year after the implementation of the decal law (Curry, Pfeiffer, Localio, & Durbin, 2013), which was still observed 2 years after (Curry, Elliott, Pfeiffer, Kim, & Durbin, 2015)
			Significant reduction of fatal crash among 16-year old drivers after the implementation of a medium or strict GDL program, but the effect is not significant for 17-year old drivers (Zhu, Zhao, Long, & Curry, 2016)
		NS	Non-significant effect of the passenger restriction (Williams et al., 2010), or the introduction of a minimum number of required supervised driving hours (Ehsani et al., 2013)
		↗	Significant increase in injury crash rate after night-time driving and passenger restrictions (GDL stage 2, intermediate licensing phase, Lyon et al., 2012)

	> 18	↘	Significant reduction in the fatal crash rate amongst 18 to 20 year old drivers after the implementation of a stricter GDL program (Conner & Smith, 2016)
		NS	Non significant change in crash rate among 18 year old drivers after the implementation or revision of GDL programs (Ehsani et al., 2013; Rouse et al., 2013; Williams et al., 2010)
		↗	Significant increase in crashes incidence after strict or lenient GDL implementation (Conner & Smith, 2016; Masten et al., 2011)
Citation / Traffic violation rate / Offence	<18	↘	Significant reduction in the self-reported offence rate among learner drivers (men in particular) after the revision of the GDL program (Scott-Parker et al., 2011)
		NS	Non-significant change in GDL citations after GDL decal provision (Curry, Pfeiffer, Elliott, & Durbin, 2015)
		↗	Significant increase in the traffic violation rate during the first year of unsupervised driving (Chapman et al., 2014), and during the first year after the implementation of the decal law (Curry et al., 2013)

↘: positive effect; ↗: negative effect; NS: non-significant

3.3 FULL LIST OF STUDIES

Table 14. List of the coded studies (sorted by year of publication and meta-analyses first)

Reference	Study summary	Bias
Conner, K. A., & Smith, G. A. (2016). An evaluation of the effect of Ohio's graduated driver licensing law on motor vehicle crashes and crash outcomes involving drivers 16 to 20 years of age. <i>Traffic injury prevention</i> , DOI: 10.1080/15389588.2016.1209493.	This study investigated the effects of the revised GDL law on motor vehicle crashes and motor vehicle crash-related injuries involving 16- to-20-year-old drivers in the state of Ohio. The authors conducted a before-after study. The exposure variable was the GDL law. Authors compared the outcomes between the pre-GDL period (from 2004 to 2006) and the post-GDL period (from 2008 to 2010). The outcome variables were the number of crashes and the number of injured occupants in crashes involving young drivers. Chi-square tests were used to assess statistical significance ($p < 0.05$) of categorical variables between the pre-GDL and post-GDL periods. Poisson regression models were used to estimate overall crash involvement, injury crash, and fatal crash rate ratios comparing the post-GDL and pre-GDL law periods for 16- to 17-year-old and 18- to 20-year-old drivers. In addition, Poisson regression models were used to estimate rate ratios among teen occupants ages 16–20 years in crashes with at least one driver 16–20 years of age. The results showed that implementation of stricter GDL program in Ohio were associated with reductions in the incidence of crashes, injury crashes and fatal crashes among young teen drivers and their occupants. Moreover, the post-GDL period to be associated with significant decreases in fatal crash rates among drivers ages 18 years and 18–20 years combined. The results also showed the post-GDL period was significantly associated with increases in overall crash involvement for both drivers and occupants ages 19 years, 20 years, and 18–20 years combined. Hence, the authors concluded that their study supported extending GDL restrictions to novice drivers ages 18–20 years to reduce crashes in that group.	The sample size for fatal crashes in this study was relatively small and, as a result, confidence intervals were large. Underestimation of injury crashes due to lack of data related to injury status or medical outcome. Missing standard error

Reference	Study summary	Bias
<p>Kosola, S., Salminen, P., & Kallio, P. (2016). Driver's education may reduce annual incidence and severity of moped and scooter accidents. A population-based study. <i>Injury</i>, 47(1), 239-243.</p>	<p>This study evaluated the effect of legislative change for moped and scooter drivers in reducing trauma from adolescents' accidents in Finland. The authors conducted a before-after study. The exposure variable was a new Finnish law enactment on June 2011 (before: 2008-2010; after: 2012-2013). The outcome variables were the driver status (alone, with passenger, or as passenger), the self-reported speed (<20 km/h, 20-45 km/h, or >45 km/h), the accident type (fall, collision, or undefined), the helmet status (intact, broken, fell off, or not in use), the trauma type (head, fracture, internal, or multiple), the proportion of hospitalisations, the proportion of surgical operations, and the incidence of injury. Chi square or Fisher's exact tests were used to compare data before and after the law enactment. The results showed that the increased moped/scooter license requirements associated with positive changes in accident patterns, helmet use, need for in-patient care and diagnosed trauma. Moreover, a positive change was noted in estimated injury incidence per moped/scooter license.</p>	<p>Due to the fact that this is a retrospective study, some information were missing (for example, data on, helmet use and velocities).</p> <p>Subjectivity of the speed-related data.</p> <p>Incidence figures per driver's license are only estimates and should be interpreted cautiously. These estimates are, however, based on circa a fifth of the population of appropriate age in Finland.</p>
<p>Zhu, M., Zhao, S., Long, D. L., & Curry, A. E. (2016). Association of graduated driver licensing with driver, non-driver, and total fatalities among adolescents. <i>American journal of preventive medicine</i>, 51(1), 63-70.</p>	<p>This study investigated the effectiveness of the graduated driver licensing programs on the traffic fatalities involving 16- and 17- year-old U.S. drivers. The authors conducted a before after study. The exposure variable was the GDL, classified in two ways: i) presence or absence, and ii) depending on its strength (weak, medium, strong). The outcome variable was the traffic fatalities collected from the Fatality Analysis Reporting System, which is maintained by the National Highway Traffic Safety Administration. Poisson regression models were used to estimate adjusted fatality rate ratios among teens aged 16-17 years, depending on the presence of a GDL program. The results showed that the presence of GDL programs (medium or strong GDL) significantly reduced the fatality rates of 16-year-old drivers. Seventeen-year-old road users generally did not experience substantial increase or decrease in fatalities after GDL implementation. Moreover, the findings indicated that GDL programs were not associated with increased fatalities for adolescents aged 16 and 17 years as passengers, pedestrians, bicyclists, and bus riders.</p>	<p>Missing standard error</p> <p>The licensure status of adolescents was unknown: the authors were not able to estimate the effects of individual GDL components (extended learner permit, night-time restriction, passenger restriction)</p> <p>As the sample size for pedestrians and bicyclists was relatively small, they were analyzed grouped together.</p>
<p>Begg, D., & Brookland, R. (2015). Participation in driver education/training courses during graduated driver licensing, and the effect of a time-discount on subsequent traffic offenses: Findings from the New Zealand Drivers Study. <i>Journal of safety research</i>, 55, 13-20.</p>	<p>This study investigated the effect of a three-month-time-discount on the first stage of the GDL obtained by learner drivers in New Zealand who attended a defensive driving course (DDC), on their traffic offense risk, once they were fully licensed. The authors conducted a prospective cohort study. The exposure variable was the time-discount obtained by drivers who attended to a DDC (two conditions: exposed/non-exposed). The outcome variable was the number of traffic offenses. Poisson regression with robust error variance was used to examine the effect of the time-discount on being issued with a traffic offence as a fully licensed driver. The results showed that the time-discount drivers had a higher relative</p>	<p>The use of the years on full license as a proxy measure for driving exposure on a full license is a potential limitation.</p> <p>Missing standard error</p>

Reference	Study summary	Bias
	<p>risk of receiving a traffic offense notice in their first years of full privilege driving, than those who had not received a time-discount. Moreover, the authors indicated that the most common offense was speeding, with 46% of the time-discount group receiving at least one speed offense notice, compared with 30% of the others. To conclude, it appeared that drivers who attended a DDC did not show increased safety benefits. Conversely, it seemed that the time-discount resulted in an increased risk of offending once young drivers were fully licensed. Hence, this time-discount should not be given for attending this kind of course.</p>	
<p>Bonander, C., Andersson, R., & Nilson, F. (2015). The effect of stricter licensing on road traffic injury events involving 15 to 17-year-old moped drivers in Sweden: A time series intervention study. Accident Analysis & Prevention, 83, 154-161.</p>	<p>This study investigated the impact of the AM driving license introduced in Sweden in October 2009 and required to drive Class 1 moped, on the rate of injury among road users involved in crashes involving teenage moped drivers (15-17 years old). The authors conducted a before-after study (before the intervention, from Jan 2007 to Sept 2009; after intervention, from Oct 2009 to Dec 2013). The outcome variables were the number of road traffic injury events and the number of persons involved in these crashes, both reported by the police during the study period (2007-2013). The exposure variable was the introduction of the AM license driving in October 2009. The instant effect of the intervention was studied from Oct 2009 for the 15-years-old moped drivers, and the delayed effects of the intervention were studied from Oct 2010 for the 16-years-old moped drivers and from Oct 2011 for the 17-years-old moped drivers. Segmented generalized additive models for location, shape and scale (GAMLSS model) were used to estimate the effect of the intervention and to control for non-linear secular trend and seasonality. The results showed that the rate of injury events involving teenage moped drivers has been reduced substantially after the introduction of the AM license. The effect could only partially be explained by changes in exposure (number of registered mopeds in traffic). There was no clear differential effect on event types or role of the injured road user (driver, passenger or counterpart), indicating that the AM driver license has reduced the rate of injury events involving teenage moped drivers in general.</p>	<p>Missing standard error</p> <p>The validity of interrupted time-series design used in this study depends on the assumption that nothing else happened at the time of the intervention that could bias the effect estimate. Hence, it is possible that campaigns or other safety initiatives introduced at the same time of the intervention could influence the size and direction of the change in injury events.</p> <p>The authors indicated that police-reported injury data may be subject to a larger degree of underreporting compared to hospital data. Moreover, the reporting of injury severity by the police is not as reliable as severity scores coded by physicians at hospitals. However, as the Swedish Traffic Accident Data Acquisition database contains incomplete data from emergency departments, police-reported injuries were thus deemed to provide the most consistent outcome measure overtime during the study period.</p>
<p>Curry, A. E., Elliott, M. R., Pfeiffer, M. R., Kim, K. H., & Durbin, D. R. (2015). Long-term changes in crash rates after introduction of a Graduated Driver Licensing decal provision. American journal of preventive medicine, 48(2), 121-127.</p>	<p>This study aimed at evaluating the 2-year effect of the New Jersey's graduated driver licensing (GDL) decal provision on the police-reported crash rates among 17 to 20 year old intermediate drivers. The authors conducted a before-after study. The exposure variable was the display of a GDL decal. Two periods were compared: pre-decal (from January 2006 to January 2010) versus post-decal (from May 2010 to June 2012). The outcome variable was the monthly rate of</p>	<p>The authors noted that the decline in crashes could be at least partly due to other aspects of New Jersey's GDL revision (e.g. continual increase in awareness around teen driving safety in the post-decal period).</p>

Reference	Study summary	Bias
	<p>police-reported crashes among drivers aged 17 to 20 years. Several crash characteristics were studied, related to injury, time of the day (midnight-4:59 AM; 11:01 PM-11:59 PM; 5:00 AM-11:00 PM), and persons involved (single-vehicle crash; multiple-vehicle crash; peer passenger). To accommodate overdispersion in the monthly counts of crashes, a negative binomial model was used. In addition, piecewise negative binomial regression models were also conducted among intermediate drivers for all crash types. The results showed a 2-year sustained reduction in the crash rate among intermediate drivers aged 17-20-years after the introduction of New Jersey's decal provision. Their overall adjusted crash rate was 9.5% lower in the post-decal period than in the 4 years prior (relative to 21- to 24-year-old licensed drivers), and they experienced a significantly greater rate of crash reduction after implementation. For several crash types, associations were particularly strong for 18- and 19-year-olds. The authors noted that the results of this study should be interpreted in light of the hypothesized mechanisms by which decals would result in a crash reduction—police officers' enforcement of GDL restrictions and teens' compliance with restrictions and other traffic safety laws. Findings of the current study—no additional reduction in post-midnight crashes after the decal's implementation, few crashes during the 11 o'clock hour, and a reduction in daytime crashes similar to that of all crashes—suggest that the decal did not exert an effect primarily through increased compliance with NJ's night restriction.</p>	<p>Missing standard error</p>
<p>Curry, A. E., Pfeiffer, M. R., Elliott, M. R., & Durbin, D. R. (2015). Association between New Jersey's Graduated Driver Licensing decal provision and crash rates of young drivers with learners' permits. <i>Injury prevention, 21(6), 421-423.</i></p>	<p>This study investigated the effect of the New Jersey's implementation of a graduated driver licensing (GDL) decal provision on the rate of GDL citations and crashes among drivers aged 16 to 20 years. The authors conducted a before-after study. The exposure variable was the display of a GDL decal. Two periods were compared: pre-decal (from January 2006 to January 2010) versus post-decal (from May 2010 to June 2012). The outcome variables were the police-reported crash rates per 10,000 drivers among drivers aged 16 to 20 years and the monthly rates of GDL citations. A piecewise negative binomial regression modelling was conducted to further account for existing crash trends among learner drivers themselves in the pre-decal period. The results showed no evidence to suggest that the decal provision was associated with a meaningful change in the GDL citation or police-reported crash rate among young drivers with learner's permits. It appears that lower crash rates post-decal were a function of a decline that began before the provision was implemented.</p>	<p>The authors were not able to directly measure changes in driving exposure that may have occurred over the study period. In particular, the recent economic recession may have led to a reduction in driving exposure among learner drivers in the pre-decal period and relative increase in the post-decal period as the economy recovered. The authors attempted to control for variations in driving exposure due to seasonal effects and economic conditions by including calendar month and gas prices in regression models.</p> <p>There were two concurrent changes in New Jersey's GDL system relevant to the permit and intermediate phases: (1) lowering of the night-time restriction from midnight to 23:01 and (2)</p>

Reference	Study summary	Bias
		<p>removal of immediate family member exemption from the passenger limit. However, occurrences of these driving conditions are expected to be very rare in this population, making these changes much less relevant than they would be for analyses of intermediate drivers.</p> <p>Missing standard error</p>
<p>Kaafarani, H. M., Lee, J., Cropano, C., Chang, Y., Raybould, T., Klein, E., ... & Velmahos, G. C. (2015). The impact and sustainability of the graduated driver licensing program in preventing motor vehicle crashes in Massachusetts. <i>Journal of trauma and acute care surgery</i>, 78(2), 265-271.</p>	<p>This study investigated the effect of the graduated driver licensing law implemented in 2007 in Massachusetts on crash rates among teen drivers aged 16-20 years. The authors conducted a before-after study. The exposure variable was the implementation of the GDL law in 2007 (pre-GDL period: 2002-2006, and post-GDL period: 2007-2011). The outcome were the rates of motor vehicle crashes (total and fatal) and the rate of total deaths (both per 100,000 population and per 100,000 licenses). Poisson regression model was used to examine whether there were significant differences in the incidence rates between the two intervals. The results showed that the 2007 GDL program was effective in decreasing the rates of total crashes, fatal crashes, and total deaths in the target teenage driver population of 16 years and 17 years. In addition, the effect of the law was sustainable over the 5 years following its passage, since the rates of total and fatal crashes and total deaths in the drivers aged 18 years to 20 years all decreased as well. Although there was a reduction in the rates of total and fatal crashes, and total deaths in the control group (25-29 years), the percentage decrease in total crashes was more pronounced in the 16-year-old to 20-year-old drivers. The percentage decrease in fatal crashes and total deaths was also higher for the 16-year-old to 20-year-old drivers, compared with the control group, but this trend did not reach statistical significance possibly because of the small number of fatalities resulting from motor vehicle crashes.</p>	<p>The existence of confounders related to changes in police logistics, resources, tactics, and enforcement or to social changes at the population level could have contributed to the positive results.</p> <p>The enactment of the distracted driver law that banned texting while driving in October 2010 could have confounded this study in its last year. However, since banning the use of mobile phones (for texting or driving) was part of the 2007 GDL law, the 2010 texting ban on adults affected only the group of 25-year-old to 29-year-old drivers and only in the last year of the study. This could have led to an underestimation of the effectiveness of the 2007 GDL law. Hence, the concomitant decrease in total and fatal crashes observed in the control group suggests that the effect noted in the drivers aged 16-17 years and 18-20 years is only partially related to the GDL laws, with a general trend toward decreased motor vehicle crashes in Massachusetts in the last few years.</p> <p>Missing standard error</p>
<p>Rajaratnam, S. M., Landrigan, C. P., Wang, W., Kaprielian, R., Moore, R. T., & Czeisler, C. A. (2015). Teen crashes declined after Massachusetts raised penalties for graduated licensing law restricting</p>	<p>This study investigated the effect of the revised version of the graduated driver licensing (GDL) law in Massachusetts implemented in March 2007, on teen driver crash risk. The authors conducted a before-after study. The exposure variable was the implementation of the revised law of the GDL in</p>	<p>Missing data on driving exposure</p> <p>Missing standard error</p>

Reference	Study summary	Bias
<p>night driving. <i>Health Affairs</i>, 34(6), 963-970.</p>	<p>March 2007. The outcome variable was the number of crashes (total and crashes causing fatal or incapacitating injury). Chi² tests were used to examine changes in crash rates from before to after the new law's implementation. Poisson regression models were used to examine whether there were significant differences in the incidence rates between the two age-groups (16-17 and 20 or older) and the two intervals (one year before the new GDL law and five years after), and whether there was an interactive effect of these two factors. The results showed that following implementation of a stricter GDL law in Massachusetts, one that included new penalties for unsupervised night driving, the rate of overall and night police-reported crashes decreased by 19.1 percent and 28.8 percent, respectively, for drivers ages 16-17, relative to drivers ages 20 and older. The rate of crashes involving a fatal or incapacitating injury fell by 39.8 percent for the younger drivers, relative to the rate for older drivers. Altogether, these findings indicated that a GDL law including significant penalties for unsupervised night driving was highly effective in reducing teen driving crashes.</p>	
<p>Shell, D. F., Newman, I. M., Córdova-Cazar, A. L., & Heese, J. M. (2015). Driver education and teen crashes and traffic violations in the first two years of driving in a graduated licensing system. <i>Accident Analysis & Prevention</i>, 82, 45-52.</p>	<p>This study investigated whether teens taking driver education differed in crashes and moving traffic violations from teens not taking driver education within a graduated driver licensing (GDL) program. The authors conducted a cohort study. The exposure variable was the provisional operator's permit obtention (POP) with either 50 hours of supervised driving documented on a certification form or a certified driver education course. The outcome variables were the number of crashes (overall and fatal/injury crashes) and the number of traffic violations (overall and alcohol-related violations). Chi-square tests were used to compare the number of crashes or traffic violations between both teen driver cohorts in the POP first and second years. The results showed that the cohort of teens who obtained their POP through driver education had significantly lower prevalence of a crash, injury/fatal crash, traffic violation, or driving under influence in both the first and second year of driving after obtaining their POP than the cohort of teens who obtained their POP through 50 h of adult supervised driving.</p>	<p>The study is confined to a single small, predominantly rural state that may not be representative of the majority of states. The study is not a true randomized controlled experiment, as teens self-select whether they will take driver education or do the certification log. There are clear demographic differences in this choice, with certification log the choice of rural, male, non-White, poorer, and older teens. The authors applied statistical controls to these demographic differences, but statistical procedures cannot fully compensate for random assignment. The psychological characteristics of teens who chose to take driver education vs those who did the 50 h of supervised driving were not considered in this study. However, they could be relevant for differences in the crash and violation outcomes of the driver education and certification log cohorts. Missing standard error</p>

Reference	Study summary	Bias
<p>Chapman, E. A., Masten, S. V., & Browning, K. K. (2014). Crash and traffic violation rates before and after licensure for novice California drivers subject to different driver licensing requirements. Journal of safety research, 50, 125-138.</p>	<p>This study investigated the evolution of crash and traffic violation rates for California novice drivers (aged 16 or 17 years and who hold their learner permits under the Graduated Driver Licensing (GDL) program, or aged 18-24 years) between the months before and the months after licensure, in comparison to older drivers aged 25-35 years. The authors conducted a before-after study. The exposure variable was the time interval since GDL, with different conditions (12 months prior to licensure, 1-3, 4-6, 7-12, 13-24, and 25-36 months after licensure). The outcome variables were the number of crashes (overall, fatal or injury crashes and at-fault crashes) and the number of traffic violations. Poisson regression models were used to estimate adjusted rate ratios comparing age 16, 17, 18, 19, 20, and 21-24 novices to those ages 25-35 during each time interval. The results showed that the crash rates of novice drivers aged 16 and 17, as well as those of most novice drivers aged 18 or older were highest during the first few months of unsupervised licensure, after which their rates declined quickly during the first year and continued to decline slowly during subsequent years. Moreover, the traffic violation rates of novice drivers aged 16 and 17 were distributed differently than their crashes. They increased steadily after licensure until around the time drivers turned age 18, which was a year or more after their crash rates reached their apex and began to decline. In contrast, the traffic violation rates for all other age groups of novices were highest during their first year of unsupervised driving, typically only months after their peak crash rates. In conclusion, it appeared that both pre-licensure crash rates and post-licensure crash peaks were more pronounced for some older age groups of novices than was the case for 16–17-year-olds. Extending learner permit holding periods for 16–17-year-old novices appears consistent with their actual behavior; requiring older novices—particularly those ages 18 to 20—to hold permits for minimum periods may reduce their initial crash rates.</p>	<p>Small sample: Results are based on novice drivers in only one U.S. state (California) Only traffic violations for which drivers were actually convicted were included in this study, because violations that are dismissed before conviction are never reported to the Department of Motor Vehicles. Crashes and traffic violations were not adjusted for differences in driving exposure (mileage), which varies according to both driver age and years of driving experience. Missing standard error</p>
<p>Rosenbloom, T., & Eldror, E. (2014). Effectiveness evaluation of simulative workshops for newly licensed drivers. Accident Analysis & Prevention, 63, 30-36.</p>	<p>This study examined the possible qualitative difference in safe driving during the first year of licensure between drivers whose training included simulator-based lessons and drivers whose training did not include simulated-based lessons. The authors conducted a quasi-experimental study. The exposure variable was the simulator-based training (two groups: an experimental group exposed to the simulator-based training and a control group). The outcome variables were the driving performance assessed by a driving expert; the driving events severity scores, and other driving dependant variables (Brake pedal press duration; Headway: time-to-collision; Headway variance previous TTC sample; Driving session: distance, speed, speed variance; Acceleration events count; Turning events count; Braking events count; Braking pedal presses count; and Headway events count). Multiple analyses of variance and t-tests were used to compare driving</p>	<p>Non-random assignment to groups: Due to the quasi-experimental design, the authors could not control the participants' assignment to driving schools, which could have entailed selection bias. Missing Confidence intervals</p>

Reference	Study summary	Bias
	<p>performances between the two groups. In addition, poisson regression models were performed to compared the safety events counts between groups. This study did not find any substantial difference between newly licensed drivers who received and who did not receive simulator training. The results showed that the driving expert's realtime driving evaluations were similar for both groups. Moreover, exact measurement of vehicle variables recorded by several monitoring systems did not indicate an overall substantial difference between drivers who received and did not receive simulator training in the amount, severity and variance of safety events measured. However, drivers who received simulator training displayed a lower headway events count and a lower headway variance, and in contrast, a higher brake pedal press count. Possibly, drivers who received simulator training monitored their headway more actively and increased their braking pattern to ensure a safe distance from any vehicle in front of them.</p>	
<p>Zhu, M., Cummings, P., Chu, H., Coben, J. H., & Li, G. (2013). Graduated driver licensing and motor vehicle crashes involving teenage drivers: an exploratory age-stratified meta-analysis. Injury prevention, 19(1), 49-57.</p>	<p>This study aimed at estimating age-specific associations between graduated driver licensing (GDL) implementation in the United States and Canada and crash rates. The authors conducted a systematic review and a meta-analysis (24 studies were included). The exposure variable was the GDL (exposed or non-exposed). The outcome variable was the traffic crash rates involving 16- to 18-year-old drivers. Poisson regression was used to estimate the association between GDL implementation and crash rates, with age-specific person-time as offsets. Inverse-variance method was used to produce pooled estimates of the adjusted rate ratios from each study. Then, random effects models were used to pool adjusted rate ratios. The results showed that GDL implementation was associated with a 22% reduction in traffic crash rates among 16 year olds, but only a 6% reduction in rates among 17 year olds. GDL implementation was unrelated to crash rates among 18 year olds. The authorshighlighted that this exploratory finding was based upon a sample of only four jurisdictions and should be treated with caution.</p>	<p>Excluded studies not listed</p> <p>Missing standard error</p> <p>Small number of studies available with age-specific data for ages 17 and 18 years.</p> <p>The authors noted that their estimates may be subject to residual confounding, as GDL effectiveness should ideally be estimated with many repeated measures of crash rates before and after GDL implementation.</p> <p>Lack of information about the amount of driving done by adolescents.</p>
<p>Curry, A. E., Pfeiffer, M. R., Localio, R., & Durbin, D. R. (2013). Graduated driver licensing decal law: effect on young probationary drivers. American journal of preventive medicine, 44(1), 1-7.</p>	<p>This study investigated the effect of GDL decal laws on police enforcement of graduated driver licencing restriction. The authors conducted a before-after study. The exposure variable was the GDL decal laws. The pre-law period was defined as January 2008-January 2010 and post-law period as May 2010-May 2011. The outcome variable was the monthly crash rate, per 10,000 probationary drivers aged <21 years; and the monthly citation rate, per 10,000 probationary drivers aged <21 years. Negative binomial regression models were used to determine the law's effect on crash and citation rates and estimate prevented crashes. The results showed that in the first year after implementation of the decal law, there was a 14% increase in the rate of GDL-related citations issued to young probationary drivers, a</p>	<p>Missing standard error</p>

Reference	Study summary	Bias
	9% reduction in the rate of police-reported crashes among such driver.	
de Craen, S., & Vlakveld, W. P. (2013). Young drivers who obtained their licence after an intensive driving course report more incidents than drivers with a traditional driver education. Accident Analysis & Prevention, 58, 64-69.	This study investigated the effect of an intensive driving course on the self-reported number of crashes involving novice drivers. The authors conducted a two-year longitudinal study. The exposure variable was the intensive driving course performed by the experimental group. The control group completed a traditional driving education. The outcome variable was the total number of self-reported crashes (defined as incidents inducing property damage or person injury). Chi-square test was used to compare the proportion of crashes between the two groups of novice drivers. The results showed that novice drivers who obtained their driving license through the intensive driving course reported a crash significantly more often (43%) during the two years following their licensure than novice drivers who obtained their driving license through a traditional driving education (26%). The authors concluded that the available knowledge on learning complex skills indicates that intensive driving courses are not recommendable, from a road safety point of view.	Possible self-selection bias due to the fact that the novice drivers have not been randomly assigned to one of the two programmes. The drivers from the test group chose the intensive driving course over a traditional education. Small sample: few drivers in the test group (only 39 over the 434 novice drivers).
Ehsani, J. P., Bingham, C. R., & Shope, J. T. (2013). Graduated driver licensing for new drivers: effects of three states' policies on crash rates among teenagers. American journal of preventive medicine, 45(1), 9-18.	This study examined the effects of the GDL in three American states (Florida, Michigan and Maryland) on crash rates involving drivers aged 16, 17 and 18 years. The authors conducted a time-series analysis. The exposure variable was the GDL program implemented in 1996, 1997 or 1999 depending on the state considered. The outcome variable was the crash rates (causing either i) fatal/disabling injury, or ii) nondisabling injury, or iii) possible injury or property damage only). Auto-Regressive Integrated Moving Average (ARIMA) interrupted time-series analysis was used to analyze monthly crash rates for each state. The results showed that in Florida, crash rates for drivers aged 16 and 17 years significantly declined after the revision of the GDL program. For the 18-year-old drivers the GDL's introduction and revision were not associated with any changes in crash rates. In Michigan, crash rates of 16-year-old drivers significantly decreased after the GDL's introduction (all crash types). For the 17-year-old drivers, only fatal and disabling injury crash rates significantly decreased after the GDL's introduction; and for the 18-year-old drivers, this significant reduction concerned possible injury and possible damage only crashes. Finally, in Maryland, the GDL did not significantly reduce the fatal crash rates among 16-year-old drivers but decreased their nondisabling crash rates. The GDL significantly decreased the fatal and disabling injury crash rates among the 17-year-old drivers. For the 18-year-old drivers, the GDL's revision significantly decreased the possible injury and property damage only crash rates.	Small sample: Crash data for only three states have been included in this study. Inclusion of more states might have strengthened the finding that GDL policies that are applied exclusively to novice drivers aged <18 years may result in increased crash rates for drivers aged 18 years. Differential GDL effects on crash rates by gender were not examined. Missing standard error and confidence intervals
Ehsani, J. P., Bingham, C. R., & Shope, J. T. (2013). The effect of the learner license Graduated Driver Licensing components on	This study aimed at quantifying the effect of two graduated driver licensing components (the duration of the learner license and the number of required hours of supervised driving) on 16- and 17-year-old	Only fatal crashes were considered in this study not all types of crashes.

Reference	Study summary	Bias
<p>teen drivers' crashes. <i>Accident Analysis & Prevention</i>, 59, 327-336.</p>	<p>drivers' fatal crash rates. The authors conducted a time-series analysis. The exposure variables were the introduction of a minimum duration of the learner license (months) and the introduction of a minimum number of required supervised hours. The outcome variable was the rate of fatal crashes involving 16- and 17-year-old drivers (per 100,000 population). The effects of each GDL component on combined 16- and 17-year-old drivers' crashes were pooled across states using a random effects meta-analytic model. The results showed that the introduction of the learner license minimum holding period resulted in a significant decline in teen drivers' fatal crash rates, while the introduction of a minimum number of required supervised driving hours had no effect.</p>	<p>Missing standard error</p> <p>In some of the states, components were introduced within an existing GDL system. Consequently, the additive effect of multiple co-existing GDL components could not be disentangled.</p>
<p>Gulliver, P., Begg, D., Brookland, R., Ameratunga, S., & Langley, J. (2013). Learner driver experiences and crash risk as an unsupervised driver. <i>Journal of safety research</i>, 46, 41-46.</p>	<p>This study investigated the crash risk during the restricted license stage, for drivers who drove unsupervised at the learner license stage. The authors conducted a cohort study. The baseline interviews were conducted during cohort recruitment (from 1st February 2006 to 31st January 2008). Two follow-up interviews took place on the 17th September 2010 and on the 30th May 2011. The exposure variable was the unsupervised driving at learner license stage (exposed / non-exposed). The outcome variable was the number of crash in which the drivers were involved during the restricted license stage. Poisson regression model was used to estimate the relative risks of learner license variables with crash involvement. The results showed that drivers who had driven unsupervised as a learner driver were at heightened risk of crash involvement in the restricted license stage. Moreover, the authors conclude that learner drivers should be encouraged to spend more time on their learner license to enable them to gain skills and experience to help reduce their crash risk when they are allowed to drive unsupervised.</p>	<p>Missing standard error</p>
<p>Langley, J., Begg, D., Samaranayaka, A., Brookland, R., & Weiss, H. (2013) Unsupervised driving by learner licence holders: Associated characteristics and crash risk. <i>Accident Analysis & Prevention</i>, 60, 24-30.</p>	<p>This study aimed to determine whether learner drivers who drove unsupervised were at higher risk of crash than those who did not. The authors conducted a prospective cohort study. The exposure variable was the adherence to the supervisory driving restriction with three conditions: full, medium (1-12 unpervised trips per year) or non-adherence (more than 13 unsupervised trips per year). The outcome variable was the number of crashes. Modified Poisson model was used to estimate the independent effect of unsupervised driving on the crash occurrence after adjusting for confounders. The results showed that learner drivers who reported driving unsupervised 1–12 times per year were 80% more likely to be involved in crash than those who reported never having done this. The risk approximately doubled for those in the 13+ group. Given that a significant portion of learner licence holders report driving unsupervised and those that violate this condition the most are more likely to crash, improving compliance with learner licence supervised driving conditions warrants increased attention.</p>	<p>Missing standard error</p>

Reference	Study summary	Bias
<p>Masten, S. V., Foss, R. D., & Marshall, S. W. (2013). Graduated driver licensing program component calibrations and their association with fatal crash involvement. <i>Accident Analysis & Prevention</i>, 57, 105-113.</p>	<p>This study aimed at identifying the graduated driver licensing (GDL) component calibrations associated with the largest reductions in fatal crash involvements for 16–17-year-olds. The authors conducted a before-after study. The exposure variables were the components of the GDL (the learner permit minimum holding time period, the number of supervised driving hours, the night-time driving restriction, the passenger restriction, the learner stage minimum entry age, intermediate stage minimum age, and the unrestricted licensure minimum age). The outcome variable was the fatal crash incidence (rate per 100,000 person-years). Age-specific poisson regression models were used to estimate driver fatal crash involvement rate ratios for learner drivers aged 16 and 17 years. The authors concluded that there was compelling evidence that (a) a minimum learner permit holding period of 9–12 months and (b) a passenger restriction allowing only one teen passenger for 6 months or longer were the calibrations for these components associated with the largest reductions in 16–17-year-old driver fatal crash involvements. There was less compelling evidence limited to only 16-year-olds suggesting that (a) disallowing learner driving until age 16, (b) disallowing intermediate licensure until age 16½ to 17, and (c) a night-time driving restriction starting at 10 PM or earlier were the calibrations for these components associated with the largest reductions in 16-year-old driver fatal crashes. And finally, there was no clear evidence to support particular calibrations for supervised driving hours or unrestricted license ages.</p>	<p>Only fatal crashes were considered in this study, not all type of crashes</p> <p>Missing standard error</p>
<p>Petzoldt, T., Weiß, T., Franke, T., Krems, J. F., & Bannert, M. (2013). Can driver education be improved by computer based training of cognitive skills?</p>	<p>This study investigated the effectiveness of a computer based training of cognitive driving skills on the visual scanning and the detection of potential hazards during a driving simulator task conducted among learner drivers. The authors conducted an experimental study. The exposure variable was the cognitive training (with two experimental conditions: a computer based training and a paper based training; and one control group). All the participants were recruited from local driving schools. The outcome variables were related to the glance behavior (e.g. time to detect the hazard indicator). One-factorial between subjects ANOVAs were calculated to compare the performances of the different groups. The results showed that the computer baser training had a positive effect on learner drivers' glance behaviour. Participants were faster in fixating the hazard indicator, and faster in completing a critical glance sequence than participants from the two other groups. This positive effect occurred in near as well as far transfer situations. The authors concluded that this type of training can potentially assist inctruction of cognitive skills necessary for safe driving. However, although the results seem to indicate positive effects of the computer based training compared to another form of training or to a control group, the authors noted the lack of information about how this training allows the learner to become an experienced driver.</p>	<p>Small sample: less than 15 participants per group.</p> <p>The fact that a rather small sample with was tested in a rather variable environment (the driving simulation) leads to a lot of variance, which makes a scenario-wise analysis impossible. In that sense, the results of this study can only serve as a broad indicator that a CBT can have positive effects on glance behaviour, without too specific interpretations of CBT items or driving scenarios.</p>

Reference	Study summary	Bias
<p>Rouse, H. L., Aitken, M. E., Lein, S. D., Leath, K. J., Halverson, P., & Thompson, J. W. (2013). Statewide policies for safer teen driving: An evaluation of the impact of graduated driver licensing in Arkansas.<i>Journal of trauma and acute care surgery, 75(4), S281-S284.</i></p>	<p>This study investigated the effectiveness of the GDL program in improving road safety in Arkansas. The authors conducted a before-after study. The exposure variable was the GDL program. As the GDL law was implemented in 2009, two periods were considered: 2008 (pre-GDL) and 2010 (post-GDL). The outcome variable was the number of crashes (overall and fatal). Chi-square analyses were used to test the significance of differences between each rate found for each age group (<16, 16, 17, 18, 19, 20-24, 25-29, 30-34, 35-69 years) between 2008 and 2010. The data (obtained from the Arkansas State Police Motor Vehicle Crash Data and the US Department of Transportation's Federal Highway Administration) were used to create crash rates per 10,000 licensed drivers during each calendar year by age (<16, 17, 18, 19, 20-24, 25-29, 30-34, and 35-69 years). Rates of crashes that resulted in at least one fatality were calculated similarly for each year by age. The results showed substantial reductions in overall crash rates and fatal crash rates for teen drivers in Arkansas during the first year after implementation of the GDL law. 18-year old drivers or younger and subject to the provisions of the GDL, demonstrated significant reductions in the number of crashes (-22%) and the number of fatal crashes (-59%). Conversely, no reduction in crash rates was observed during the study time frame for drivers aged more than 18 years. The analyses also revealed a 76% reduction in teen driving fatalities during night-time hours and a 20% reduction in crashes involving teen drivers carrying five or more passengers. Hence, these findings support the night-time driving and passenger restrictions for teen drivers.</p>	<p>The small sample sizes result from the exclusive focus on 2 years' data. But, statistically significant results were still found.</p>
<p>Høye, A. & Vaa, T. (2012). Graduated driver's license and driving restrictions. The handbook of Road Safety Measures, Norwegian (online) version. tsh.toi.no/index.html?22047</p>	<p>This meta-analysis shows the effect of graduated driver's license GDL and driving restrictions on road safety. Based on 14 studies, estimate for the effect on accidents (unspecified, injury and fatal) on three types of measures within GDL are presented. These are: Prohibition to drive during night, driver's license test and graduated driver license (restrictions vary between GDL programs). Additionally, the effect of GDL programs in the US are presented and classified as good, fair, marginal or poor depending on the length of the training period and restrictions (Morrisey m.fl., 2006). In the night restriction period, the number of injuries significantly decreased by 36%. Driving license with test period has a significant accident reduction effect by 3%. Results show that best effect of GDL on accidents is a 19% drop in accidents of unspecified severity. For personal injuries, the estimated decline is 14% and for fatal accidents 26%, so the effect is larger for more serious accidents. The largest accident-reducing effect of GDL was night accidents (-31%) and single accidents (-21%). A reduction of 23% were found in alcohol related accidents but this effect is not significant. Results and differences between the results of several studies suggest that the stated effects can be 2 to 4 times as large as they would have been with control of the number of license holders and trend. There are</p>	<p>Results and differences between the results of several studies suggest that the stated effects can be 2 to 4 times as large as they would have been with control of the number of license holders and trend.</p>

Reference	Study summary	Bias
	only few studies that have investigated the effects of GDL on men and women, and there are no clear results about the differences between the sexes	
<p>Cheng, J. D., Schubmehl, H., Kahn, S. A., Gestring, M. L., Sangosanya, A., Stassen, N. A., & Bankey, P. E. (2012). Impact of a graduated driver's license law on crashes involving young drivers in New York State. <i>Journal of trauma and acute care surgery</i>, 73(2), 457-461.</p>	<p>This study investigated the effect of the graduated driver licensing (GDL) law enactment in September 2003 on the number of crashes involving young drivers (<18 and 18- to 20-year-old) in the state of New York, USA. The authors conducted a before-after study. The exposure variable was the GDL law enactment in September 2003. Three periods were considered: i) the pre-GDL period from 2001 to 2003, ii) the first post-GDL period from 2004 to 2006, and iii) the second post-GDL period from 2007 to 2009. From 2004 to 2006, drivers training under the new system eventually replaced the 16-year-olds and 17-year-olds who were licensed under the old system. Lastly, 2007 to 2009 consisted entirely of drivers licensed under GDL laws. The outcome variable was the number of crashes. Two types of crashes were considered, depending on their severity: fatal crashes and personal-injury crashes. Pearson's Chi-square statistic was used to compare the proportion of fatal and personal-injury crashes between i) the pre-GDL period and the first post-GDL period, and ii) the first post-GDL period and the second post-GDL period. The results showed a statistically significant decrease in the number of fatal and personal-injury motor vehicle crashes involving young drivers in New York State from the 2001-2003 time period to the 2007-2009 time period, after the enactment of the 2003 GDL laws. The authors suggested the changes in motor vehicle crashes and fatality rates noted cannot definitively be attributed solely to GDLs due to the potential for other confounders, namely improvements in car safety and financial restrictions on driving experience from the economic downturn. However, the authors suspected that the minimal reduction in motor fuel consumption and changes in vehicle and driver demographics alone cannot fully explain the 50% decrease in young driver mortality and the more than 40% decrease in personal-injury crashes during the study period.</p>	-
<p>Lyon, J. D., Pan, R., & Li, J. (2012). National evaluation of the effect of graduated driver licensing laws on teenager fatality and injury crashes. <i>Journal of safety research</i>, 43(1), 29-37.</p>	<p>This study aimed at analyzing the relative effects of graduated driver licensing (GDL) stages 1 and 2, depending on the strictness of their restrictions, on crash risk among road users aged 15- to 17-year-old. The authors conducted an observational study. The exposure variable was the strictness of the GDL stages. The stage 1 referred to the permit license period and the stage 2 referred to the intermediate license period. Depending on the strictness of restrictions, each GDL stage was classified into one of three categories, with A being the strictest and C the most lenient. The outcome variable was the number of crashes involving teen road users (15-17 years). Several types of crash were considered: fatal crashes, injury crashes, "night" injury crashes which occurred between 11 pm and 6 am, and "passenger" injury crashes which involved more than two passengers</p>	<p>The authors note that variance among state effect estimates underline that there exist other significant variables that are not directly accounted for in their model.</p> <p>Missing data on driving exposure</p> <p>Missing standard error</p>

Reference	Study summary	Bias
	<p>between ages 15 and 19. Negative binomial generalized linear model with random state effects was used to analyse the relative effect of different stages of GDL on teenage crash risk. The results showed that, for each crash type observed and relative to a lenient stage (C), the effect estimate for a moderate stage (B) was more limited than that of a strict stage (A). The reduction of injury crashes, as far as they can be attributed to GDL, was almost exclusively associated with a stricter stage 1 (A). Even though the intermediate restrictions (B) were less effective at reducing overall crashes, they did appear to help reduce the fatal ones. The authors concluded that a strong stage 1, regarding stricter permit laws, appeared to have had a strong impact on all crash types. Intermediate licensing, taking the form of night or passenger restrictions, have also been significantly associated with a reduction in fatality crashes and night-time and multiple passenger injury crashes. However, the results suggested that intermediate restrictions were not effective at reducing the number of injury crashes overall. There was evidence that the number of crashes with one or less teenage passengers may actually increase, possibly because passenger restrictions encourage teenagers to drive separately, putting more vehicles on the road. In other words, the modes of injury crashes have shifted due to these restrictions.</p>	
<p>Amundsen, A. (2011). Basic driver training. The Handbook of Road Safety Measures, Norwegian (online) version. tsh.toi.no/index.html?22047</p>	<p>In this meta-analysis, a comparison was made of 16 studies on formal driver training with informal training on the effect of on road safety. The best research is organized as experiments, where drivers randomly were divided between formal and informal education. These studies show that drivers who have received formal training has the same number of accidents per driver ($0 \pm 4\%$) compared to drivers who have not received formal training and that they have 11% (+ 8%; + 15%) more accidents per kilometer driven than drivers who have not received formal training. The more driving lessons you have in formal training, the more increases the risk of accidents per kilometer driven. In sum the results cannot prove that the formal training drivers reduces drivers' accident rate. When the results of all studies are considered together, regardless of the methodological quality, results show that drivers who have undergone formal training have 2% fewer accidents (-4%; 0%) per driver than drivers who have not undergone formal training and 4% (-6%; -2%) fewer accidents per kilometer driven than drivers without such training. The results concerns, mostly, the number of accidents per driver or per kilometer driven the first 1-2 years after the driving test is passed. The relation between the number of driving hours and impact of formal training on drivers' accident were also presented as a graph with the equation $y = 13.965 \ln(x) - 21.851$.</p>	<p>Lack of methodological detail: No information about which studies are experimental corresponding to data</p> <p>Meta-analysis: Excluded studies not listed, no studies after 1996 were included</p>
<p>Amundsen, A. (2011). The driving test. The Handbook of Road Safety Measures, Norwegian</p>	<p>This meta-analysis describes the relation between different forms of driver license tests and the amount of accidents. The results showed that drivers who</p>	<p>Small sample, very few studies per measures</p>

Reference	Study summary	Bias
<p>(online) version. tsh.toi.no/index.html?22743</p>	<p>passed a theory test had the same accident rate as drivers who failed the test. Driving tests are more disparate and drivers who passed the final preliminary examinations in formal training showed 7% lower accident risk than drivers who failed this test. Drivers who passed the examination of a voluntary, advanced driving test had 25% lower risk than drivers who failed the test. Professional drivers who passed a voluntary Commercial Driving License Test for heavy vehicles had 11% fewer accidents. The effects of a more rigorous theoretical and driving tests for drivers of heavy vehicles, showed that the number of injury increased by about 5% after the rigorous driving test was introduced, it is unclear why.</p>	<p>Meta-analysis: Excluded studies not listed, no studies after 1996</p>
<p>Fell, J. C., Jones, K., Romano, E., & Voas, R. (2011). An evaluation of graduated driver licensing effects on fatal crash involvements of young drivers in the United States. <i>Traffic injury prevention, 12(5), 423-431.</i></p>	<p>This study aimed at evaluating the effect of GDL laws on the fatal crash involvements of novice drivers while controlling for possible confounding factors not accounted for in prior studies. The authors conducted a cross-sectional study and a time-series analysis. The exposure variable was the GDL rating (any, good, less than good). The outcome variable was the number of fatal crashes. The authors compared the 16- and 17-year-old driver involvement in fatal crashes (where GDL laws are applied) relative to two other driver age groups (19–20, 21–25) where GDL would not be expected to have an effect. The authors applied the autoregressive integrated moving average (ARIMA) intervention regression method to evaluate the effect of the GDL law enactment on the fatal crash incidence among 16-17-year-old drivers relative to the 2 older driver age groups. To account for crash exposure, the authors computed and compared ratios of the 16-17-year-old drivers involved in fatal crashes with 19-20 and 21-25-year-old drivers. The ratios were log-transformed to normalize the distribution. The results showed that the adoption of a GDL law of average strength was associated with a significant decrease in fatal crash involvements of 16- and 17-year-old drivers. Moreover, it appeared that "good" GDL laws produced greater reductions in the fatal crash ratios than did the average GDL laws. Conversely, the analysis of the effectiveness of the "less than good" laws found that (with one small exception) they did not appear to be effective in reducing 16- and 17-year-old driver fatal crashes. It should be noted, however, that the effectiveness of GDL laws varies with the extent to which their key components are implemented. Thus, the strength of the GDL laws provides additional evidence for their effectiveness.</p>	<p>A number of the sample sizes for 16- and 17-year-old driver involvements in fatal crashes in the state-by-year analyses were small, increasing the year-to-year variance in the ratios of fatal crashes for age groups.</p> <p>Differences in exposure: Changes in crash exposure that occur differently across age groups may not have been fully accounted for by the use of fatality ratios. The older comparison group (21-25 yo) exhibited a large reduction in crash involvements over the period of the study. The use of a crash ratio and a time trend in the analysis may not have fully compensated for the adult trend.</p> <p>Gender or ethnicity were not considered in this study</p>
<p>Fell, J. C., Todd, M., & Voas, R. B. (2011). A national evaluation of the night-time and passenger restriction components of graduated driver licensing. <i>Journal of safety research, 42(4), 283-290.</i></p>	<p>The study investigated the effectiveness of two elements of GDL laws: night-time driving restrictions and passenger limitations. The authors conducted a before-after study. The exposure variables were the GDL night-time driving restriction (four categories: absence of restriction; restriction from 11:00 P.M. or earlier; restriction from midnight; or overall night-time restriction); and the passenger restriction (two modalities: exposed or non-exposed). The outcome variable was the number of fatal crashes. Ratio of</p>	<p>Smaller sample size</p> <p>The authors were unable to control for differences in traffic enforcement intensity; publicity surrounding GDL laws, or parental influence on driving.</p>

Reference	Study summary	Bias
	<p>fatal crashes were calculated depending on the age of the driver (four categories: 16-17; 19-20; 19-25; 19-29); the time of the accident (two modalities: night-time, from 9 p.m. to 5 a.m.; daytime, from 5 a.m. to 9 p.m.); the alcohol consumption (two modalities: drivers with BACs\geq.01 g/dL; drivers with BACs\leq.00 g/dL); and the presence of a passenger (Yes/No). A log transformation was performed to reduce skewness in distributions of the ratio measures. Then, linear mixed models were used to examine the effect of GDL restrictions. The results showed that both night-time restrictions and passenger limitations are effective in reducing novice driver fatal crashes, which confirm the effectiveness of these measures in GDL systems.</p>	
<p>Jiang, X., & Lyles, R. W. (2011). Exposure-based assessment of the effectiveness of Michigan's graduated driver licensing night-time driving restriction. <i>Safety Science</i>, 49(3), 484-490.</p>	<p>This study investigated the effectiveness of the Michigan's graduated driver licensing (GDL) night-time driving restriction on 15- to- 17-year-old drivers' road safety. The authors conducted a before after study. The exposure variable was the GDL program (pre-GDL period from 1994 to 1996; post-GDL period from 2000 to 2002). The outcome variables were the numbers of drivers responsible and non-responsible for a crash. Two age groups were considered: 15- to-17-year-old drivers and 35- to- 50-year-old drivers (reference group). Two-tailed difference of proportion test was used to verify the significant status of the change in the total number of non-responsible drivers between pre- and post-GDL. Moreover, Chi-square was used to compare the total number of responsible and non-responsible drivers between pre- and post-GDL. As there was only one degree of freedom, an adjustment, the Yates correction, was used for continuity. The results showed a significant reduction in the number of non-responsible 16- to- 17-year-old drivers, which indicates the capability of the curfew law to discourage the young drivers from driving illegally. Moreover, the results showed a significant reduction of the relative involvement ratios (which represents crash risk) of the 16- to- 17-year-old drivers between pre- and post-GDL, suggesting that the GDL program is effective to improve young drivers' road safety. Furthermore, the accident risk disaggregated by time of day appears to be reduced under post-GDL, albeit not statistically significant. The authors suggested that this statistical insignificance could have been due to the small sample size. Indeed, the sample sizes were substantially reduced when the accident data were finely disaggregated to reflect accidents occurring in a specific hour for a relatively small driving cohort.</p>	<p>The use of quasi-induced exposure in estimating the risk can be discussed as its underlying assumptions are not convincingly validated or verified, in part because the risk estimates derived using quasi-induced exposure are not sufficiently or convincingly compared to more conventional techniques.</p> <p>Small sample: After a series of manipulations where crash data are "cleaned" to be useful for application of the quasi-induced technique, the total number of non-responsible 15-year-old drivers becomes very small (3–5 crashes/year) for all six years. Hence, the comparison of exposure change for the 15-year-old drivers could not have been conducted, since a small bias in the crash data would have led to significant errors.</p>
<p>Masten, S. V., Foss, R. D., & Marshall, S. W. (2011). Graduated driver licensing and fatal crashes involving 16-to 19-year-old drivers. <i>Jama</i>, 306(10), 1098-1103.</p>	<p>This study investigated the effect of graduated driver licensing (GDL) programs in the US on fatal crashes risk for drivers aged 16- to 19- years old. The authors conducted pooled cross-sectional time series analyses. The exposure variable was the GDL programs. The different conditions tested were "no mandatory learner permit holding period or initial license restrictions", "mandatory learner permit holding period but no initial license restrictions",</p>	<p>Findings are only based on fatal crashes, which represent a small and atypical subset of all crashes. The etiology of fatal crashes differs from that of less serious crashes. High-risk behaviors such as alcohol use and excessive speeding</p>

Reference	Study summary	Bias
	<p>"initial license restrictions but no mandatory learner permit holding period", weaker GDL program (GDL with 1 license restriction during unsupervised driving), and stronger GDL program (GDL with 2 license restrictions during unsupervised driving). The outcome variable was the quarterly 1986-2007 incidence of fatal crashes involving drivers aged 16 to 19 years for all 50 states and the District of Columbia combined (rate per 100,000 person-years). Four age-specific Poisson regression models were used to estimate separate driver fatal crash involvement rate ratios for 16-, 17-, 18-, and 19-year-old drivers. The results suggested that the implementation of GDL in the United States from 1996-2007 was associated with substantially decreased incidence of fatal crashes involving 16-year-old drivers and somewhat increased incidence of those involving 18-year-old drivers. More precisely, stronger GDL programs appeared to be associated with a larger reduction in fatal crashes among 16-year-old drivers (-26%) than weaker GDL programs (-16%). The increase in fatal crashes involving 18-year-old drivers was similar under both types of GDL program. Hence, these results suggested that modifying weaker existing state GDL programs to include night-time as well as passenger restrictions may result in additional crash savings among 16-year-olds as well as a larger net savings among teen drivers overall. Nevertheless, the reasons why GDL programs appear to be associated with higher incidence of fatal crashes for 18-year-old drivers are not known.</p>	<p>are much more common among drivers involved in fatal crashes. The estimates from the present analyses are based on coding the licensing programs under the assumption that all teens pursue unrestricted licensure as early and quickly as possible. The effect of this assumption on the estimates is unknown. The analyses do not directly take into account "grandfathering"—ie, allowing teens who applied for a license prior to GDL to avoid some or all program requirements - that sometimes occurred as GDL programs were implemented. Moreover, transitory increases and decreases in crash rates sometimes occur when GDL programs are implemented. Neither these, nor the gradual increases in program effect as greater proportions of licensed teens became subject to all program components, were directly modeled. However, the inclusion of long periods before and after most GDL programs were implemented reduces the influence of these temporary effects on the parameter estimates. Missing standard error</p>
<p>Rogers, S. C., Bentley, G. C., Campbell, B., Borup, K., Saleheen, H., Wang, Z., & Lapidus, G. (2011). Impact of Connecticut's graduated driver licensing system on teenage motor vehicle crash rates. <i>Journal of Trauma and Acute Care Surgery</i>, 71(5), S527-S530.</p>	<p>This study investigated the effect of the graduated driver licensing (GDL) system over the past 10 years on teen motor vehicle crashes (MVC) in Connecticut. The authors conducted time-series analyses and before-after study. The exposure variable was the GDL. The outcome variable was the MVC rates per 10,000 registered drivers. To estimate the decrease of MVC rates each year, during the 10-year period, the authors applied linear regression analysis which used the year as a predictor and MVC rates in 10 years as the outcome. Moreover, to measure the impact of the GDL passenger restrictions, the authors calculated the percent change in the average MVC rates by driver age (1999–2004 vs. 2005–2008). To measure the impact of the GDL night restrictions, the authors calculated the percent change in the average MVC rates by driver age (1999–2005 vs. 2006–2008). This study provides evidence of GDL system effectiveness</p>	<p>Level of significance is missing for many effects (data not shown here) The authors did not use the number of miles traveled as covariate. The authors emphasized that the reduction in MVC rates may be part of a national trend resulting from multiple safety countermeasures as well as the higher fuel prices and less driving from the US economic recession.</p>

Reference	Study summary	Bias
	<p>in reducing MVC rates among young, novice drivers in Connecticut. Compared with older age groups, there were significant reductions in MVC rates among 16-year-old and 17-year-old drivers and reductions during the night restriction hours and among MVC involving passengers.</p>	
<p>Scott-Parker, B. J., Bates, L., Watson, B. C., King, M. J., & Hyde, M. K. (2011). The impact of changes to the graduated driver licensing program in Queensland, Australia on the experiences of Learner drivers. Accident Analysis & Prevention, 43(4), 1301-1308.</p>	<p>This study investigated the effect of a revision of the graduated driver licensing (GDL) program in Queensland, Australia, on the self-reported crashes and traffic offences among learner drivers aged 17-19 years. The authors conducted a quasi-experiment. The exposure variable was the revision of the GDL program which occurred on the 1st of July 2007. There were two groups of interest: drivers who obtained their provisional license through the former-GDL program and those who obtained their provisional license through the current-GDL program. The outcome variables were the self-reported crash involvement and the self-reported offences. Pearson Chi-square tests were used to compare the categorical items (yes/no). The authors also conducted separate gender analyses. The results showed that the revision of the GDL program in Australia allowed i) a significant reduction in the rates of self-reported offence among the current-GDL sample, and more specifically among male learners; and ii) a significant reduction in the rates of crash involvement among the current-GDL participants, suggesting that increasing the hours of supervised practice may have broader benefits for learner drivers in general, and female learners in particular.</p>	<p>The authors used self-reported data on crash involvement and traffic offences. Small sample Although participants from the current- and former-GDL groups did not differ significantly on age and gender, they significantly differed regarding other sociodemographic characteristics (with the current-GDL novices more likely to be studying, single, less educated, and not engaged in employment than the former-GDL novices). Non-representative sample: The former-GDL Learners comprised only two larger licensing regions in Queensland. Whilst the overall current-GDL sample was drawn from across the entire state, the sub-group used to compare with the former-GDL was narrower in scope to facilitate a valid comparison. Non-random assignment to groups</p>
<p>Williams, A. F., Chaudhary, N. K., Tefft, B. C., & Tison, J. (2010). Evaluation of New Jersey's graduated driver licensing program. Traffic injury prevention, 11(1), 1-7.</p>	<p>This study investigated the effect of the graduated driver licensing (GDL) program on 16-18-year-old drivers' crash rate in New Jersey. The authors conducted a before-after study. The exposure variable was the GDL. Two periods were compared: pre-GDL (1998-2000, or 1995-2000, depending on the outcome variable considered) and post-GDL (2002-2005 or 2002-2007, depending on the outcome variable considered). The outcome variable was the change in fatal, injury or overall crash rate ratio for young drivers (16, 17, or 18-year-old), compared to older drivers (25-59-yo). Z-tests were used to evaluate the statistical significance of differences in rate ratios between the before and after GDL periods. The results showed higher benefits of the GDL system for 17-year-olds (reduction in all police-reported crashes, injury-only crashes, and fatal crashes after the GDL implementation). For 18-year-olds, there was also solid evidence of positive effects based on data encompassing all crashes and injury-only crashes.</p>	<p>Both sets of data have weaknesses: issues of completeness and quality in the New Jersey police-reported crash information and limited statistical power in the case of FARS.</p>

Reference	Study summary	Bias
	Although there was not a significant reduction overall in fatal crash involvements of 18-year-olds, the reductions were concentrated in the restricted hour period and when carrying two or more passengers. The police-reported crash data provided no evidence of an effect for 16-year-olds, but the fatal crash data did. However, the number of 16-year-olds involved in fatal crashes was small so this result has to be considered cautiously. Moreover, there is good evidence from this study that the night-time restriction has been an effective GDL component in New Jersey. On the other hand, the contribution of the passenger restriction is uncertain.	

3.4 REFERENCES

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Alcohol interlock

Nieuwkamp, R., Martensen, H., & Meesmann, U.



Please refer to this synopsis as
Nieuwkamp, R., Martensen, H, & Meesmann, U. (2017). European Road Safety Decision Support System, developed by the H2020 project SafetyCube

1 Summary

BRSI, 24th July, 2017



1.1 COLOUR CODE: GREEN

The results of the research on the effectiveness of the alcohol interlock are positive in terms of reducing recidivism. However, once the device is uninstalled, the recidivism rates become comparable to those in the control group. Therefore, the effect on road safety is positive but only while the device is installed and remains installed.

1.2 KEY WORDS

Alcohol interlock, recidivism, offender, DUI, DWI, alcohol, rehabilitation; driving under the influence; impaired driving; drink driving; alcohol ignition interlock; alcolock

1.3 ABSTRACT

For many years, drink driving has posed a serious threat to road safety. That threat can be countered most efficiently by preventing drunk drivers from driving. An alcohol interlock can verify whether or not a driver's Blood Alcohol Concentration (BAC) is lower than the maximum threshold set by the legislator. If the driver's BAC exceeds that threshold, the vehicle will not start and as a result prevents driving. In relevant studies, the recidivism rates are typically compared between offenders who had an alcohol interlock installed (experimental group) and those who did not (control group). Such a comparison can be carried out during the period while the device is installed and/or during a follow-up period after the device is removed. The results from a recent meta-analysis show that installing an alcohol interlock reduces recidivism risk by 75%. However, in a follow-up period after the alcohol interlock is removed, recidivism risk is only decreased by 7% compared to the control group. That difference is not statistically different from those who had not installed an alcohol interlock. A similar pattern of results also emerges from most recent studies. Alcohol interlocks do what they promise to do: while installed they reduce the risk on drink driving, however, once removed the recidivism rates increases towards their initial level.

1.4 BACKGROUND

What is an alcohol interlock?

In short, an alcohol interlock is "a device installed in a vehicle that requires the driver to provide a breath sample every time an attempt is made to start" (Silverans et al., 2006, p. 10). The alcohol interlocks have four key elements: 1) "a breath alcohol sensor in the vehicle (and a control unit under the bonnet) that records the driver's blood alcohol concentration (BAC) and can be set to provide a warning if any alcohol is detected and [...] that recommends the vehicle not to start if the BAC exceeds a certain threshold"; 2) "a rolling retest system, which requires at least one retest after the vehicle is underway, but in most applications a retest is required every 20 to 30 minutes while driving (the purpose of the retests is to prevent a non-driver from starting the vehicle for a person who has been drinking and also to prevent drinking once the vehicle is underway); 3) a tamper-proof system for mounting the engine part of the unit, [...] along with a system to detect hotwiring or other means that bypass the interlock; and 4) a data-recording system that logs the BAC results, test compliance and engine operation, and creates a record to ensure that the offender is actually using the vehicle as expected and not simply parking it while driving with another vehicle" (Marques & Voas, 2010, p.1).

Besides the device installed in the vehicles, the offenders are also participating in accompanying rehabilitation programs. These rehabilitation programs ideally combine therapy, education, sanctions and supervision measures (Houwing, 2016). The specific implementation of such measures

depends on the legal framework of the concerned countries. Such rehabilitation programs are effective in reducing recidivism in drunk drivers¹ and can be combined with an alcohol interlock. However, when combining both measures the rehabilitation program should fit the offender's need very well in order to be effective (Boets, et al., 2008) as is explained in more detail below.

How does an alcohol interlock affect road safety?

About 25% of all lethal accidents in Europe are caused by drink driving (Houwing, 2016). It is clear that if these drivers were not allowed to take part in traffic, when their BAC exceeds a certain threshold, the roads would become safer. Indeed, in the Netherlands it is estimated that eight to ten road fatalities could be annually avoided if offenders with a BAC of 2.1‰ or more would participate in an alcohol interlock program which would prevent them from drink driving (SWOV, 2009). Four risk groups of drivers have been identified who have the highest risk of having an accident while driving under the influence of alcohol (Houwing, 2016). Of these groups, the group of re-offenders is of particular interest. Even when they have been caught drink driving and have been sentenced, they persist in that dangerous behaviour. The best way to protect other road users against this risk group of drivers is preventing them from driving while they are intoxicated. With the help of an alcohol interlock, these drivers could be excluded from traffic when attempting to drive while intoxicated (DWI). Rather than a withdrawal revocation of the driving licence, the offenders are allowed to drive when their BAC is below a certain threshold. By applying this method, the offenders are immediately punished for showing unacceptable behaviour (they will not be able to drive the car while intoxicated) and will be rewarded for showing positive behaviour (they will be able to drive the car when they are sober). An alcohol interlock program is not strictly limited to re-offenders, also first offenders can be included.

How is the effect of an alcohol interlock on road safety measured?

The most frequently used outcome measure to determine the effectivity of the alcohol interlock, is recidivism. Typically, two groups of DWI offenders are included: a (quasi) experimental group (i.e., drivers who had installed an alcohol interlock) and a control group (i.e., drivers without an alcohol interlock). The drivers in the control group are convicted to a classical sentence (e.g. paying a fine and/or revocation of the driving licence) in the same period. Recidivism can be measured during the time while the device is installed (e.g., Assailly & Cestac, 2014) or in a follow-up period after the alcohol interlock has been uninstalled (e.g., Voas et al., 2013). During the installation and/or during the follow-up period, the recidivism rates between both groups are compared.

1.5 OVERVIEW OF RESULTS

It is important to note that in earlier literature reviews, the effectiveness of the alcohol interlock has been demonstrated to reduce recidivism in drink driving, varying from 40 to 95%, while installed (e.g., Houwing, 2016; Silverans et al., 2006; Willis, Lybrand, & Bellamy, 2004).

The starting point for the present literature review is the most recent meta-analysis (Elder et al., 2011). Four more recent studies were included that were conducted after this meta-analysis. The results of the present review are in line with the findings described above: once the device is installed, the risk on recidivism is drastically reduced compared to (matched) control groups but once the device is removed, the risk on recidivism is equally high in all groups.

¹ Sloomans, Martensen, Kluppels, Meesman (2017). Road Safety Decision Support System, developed by the H2020 project SafetyCube

2 Scientific details

2.1 GENERAL LITERATURE

As discussed above, there is consensus in the scientific literature that an alcohol interlock can improve road safety by reducing the risk of drink driving by 40 to 95% while installed. These conclusions are underlined in a recent meta-analysis (Elder et al., 2011); while the alcohol interlock is installed, there is lower recidivism risk compared to the control group. However, long-term effects are not evident.

Typically studies investigating the effect of alcohol interlocks refer to a certain point in time when a number of people are convicted for DWI. Some of them are sanctioned by an ordinary sanction (e.g., paying a fine, revocation of driving licence: control group), while others can install an alcohol interlock as alternative measure (experimental group). Due to ethical reasons, it is not possible to randomise the offenders to an experimental or control group. Therefore, a quasi-experimental design is typically chosen where the control group is matched to the experimental group to allow for comparison on number of factors (e.g., age, gender BAC level at arrest). The results should therefore be interpreted with caution: differences between the groups can be either due to pre-existing differences between the groups or by the effect of the installation of an alcohol interlock. Given the lack of random assignment to the two groups, matching techniques based on various criteria are the preferred statistical solution, to be able to measure effect of the alcohol interlock and to minimize pre-existing differences.

Modifying conditions

The following four remarks should be taken into account when interpreting the results. First, in general, in almost all studies the performance of the experimental group was compared to a matched control group. Almost no randomised experiments are conducted and therefore we need to carefully interpret the results in terms of transferability. The observed difference between the groups could be explained by pre-existing differences between the groups, however, as argued above such potential difference are thought to have a minimal effect on the observed difference between the groups.

Second In some studies, recidivism rates are compared between the groups while the alcohol interlock is installed (e.g., Assailly & Cestac, 2014) in other studies, however, the recidivism rates are compared after a follow-up period after the device was uninstalled (e.g., Voas et al., 2013).

Third, the educational component in every program also varies, but typically the BAC's while the alcohol interlock was installed are discussed with the offender. These conversations may help estimating whether or not the driver is eligible to have the alcohol interlock uninstalled. Given this diversity, it is difficult to compare the studies on a one-to-one basis. Last, the data in all the presented studies are based on official database records. Such databases only include the data of the people who actually were convicted and therefore do not represent the entire population of offenders (e.g., Nochajski & Stasiewicz, 2006). Despite that limitation, research based on the official data is faster, cheaper and contains more subjects compared to a survey among road users. Furthermore, the latter method is prone to socially desirable answers, especially when traffic re-offenders are questioned (Cavaiola, Strohmets, & Abreo, 2007; Lajunen & Summala, 2003; Schell, Chan, & Morral, 2006). Applying such a method would probably result in underreporting of the actual behaviour.

2.2 METHODOLOGY

A systematic literature study was conducted. The search strategy is explained in section 3.2 of this document. The most recent meta-analysis (Elder et al., 2011) was taken as starting point for our literature search. Although the paper was published in 2011, only papers published until January 2008 were included. Only four additional papers met our prior set inclusion criteria (Assailly & Cestac, 2014;

Ma, Byrne, Bhatti, & Elzohairy, 2016; Voas, Tippetts, Bergen, Grosz, & Marques, 2016; Voas et al., 2013). Table 1 provides an overview of the main characteristics of the coded studies. It should be noted that most of the (coded) studies on the effectiveness of the alcohol interlock were conducted in the United States of America.

Table 1
Selected papers and short description of the used study designs

Authors, Year, Country	Study type	Sample/Measurement	Analysis
Elder et al., 2011, (World)	Meta-analysis; systematic literature review	This paper provides a systematic review and meta-analysis of the literature on the effectiveness of the alcohol interlock in reducing alcohol-impaired driving. In short, their paper extends the systematic review of the literature that was conducted by the Cochrane Collaboration by adding more recent studies to that review and investigating the link between the installation of an alcohol interlock and (a reduction in) recidivism. A meta-analysis was conducted on nine prior studies in the Cochrane Collaboration review and four new studies were included. The included studies were mainly conducted in North America.	The decrease in recidivism is either expressed in a relative risk, a hazard rate (the time to recidivism based on survival analyses) or by displaying the percentage of recidivism for various groups of offenders.
Assaily & Cestac, 2014 (France)	Quasi-experimental design	Two groups of offenders were compared. Drivers were convicted between 2006 and 2011. Only 45 cases of recidivism observed.	Percentage recidivism reported in June 2012; 17 cases in the experimental group and 28 in the control group.
Ma et al., 2016 (Canada)	Quasi-experimental design	The paper presents a longitudinal study (2005 – 2014) of three groups of drivers and their recidivism rates between two experimental conditions and one control group. Eligible first offenders were included in the 'Reduced Suspension with ignition interlock Conduct Review' (RSCR) program and three streams were put together: Stream A (N = 4817) when they plead guilty within 90 days; Stream B (2244) when they plead guilty but after 90 days; the remaining offenders were included in Stream C (N = 2265), the control condition. Their recidivism rates were determined while the alcohol interlock was installed, during pre-trial (time between the offence and sentence) and during a follow-up period. The participants were matched on: age, gender, criminal code (of the law) and offence history.	No differences in recidivism were observed between streams a and b and the control group (stream c). Only 56 cases of recidivism were observed.
Voas et al., 2013, (USA)	Observational study	A longitudinal study was conducted evaluating the 'Administrative Reinstatement Interlock Program' (ARIP) in Florida that was implemented in 2002 until 2012 covering 120.000 drivers. No control group was included.	The recidivism rates during the time on the alcohol interlock were reviewed after six and 12 months. After the alcohol interlock was removed the recidivism rates were monitored.

Authors, Year, Country	Study type	Sample/Measurement	Analysis
Voas et al., 2016 (USA)	Quasi-experimental design	The paper discusses the effectiveness of the Florida alcohol interlock program (AUD) for the re-offenders who had been drink driving in the period between October 2010 and January 2013. The offenders in both groups had an alcohol interlock installed. The experimental group had three or more violations while the alcohol interlock was installed (i.e., lock-outs) and the comparison group had less than three violations. The comparison group was matched to the experimental group based on: demographics, prior DWI record and performance on the alcohol interlock.	Survival analyses were conducted to compare both groups in terms of time to recidivism. Installation of an alcohol interlock led to 32% decrease in recidivism rates.

2.3 ANALYSIS AND RESULTS

Five studies were coded on the effects of the alcohol interlock with regard to (reducing) recidivism. Table 2 summarises the main results per paper.

In the 2004 SWOV factsheet² it is stated that: "Various international studies show 65-90% fewer re-offences for users of an alcohol interlock device than for drivers with a suspended or a revoked driving licence (Bax et al., 2001)". That finding is underlined by the literature review of the Cochrane Collaboration (Willis, Lybrand, & Bellamy, 2004) and the results of a 2006 literature review, financially supported by the European Commission³. The latter concluded that alcohol interlocks: "lead to 40-95% reductions in the rate of repeat driving under the influence (DUI) offences of convicted DUI offenders (ICADTS, International Council on Alcohol, Drugs and Traffic Safety, 2001). The recidivism rates of the offenders on the alcohol interlock programme are significantly smaller than in the control groups but only as long as the alcohol interlocks are installed" (Silverans et al., 2006, p. 10).

Elder and his colleagues (2011) conducted a meta-analysis on nine studies presented in the Cochrane Collaboration review. They concluded that the installation of an alcohol interlock decreased the risk on recidivism by 75% compared to the control group in the period that the device was installed. During the follow-up period (on average, 31 months; [21 months minimum, 48 months maximum]), a non-significant decrease of 7% was observed between the experimental and group control group.

In addition to the conducted meta-analysis, Elder et al. (2011) included four more recent studies to the systematic literature review of the Cochrane Collaboration. They added three studies from the USA and one study from Sweden. In the USA studies it came to light that the installation of an alcohol interlock reduced the risk of drink driving by 65% among re-offenders (Roth, Voas, & Marques, 2007) and 61% for first offenders (Roth, Marques, & Voas, 2007). After the removal of the alcohol interlocks the risk on recidivism was only 9% and 18% lower than the control groups. In the other USA study no pre-and post-measures were administered but in general, the risk on recidivism decreased by 34% for all offenders and by 41% for re-offenders (DeYoung, Tashima, & Masten, 2005). These differences are statistically different from the control group. In the Swedish study none of the drivers in the experimental group recidivated during the follow-up period compared to 4.4% of the control group (Bjerre, 2005). The selection of drivers was, however, different from other studies. People were included who failed to comply with their alcohol treatment plan. That might explain why no difference between the groups is observed. It should be noted that rehabilitation courses are in general effective in preventing drink driving offences. ⁴ The alcohol interlock can be combined with such rehabilitation course (Silverans et al., 2006). That study revealed that the rehabilitation programs, combined with an alcohol interlock, should be fitted to the driver's needs in order to be successful (Boets, et al., 2008).

In the present synopsis we continued building on previous overview studies by adding four more recent studies to the overview of Elder and colleagues (2011). Two studies were conducted in Florida (Voas et al., 2016, 2013) and are in line with the previous findings. While the device was installed the recidivism rates varied between 0.55% and 1.20% (absolute percentage); those rates increased once the device was removed to 6.8% (Voas et al., 2013). In the most recent study, the risk on recidivism was reduced with 32% while the device was installed (Voas et al., 2016). The younger the drivers, the higher the risk on recidivism, for instance: drivers under the age of 25 were five times more likely to recidivate compared to drivers aged 55 or older. In the study by Ma and her colleagues (2016) only 56 cases of recidivism were observed in Canada that yielded no differences between the groups. The French study from Assailly and Cestac (2014) found no statistical difference between both groups (10% vs. 12% recidivism for the experimental and control group). It should be noted that in the

² <https://www.swov.nl/en/facts-figures/factsheet/alcohol-interlock-devices>

³ Alcoholock: Alcolock implementation in the European Union

⁴ For a detailed overview, please refer to the synopsis by Slootmans, F.; Martensen, H.; Kluppels, L.; Meesmann, U. "Rehabilitation courses as alternative measure for drunk driving offenders".

latter study 45 cases of recidivism were observed (17 cases in the experimental condition and 28 in the control condition). The small number of cases might explain why no statistical differences were observed between the groups.

It should be noted, that a new subfield of research is starting to emerge to better predict drink driving in the future by evaluating bio-markers that are indicative of heavy drinking (e.g., Bean et al., 2014; Kummer et al., 2016; Maenhout et al., 2014; Marques et al., 2014). Simply put, biomarkers are biological indicators that are visible in a subject's body and are caused by heavy drinking behaviour (i.e., four or more daily alcohol consumptions for males or three or more consumptions for females). One can distinguish direct and indirect markers (Bean et al., 2014). Direct markers can be found in the body after the alcohol has been metabolised (e.g., EtG: ethyl glucuronide). Indirect markers are residuals that can be found in the body and are caused by heavy drinking (e.g., gamma-glutamyltransferase: GGT, a liver enzyme).⁵ The research started in order to explain why the recidivism rates increased once the device was uninstalled (Marques et al., 2014). In the research on the effectiveness of an alcohol interlock on reducing recidivism, it was assumed that offenders in the experimental group would, in general, adapt their drinking behaviour resulting in drinking less alcohol than the control group (Marques et al., 2014). However, when indirect biomarkers are examined before the installation of the alcohol interlock and after eight months while the device was installed, no differences were observed in these indicators. It is therefore more likely to assume that an alcohol interlock does what it promised to do: it separates drinking and driving but does not lead to an overall decrease in drinking behaviour. These results might explain why a substantial number of offenders in the experimental group relapse after the device is removed: their drinking behaviour is not altered compared to when the offender was convicted. In other words, no learning effect is observed. As stated above an alcohol interlock can be combined with additional rehabilitation measures in order to increase its effectiveness for long term effects.⁶ It might therefore be argued that bio-markers may be a better predictor in determining when it is 'safe' to remove the alcohol interlock. However, this research is still in its infancy and the researchers do not (yet) agree what indicators are most valid. Therefore this new subfield of research is included in this synopsis rather than in a separate synopsis because at this point there is much ambiguity in the equation.

⁵ A helpful overview of various biomarkers is provided in Boets, et al. (2008, p.103-107).

⁶ Sloomans, F.; Martensen, H.; Kluppels, L.; Meesmann, U. "Rehabilitation courses as alternative measure for drunk driving offenders".

3 Supporting document

3.1 DESCRIPTION OF STUDIES

Meta-analysis

Based on a meta-analysis of nine international studies, Elder et al. (2011) found that an alcohol interlock can help to reduce recidivism by 75% for all offenders: first offenders and re-offenders during the installation period.

3.2 LITERATURE SEARCH

The search was conducted in Scopus and the TRID database. The search criteria are displayed in Table 3. After the search was completed, all duplicate papers from the two data sources were removed and the remaining papers were prioritised based on the title and the abstract. In general, we focused on the methods to determine the effectiveness of the alcohol interlock by which the implementation adds to improving road safety (i.e., in this case reducing recidivism). The following topics were excluded from our search:

- Way to measure/ detect/ assess alcohol/ drug consumption/ dependency/ sobriety;
- prevention of drink-driving in general (i.e., for primary prevention) [Only selected: Alcolock for offenders/recidivist, i.e., for secondary prevention];
- prevention programs (that are not focused on offenders/recidivists) / programs to reduce DUI;
- effects on the rehabilitation programs (e.g., on health-care (costs); on hospital care utilisation; and on sick leave);
- how to improve the effectiveness of rehabilitation programs;
- monitoring of identified offenders.

Table 2

Summary of the main effects of the (decreased) recidivism in the coded studies

Name authors and (country)	Type of offenders	Measure on the alcohol interlock	Relative decrease in risk on recidivism (%)	Effects on road safety
Elder et al., 2011, (World)	All offenders	During installation	75%	↗
	All offenders	After installation	7%	–
	Re-offenders	During installation	65%	↗
	First offenders	During installation	61%	↗
	All offenders	After installation	32%	↗
	Re-offenders	After installation	41%	↗
	All offenders	During installation	100%	↗
	Re-offenders	After installation	1.8% recidivism rates	?
Assaily & Cestac, 2014 (France)	All offenders	During installation	10% recidivism (alcohol interlock) vs. 12% (control group)	?
	All offenders	Before installation	13% recidivism (alcohol interlock) vs. 35% (control)	?
Ma et al., 2016 (Canada)	First offenders	After installation	/	– (only 56 cases of recidivism in a short period of follow-up which might explain why no effect was found)
Voas et al., 2013, (USA)	All offenders	During installation (6 months)	0.6% recidivism	– (no control group)
	All offenders	During installation (12 months)	1.2% recidivism	– (no control group)
	All offenders	After installation	3.6% recidivism	– (no control group)
	All offenders	After installation	6.8% recidivism	– (no control group)
Voas et al., 2016 (USA)	Re-offenders	After installation	32%	↗
<p>Note: ↗ is indicative for a significant positive effect on road safety ↘ is indicative for a significant negative effect on road safety – is indicative for a non-significant negative effect on road safety ? is indicative for an unknown effect on road safety</p>				

Table 3
 Search strategy for the systematic literature review

SCOPUS			
	search no.	search terms / operators / combined queries	hits
Rehabilitation	#1	(TITLE-ABS-KEY ("Alcohol ignition interlock*" OR "Alcohol interlock*" OR "ignition interlock*" OR "Alcohol ignition") AND TITLE-ABS-KEY (training* OR course* OR program* OR rehabilitation OR "driver improvement" OR diagnostic OR "fitness to drive")) AND PUBYEAR > 1989	84
	<p style="text-align: center;">TRID database</p>		
Rehabilitation	Not selected	(drunk* OR speed* OR drink* OR aggress* OR offender* OR offense* OR recidivis* OR alcohol OR drug* OR intoxicated OR "driving under the influence" OR "Alcohol ignition interlock*" OR "Alcohol interlock*" OR "ignition interlock*" OR "Alcohol ignition") AND (rehabilitation OR program*)	12,627
	#2	("Alcohol ignition interlock*" OR "Alcohol interlock*" OR "ignition interlock*" OR "Alcohol ignition") AND (training* OR course* OR program* OR rehabilitation OR "driver improvement" OR diagnostic OR "fitness to drive")	269
<p><i>Note: Limitations/ Exclusions:</i></p> <ul style="list-style-type: none"> • Search field: TITLE-ABS-KEY or TITLE • Published: 1990 to current • Document Type: ALL 			

The total selection contained 72 papers in which young drivers and/or young offenders were underrepresented. Therefore, the group of young offenders was merged with the general group of offenders. A recent meta-analysis (Elder et al., 2011) was taken as starting point for the inclusion of more recent papers. This analysis included studies which were published before January 2008. Therefore, the present literature research was limited to studies published after January 2008. The primary variable of interest in that review was recidivism during the installation of the alcohol interlock and/or after the alcohol interlock was removed from the vehicle. The hypothesis is that the installation of an alcohol interlock will prevent more intoxicated drivers from actually driving in traffic compared to the control group. The control group most often consists of a group of offenders who are also convicted for DWI, but in whose cars no alcohol interlock was installed. Based on the aforementioned criteria, a total of 17 more recent papers were selected. That selection was further narrowed down based on the following criteria (the number of *remaining* papers is displayed in brackets):

- the study needed to be published in a scientific journal (8);
- the full-text paper needed to be available (8);
- the study should (at least) have recidivism as (one of the) outcome measures (4); and
- needed to be relevant (4).

The study designs are displayed in Table 1 and the most important results are summarised in Table 2.

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Rehabilitation courses as alternative measure for drink driving offenders



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1 Summary

1.1 COLOUR CODE

Green: Rehabilitation courses – if properly performed – can reduce the likelihood of recidivism. Important characteristics of a course are a focus on behavioural change (i.e. concrete plan of what to do when a relapse is imminent) rather than simply providing information. Furthermore, it should be spread over at least several weeks.

1.2 KEY WORDS

Driving under the influence; offender; rehabilitation; recidivism; alcohol; drugs; behaviour change

1.3 ABSTRACT

The main purpose of rehabilitation courses is to reduce recidivism with respect to drink driving offences. Such a course is educational or psychologically oriented, and typically organised in small groups. Recent studies were analysed. The main outcome variable in all of these studies was recidivism for 'driving under the influence of alcohol' (DUI) in the 2 to 3 years following the course. Participants were compared to non-participants (as e.g. DUI-offenders who were charged with a more traditional sentence such as a prison sentence).

The results show that rehabilitation courses for DUI-offenders can reduce recidivism and thus have a positive effect on road safety. Studies comparing the percentage of recidivists in the participant group with the percentage of recidivists in the control group show a decrease in recidivism of up to 36%. A meta-analysis of the studies, which use a logistic regression or cox regression, showed that rehabilitation courses can reduce recidivism by 40%.

A weakness of almost all studies in this area is that the analysis of recidivism is based on participants who completed the course. The percentage of completers is variable and is not routinely evaluated as an aspect of course-quality. There is also the problem of matching variables between the experimental group and the control group. Unseen confounding factors could have biased the results.

1.4 BACKGROUND

This synopsis focuses on the effectiveness of rehabilitation courses in reducing DUI-recidivism.

- *What is a rehabilitation course?*

Rehabilitation courses were introduced when the idea grew that traditional sentences (prison sentence, fines, licence withdrawal) alone are not the right way to reduce recidivism. Studies indicated that recidivism rates were very high, especially for serious offenders.

There are two approaches to rehabilitation courses: (1) an educational oriented course focused on knowledge and (2) a psychological oriented course in which the emphasis is put on behavioural change.

- *How should a rehabilitation course be organised?*

A couple of directives should be followed for an effective rehabilitation course:

- 1) multiple sessions spread over several weeks;
- 2) content and approach adapted to the needs of the participants;
- 3) participation must be an 'automatic' standard response following the offence;
- 4) mix of educational and psychological methods;
- 5) course leaders and methods must be of high quality;

6) differentiation between specific risk groups (e.g. severe recidivist, alcohol and drug driving offenders).

- *How is the effect of a rehabilitation course measured?*

Rehabilitation courses are either evaluated in terms of recidivism or in terms of self-reported behaviour or attitude measurements. This synopsis focuses on effects on recidivism as the more objective measure.

Typically participants and non-participants are evaluated after two to three years. Usually the percentage of recidivists is compared directly between participants and non-participants. Additionally recidivism is also sometimes analysed in a logistic regression analysis or in a cox-regression or survival analysis.

- *What are the challenges in evaluating rehabilitation courses?*

There are a lot of methodological difficulties in setting up a reliable, valid study. A classic experimental design means that participation in a programme depends on coincidence. This is however very difficult to organise in a legal context.

Also, most studies are based on court or police records of recidivism and there is no one-to-one relation between actually (re-)committing offenses and being *registered* for them, as the probability of being caught for these offences is extremely variable between countries.

A simple comparison between the 'experimental' and the control group over the same period of time could be very misleading. During an imprisonment and during the withdrawal period, people do not drive and as a consequence they cannot be caught for drink driving. Studies therefore should compare individual participants only during the time they were allowed to drive.

1.5 OVERVIEW OF RESULTS

Ten studies were selected. All studies concerned a comparison of participants of rehabilitation courses for drink driving offenders, to offenders who did not take part in a course.

Four studies reported the percentages of recidivism in the treatment versus the control group. Two of these studies found that participation in a rehabilitation course had a significant positive effect on road safety, meaning that participants had a statistically significant lower recidivism rate than non-participants. However, one of these two studies found that the positive effect disappears completely after 6 months. The third study found that participants of the course had a lower recidivism rate than non-participants, but the difference was not statistically significant.

The fourth study showed a negative effect on road safety: participants of the rehabilitation course had a higher recidivism rate than non-participants. However, the result is no longer significant once prior convictions are entered into the equation.

Six studies which used cox- or logistic regression – were selected for a meta-analysis. The regression analyses allow the inclusion of covariates like age, gender, and prior convictions (DUI and other). A random effects meta-analysis was conducted on the ratios estimated by logistic or cox-regression for completers. The results indicate that rehabilitation courses can reduce the rate of recidivism by 40%.

2 Scientific overview

2.1 THEORETICAL BACKGROUND

Aim and methods of DUI rehabilitation courses

In several countries all over the world, rehabilitation courses for traffic offenders were introduced a long time ago.

The idea was that punishment alone (fines, licence withdrawal or imprisonment) could not be the right answer for traffic offenders. In fact, recidivism rates stay very high, especially for severe offenders (those who were convicted by a court). Blom, Bergman & Wartna (2011) discovered that 30% of traffic offenders in the Netherlands are brought to court a second time within 2 years, following their first conviction. Most of them (77%) had committed the same offence. The recidivism rate was even 56% for DUI-offender specifically. Other studies, like Elvik & Christensen (2007) also give evidence that an increase of the punishment itself would have no influence on recidivism rates.

Traffic psychology indicates that driving behaviour is not always a planned and well-considered behaviour. It's more an amalgam of automatic responses and habits, with a strong influence of the actual circumstances. Drink driving is also partly a habit and more or less linked with alcohol abuse or alcoholism. A more psychological approach is necessary to solve the problem, not only punishment. In general we distinguish between two kinds of approaches for rehabilitation courses for DUI-offenders:

- 1) more educational oriented courses whereby the main objectives are centred around knowledge (of the risks, insight in one's own behaviour, knowledge of the impact of alcohol on the body and mind, ...);
- 2) psychologically oriented courses in which more emphasis is put on behaviour change (planning the change process, working on relapse prevention, etc.).

Most of the courses are organised in small groups, and in some cases there are pre- and post-interviews held on an individual basis.

Course effects and influencing factors

Since the beginning of these courses in the early 80s, a lot of research has been carried out on the possible effects (Vanlaar et al. 2003). The results are not always comparable and many studies contradict each other. Wells-Parker and colleagues (1995a) gathered 215 evaluation studies of rehabilitation courses. Their meta-analysis shows that:

- 1) Good methodological studies indicate that rehabilitation courses lead to a decrease in recidivism rate of 8 to 9%, in comparison with DUI-offenders who are charged with a classical punishment (e.g. imprisonment, fines, withdrawal of the driving licence, or a combination of these measures).
- 2) There was even a small positive effect on DUI-accidents, meaning that DUI rehabilitation courses were associated with lower accident risk.
- 3) A higher decrease of recidivism can be achieved by combining a classical punishment with a rehabilitation course.
- 4) The better the methodology of the effect study, the smaller the difference between control group and experimental group.

Probably the most cited study in Europe, especially in the German speaking countries, was done by Schützenhöfer and Krainz in 1999. In this study DUI-offenders could volunteer to follow a course during their withdrawal period. Recidivism among course participants was less than half of that among those DUI offenders who had not volunteered to take part in this course. This difference even persisted after 3 years. Part of this large effect is probably due to group differences that existed already before the course and led the offenders to either volunteer for participation or not.

Two big European research projects were devoted to getting more insight into the possible effects of rehabilitation courses (in Europe mostly indicated as 'driver improvement courses'). The Andrea-project (Analysis of driver rehabilitation programmes – Bart, Assailly, Chatenet, Hatakka, Keskinen, Willmes-Lenz, 2002) focuses on the process evaluation of these courses. This study was performed in several European countries and led to two main conclusions:

- 1) The content and the approach of these courses must be adapted to the specific needs of the participants.
- 2) Differentiation between specific risk groups is necessary: especially for severe recidivists, the approach must be a more therapeutic one and has to be spread over a longer period of time than e.g. for first time offenders.

The DRUID-project (Driving under the influence of drugs, alcohol and medicines –Bukasa, Braun et al. 2009) was a larger project on several aspects of DUI. One of the work packages was dedicated to rehabilitation courses. It was concluded that, in order for a rehabilitation course to be effective, 5 main directives should be followed:

- 1) It must be a course consisting of multiple sessions, spread over several weeks.
- 2) Content and approach must be adapted to the needs of the participants. Some sort of previous diagnostic interview is desirable, to be able to distinguish for example severe DUI recidivists from first time offenders without an addictive disorder .
- 3) Participation may not depend on the free will of the person or the choice of a judge or prosecutor. It must be an 'automatic' standard response following the offence.
- 4) The approach must consist of a mix of educational and psychological methods. Most important is the focus on the person and his or her ability and motivation to change.
- 5) Course leaders and methods must be of high quality. Evidence-based methods are a necessity and permanent monitoring of the activities is necessary.

Challenges in evaluating rehabilitation courses

Although it seems straightforward to compare recidivism rates of groups of offenders, in practice there are a lot of methodological difficulties in setting up a reliable and valid study.

Rehabilitation courses are either evaluated in terms of recidivism or in terms of self-reported behaviour. In the present evaluation it was decided to focus on the effects on recidivism as the more objective measure. It must be noted however, that all reviewed studies are based on court or police records of recidivism and that there is no one-to-one relation between actually (re)committing offences like speeding and driving under the influence of alcohol, and being registered for them, as the probability of being caught for these offences is extremely variable between countries.

Possible solutions for these aspects could be:

- to spread the research over one country or region where it can be safely assumed that the frequency of police control stays the same over time;
- to spread the research over a longer period of time. Wells-Parker et al. (1995) recommend having a minimum period of two years as follow-up;
- to work with a large number of participants; a minimum of 100 persons in each group. (Wells-Parker, et al. 1995b).

A scientifically valid evaluation of a countermeasure needs a classical experimental design (Mann et al., 1983), whereby the participation in a programme depends on coincidence. This is very difficult to organise in a judicial context. No judge or any other sanctioning body is willing to do this.

A solution for this issue is to make sure the control group is as similar as possible to the 'experimental' group. The matching procedure is extremely important and has to take into account not only the variables concerning the offence (severity of the intoxication, severity of the perceived effects, combination with other offences at the same time) and demographic information (age, sex, socio-

economic status, etc) but also variables concerning the (driving and juridical) history of the examined persons. For example, Nochajski et al. (1993) found that the juridical history of a person can be seen as the decisive factor in the success of a rehabilitation course. Recidivists have in general 24 times more chance to relapse, independently of whether they took part in a course or not.

A solution for this problem is the following: for each person in the 'experimental' group, one has to find an identical person (personal characteristics, features of the offence, and features of the juridical history) to include in the control group. An example of such an approach can be found in the recidivism study of Vanlaar et al. (2003).

Additionally, other measures may influence the recidivism rate of both groups. In the USA, most rehabilitation courses were pronounced as an alternative measure to imprisonment, and in Europe, in most cases the period of the withdrawal of the drivers' licence can be decreased by attendance at such a course. In most cases, people do not drive during imprisonment or a licence withdrawal period, and consequently they cannot be apprehended for drink driving during this period. These periods must be taken into account in the research design. A simple comparison between the 'experimental' and the control group over the same period of time could be very misleading. Studies therefore should compare individual participants only during the time they were allowed to drive (Holden, 1983).

The relation between recidivism and the actual occurrence of crashes is unknown. Crashes are a fairly uncommon occurrence, and it's impossible to determine the change in accident risk due to rehabilitation courses.

Another problem in evaluating rehabilitation studies concerns the number of completers of each course. With only very few exceptions, analyses of recidivism are limited to participants who completed the course. The percentage of completers is, however, variable and is not routinely evaluated as an aspect of course-quality.

2.2 CODED STUDIES

The present evaluation focused on recent studies (since 2007) and was based on a search of SCOPUS and TRID (see supporting document for details). All studies concerned a comparison of participants of rehabilitation courses for drink driving offenders, to drink driving offenders who did not take part in such a course. In one study (Bouffard & Richardson, 2007), methamphetamine-involved offenders who took part in a rehabilitation course were compared to methamphetamine-involved offenders sentenced to prison.

As outcome variable recidivism was selected. Other possible outcomes (not investigated here) are self-reported behaviour (drink driving, drug use, and other offences like speeding) and attitude measurements.

Typically, participants and non-participants are evaluated after two to three years, although some studies followed up participants for up to ten years. The percentage of recidivists is compared directly between participants and non-participants. Additionally, recidivism is sometimes also analysed in a logistic regression analysis (yes or no in a given time-frame) or in a cox-regression or survival analysis, measuring the time passing until an unfavourable event - here recidivism - occurs. The measure of effect in the logistic regression (recidivism yes/no) is an odds-ratio and the measure of effect in a cox regression is a hazard-ratio. Both ratios indicate the relative risk of participant as compared to non-participant. A ratio below 1 indicates a lower risk for participants and a ratio larger than 1 indicates a higher risk for participants. The regression analyses have the advantage that possible differences between participants can be corrected for. A cox-regression is considered the highest state-of-the art in analysis.

2.3 OVERVIEW RESULTS

The results from the regression analyses are presented in Figure 1. Horizontally, the resulting Odds- or Hazard- ratio is given. Vertically the inverse standard-error of this estimate is given, this means the higher the point is situated in the graph, the more reliable the estimate.

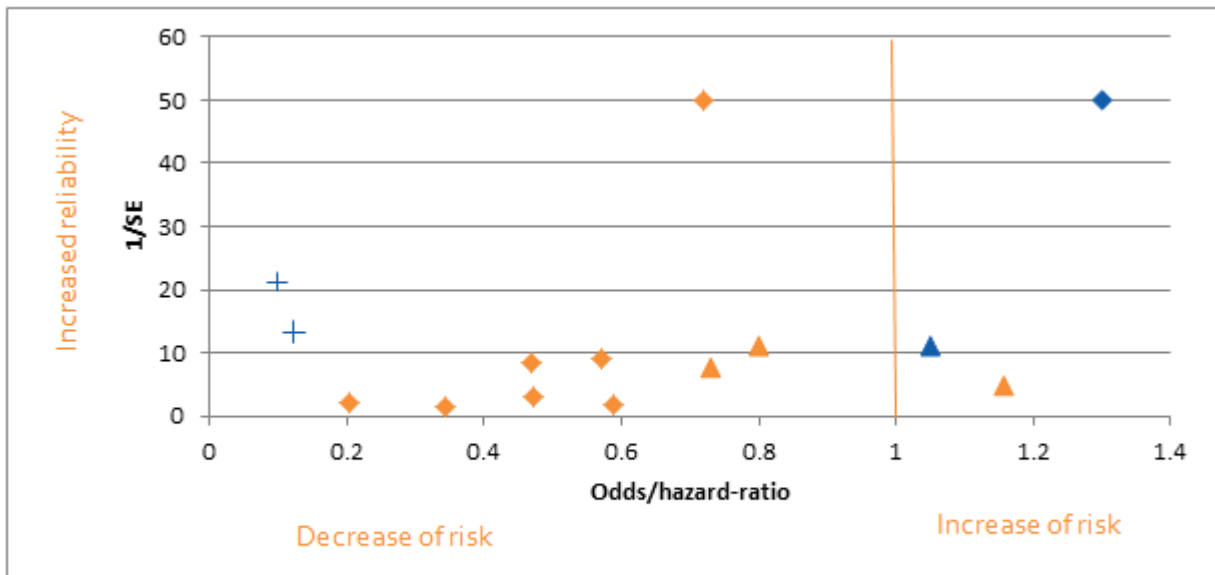


Figure 1: Odds/hazard ratio for participants vs. non-participants. Orange: completers; blue: non-completers. + Recidivism after 1 year; ♦ recidivism after 2 years, ▲ recidivism after 3 years.

The studies in Figure 1 – all those that used cox- or logistic regression – were selected for a meta-analysis. The regression analyses allow the inclusion of covariates like age, gender, and prior convictions (DUI and other). In particular prior conviction is an important predictor of recidivism and in many studies the participants and non-participants differ on this variable. By including variables in the regression model, the estimated effect concerns the group differences over and above what the covariates can explain.

A random effects meta-analysis was conducted on the ratios estimated by logistic or cox-regression for completers (see Figure 1). The results are given in Table 1.

Table 1: Results of the random effects meta-analysis

	Estimate	SE	P
Odds/hazard ratio	0.5892	0.107	<0.0001
Q (df=11)	10.64		0.474
τ^2	0.0232	0.0508	
I^2	17.81%		

The results indicate that rehabilitation courses can reduce the rate of recidivism by 40%. The other values in Table 1 (Q, τ^2 , and I^2) all indicate that the heterogeneity of the results is within the expected range, given the precision of the estimates.

The estimate of 40% reduction is substantially higher than estimates of earlier meta-analyses reporting a reduction around 8% or 9% (Vanlaar, 2003; Wells Parker et al., 1995). One reason for this result could be that the studies that had a satisfactory analysis method (i.e. at least some correction for group differences due to the use of regression analysis) also tended to have the following characteristics:

- focus on behaviour modification and relapse prevention rather than simply providing information
- spreading out sessions over a longer period (at least 4 weeks)

Another reason could be the length of experience with rehabilitation courses. Some of the evaluations stem from programs that have been running for a long time and have been continuously evaluated and improved. Therefore, attendance at these courses during the last ten years was probably more effective than previously.

The results from simple comparisons of percentages are presented in Figure 2.

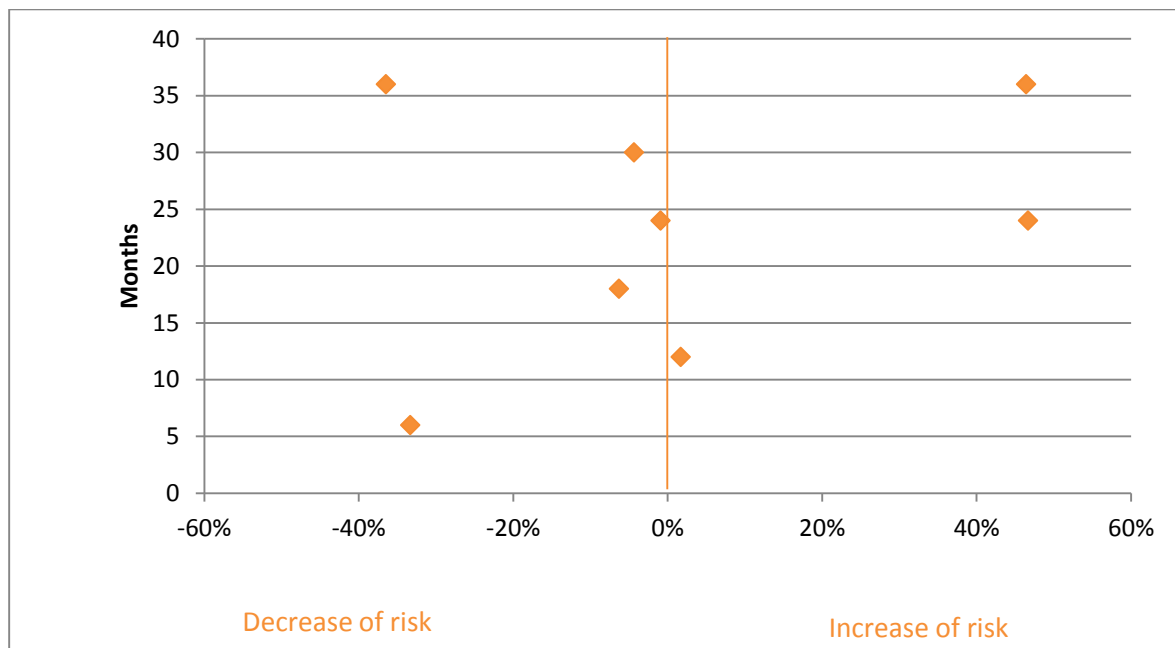


Figure 2: Increase of percentage recidivism for participants as compared to non-participants by period of evaluation in Month.

Studies comparing the percentage of recidivists in the participant group with the percentage of recidivists in the control group show a decrease in recidivism of up to 36%. However, one study also identified an association in the opposite direction, i.e. an increase of recidivism after participation in a rehabilitation course.

3 Supporting document

3.1 LITERATURE SEARCH STRATEGY

3.1.1 Research terms and hits

Database: Scopus

Date: 21st and 22nd December 2016

Limitations/ Exclusions:

- Search field: TITLE-ABS-KEY or TITLE
- Published: 1990 to current
- Document Type: ALL

	search no.	search terms / operators / combined queries	hits
Rehabilitation	Not selected	(TITLE-ABS-KEY (drunk OR speed* OR drink* OR aggress* OR offenders OR offenses OR recidivis* OR alcohol OR drug* OR intoxicated OR impaired OR "driving under the influence") AND TITLE-ABS-KEY (rehabilitation OR training OR course OR education OR program OR "driver improvement")) AND PUBYEAR > 1989	636,630
	Not selected	(TITLE-ABS-KEY (drunk OR speed* OR drink* OR aggress* OR offenders OR offenses OR recidivis* OR alcohol OR drug* OR intoxicated OR impaired OR "driving under the influence") AND TITLE-ABS-KEY (rehabilitation OR training OR course OR "driver improvement")) AND PUBYEAR > 1989	349,475
	#1	(TITLE (drunk* OR speed* OR drink* OR aggress* OR offender* OR offense* OR recidivis* OR alcohol OR drug* OR intoxicated OR "driving under the influence") AND TITLE (rehabilitation OR "driver improvement" OR diagnostic OR "fitness to drive")) AND TITLE-ABS-KEY ("road safety" OR driv* OR traffic)) AND PUBYEAR > 1989	84
	#2	(TITLE (drunk* OR speed* OR drink* OR aggress* OR offender* OR offense* OR recidivis* OR alcohol OR drug* OR intoxicated OR "driving under the influence") AND TITLE (training* OR course* OR program*) AND TITLE-ABS-KEY ("road safety" OR driv* OR traffic)) AND PUBYEAR > 1989	435

Database: TRID

Date: 27th December 2016

Limitations/ Exclusions:

- Published: 1990 to 2016
- Document source : ALL, Document Type: ALL, Subject area : ALL
- Language: English and French

	search no.	search terms / operators / combined queries	hits
	#1	(offender* OR offense* OR recidivis*) AND (rehabilitation OR program*)	868

3.1.2 Results Literature Search

Database	Hits - Rehabilitation
Scopus	519
TRID	868
Total number of studies to screen title	1387

3.2 PRIORITISATION

3.2.1 First prioritisation, based on Titles and Abstracts screening

Principles

Focus on effectiveness of methods that evaluate the fitness to drive / the rehabilitation measures

- Effectiveness of rehabilitation courses to improve road safety (reducing recidivism)

Excluded




- Way to measure/detect/assess alcohol/drug consumption/dependency/sobriety
- Prevention of drink-driving in general (i.e. for primary prevention)
- Prevention programmes (that are not focused on offenders/recidivists) / programmes to reduce DUI
- Effects on the rehabilitation programmes on health-care (costs), on hospital care utilisation, on sick leave, etc.
- How to improve the effectiveness of rehabilitation programmes
- Monitoring of identified offenders
- Proposition of new method (without any test of it)
- Assessment of the methods used in a region
- Programmes to motivate/promote/incentive the use of FDA/ rehabilitation tools
- Profile of recidivist, of persons taking part to FDA/Rehab programmes
- Papers that describe a programmes but do not give information on its effectiveness
- Recommendations, guidelines, best practices
- Duplicates

⇒ 40 selected papers (14 coding priority)

Coding priority

- Control group without training
- Comparison in terms of recidivism
- Paper available

3.3 INCLUDED STUDIES

Author(s), Year	Sample and study design	Method of analysis	Treatment group and control group	Outcome indicator	Main result	Effects on road safety
Sloan et al., 2016	Quasi-experimental study on the effect of drug court programs and DUI court programs on DUI recidivism . There is no information on sample size of the treatment group, the control group consists of 131,340 people convicted of DUI but never referred to a specialty court.	Follow-up of the treatment group and control group during 4 years in order to calculate DUI recidivism within this time frame. The Average Treatment Effect is calculated, to measure differences in recidivism rates between treatment and control groups during follow-up.	Completers versus people never referred for treatment	DUI arrests (yes-no), DUI convictions and number of DUI arrests	Recidivism rates (all three outcome indicators) were lower for completers than for people never referred to a programme in the 4 year follow up period.	 Average treatment effect: DUI arrest = 0.104 DUI conviction = 0.096 Nr of DUI arrests = 0.079
Ma et al., 2015	Quasi-experimental study on the effect of the 'Back-on-Track' (BOT) programme on recidivism. The Full BOT group received a multi-component treatment, the Edu BOT group received a single component treatment. The Full BOT group consisted of 2738 people, the Edu BOT group of 4410 people and the control group (no BOT) of 19163 people.	Follow-up of the treatment groups and control group during 3 years in order to calculate DUI recidivism within this time frame.	Completers versus people never referred for treatment	DUI recidivism	Both on-time completers and late completers in the Edu BOT group re-offended significantly less than those in the No BOT group, while on-time and late completers in the Full BOT group re-offended significantly less than those from the corresponding Edu BOT sub-groups.	 Absolute difference: NoBOT vs EduBOT = 3.1% NoBOT vs FullBOT = 1.3%
Ekeh et al., 2008	Quasi-experimental study on the effect of the treatment program	Follow-up of the treatment group and control group	Completers versus people	DUI recidivism	In the treatment group, 28% of the participants had a repeat offence. In	 Absolute difference = 14.0%

	'Drive Alive' (DA), which targets teenagers, on recidivism. 183 adolescents participated in the DA programme, 233 individuals were selected as control group.	during 2.5 years in order to calculate DUI recidivism within this time frame.	never referred for treatment		the control group, 42% re-offended. This result is statistically significant. The difference for re-offending between both groups is not significant after 6 months.		
Crew & Johnson, 2011	Quasi-experimental study on the effect of the treatment programme 'Victim Impact Panels' (VIP) on recidivism. The dataset consisted of 1533 cases and includes information on 657 people who participated in and successfully completed VIP, and 876 who did not. Both participants and non-participants were convicted for driving under the influence of alcohol.	Follow-up of the treatment group and control group during 3 years in order to calculate (DUI) recidivism within this time frame.	Completers versus people never referred for treatment	DUI recidivism, recidivism in general	12.3% of the offenders who completed VIP received new DUI convictions, but only 8.4% of offenders who did not attend VIP received new DUI convictions. When all criminal charges are included, the relapse rates are 18.2% for non-participants and 22.2% for participants. The differences are statistically significant, but unfortunately the association is in the wrong direction.	↘	Absolute difference DUI recidivism = 3.9% Absolute difference recidivism = 4.0%
Vaucher et al., 2016	Quasi-experimental study on the effect of a treatment programme which informs the participants about the dangers of drink driving and alcohol (ab)use. There were 4 groups: 242 participants in the 7 hour lecture group, 228 participants in the 4 hour lecture group, 257 people in the 2 hour lecture group and 940 people in the control group.	Follow-up of the treatment groups and control group during 10 years in order to calculate (DUI) recidivism within this time frame. Also, hazard ratios were computed using Cox regression	Completers versus people never referred for treatment	DUI recidivism	After adjusting for age, gender, and BAC at the time of the first offence, there was a non-significant 47% increase in the risk of DUI recidivism within two years of the first offence for those having attended the seven-hour series of lectures when compared to those that refused to participate in the study.	—	Absolute difference = 47.0%
Beadnell et al., 2015	Observational evaluation of a new trainings method within the <i>Driver Education and Evaluation</i>	The DUI re-arrest rates of the DEEP group and the	Noncompleters: ME vs. SC	DUI recidivism	While for non-completers, there was no difference between SC	↗	DEEP ME vs SC: odds ratio = 0.73

	<p>Program: ('<i>motivation enhancing</i>' (ME was compared to the earlier used '<i>standard care</i>' (SC). There were several subgroups in the DEEP group: non-completers (n=2083), participants with a stand-alone programme (n=1415) and the participants who received addiction treatment after programme (n=2683). For each of these groups, ME was compared to SC. (Non-completers (n=2226), Completers (n=1856), Completers+treatment, n=2004)</p>	<p>control group are compared using a logistic regression. Absolute and relative risk reduction estimates were calculated as well as number needed to treat (NNT).</p>	<p>Completers: ME vs. SC Completers + Treatment: ME vs. SC</p>		<p>and ME, for completers there were fewer recidivists for ME as compared to SC. These differences occurred for the 'prevention programme completers' group as well as the 'prevention programme and treatment completers' group.</p>	<p>DEEP program + treatment, ME vs. SC: odds ratio = 0.80</p>
<p>Mills et al., 2008</p>	<p>Quasi-experimental study on the effect of the '<i>Sober Drive program</i>' (SDP), This programme aims to reduce recidivism rates among repeat drink drive offenders by <i>promoting participants' understanding of the effects of drunk driving</i> on the self and the community at large, and by assisting participants to develop skills, strategies and knowledge to apply in future situations to prevent re-offending. The evaluation design included a comparison of recidivism rates for programme participants (n=2491) and a control group (n=11407) of convicted drink drivers who received legal sanctions alone.</p>	<p>Recidivism rates were examined using Kaplan – Meier survival analysis, as follow-up times varied between participants. Cox regression analysis was conducted to determine the impact of SDP on recidivism after controlling for confounding variables.</p>	<p>Participants versus people never referred for treatment</p>	<p>DUI recidivism</p>	<p>Re-offending among those who participated in SDP was lower than the comparison group. At the 2-year cut-off, 6.1% of all SDP participants had re-offended compared with 10.1% of the comparison group. When this analysis was repeated comparing those who completed SDP with the comparison group, the effect of SDP on recidivism was somewhat greater.</p>	<p>↗ Odds ratio = 0.47</p>
<p>Bouffard & Richardson, 2007</p>	<p>Quasi-experimental study on the effect of '<i>drug court participation</i>'. The drug court included in this study is a post conviction court. It is a hybrid DWI/drug court that accepts both drug offenders and DWI offenders. Data was collected from 87 participants in a hybrid DWI/drug</p>	<p>Cox regression to calculate DUI recidivism.</p>	<p>Completers versus people never referred for treatment</p>	<p>Re-arrest during the time period between when drug court offenders completed the programme and the date at which</p>	<p>Methamphetamine-involved offenders who completed the drug court programme - did not differ significantly in their probability of post-programme re-arrest from methamphetamineinvolv</p>	<p>— Methamphetamine, drug court vs prison sentence: relative hazard ratio = 1.064 Non-methamphetamine, drug court vs prison</p>

	<p>court. The control group consisted of 124 people convicted to a prison sentence for a DUI offense.</p>			<p>recidivism data was gathered from official records.</p> <p>DUI offenders sentenced to participate in this hybrid drug court were not significantly less likely to be re-arrested after completing the programme than are DUI offenders in the comparison sample.</p>	<p>ed offenders completing traditional sentences of prison followed by parole.</p>	<p>sentence: relative hazard ratio = 0.751</p> <p>DUI, drug court vs prison sentence: relative hazard ratio = 0.527</p> <p>Non-DUI, drug court vs prison sentence: relative hazard ratio = 1.587</p>
Robertson et al., 2009	<p>The purpose of this quasi-experimental study is to evaluate the effectiveness of the 'Mississippi Alcohol Safety Education Program' (MASEP), in reducing DUI recidivism. MASEP is a court-mandated intervention for all first-time DUI offenders in Mississippi. The recidivism rates for three groups are compared: people who did not enrol (control group, n=17937)), people who completed the programme within 3 months ('completers', n=24102) and people who enrolled but never attended as prescribed ('non-completers', n=8843).</p>	<p>Cox proportional hazards regression was used. The first model tested the effect of programme completion on DUI recidivism, the second model tested the effect of the programme version.</p>	<p>Non-completers versus people never referred for treatment</p> <p>Completers versus people never referred for treatment</p>	<p>DUI recidivism, defined as having occurred when someone mandated to MASEP gets a subsequent DUI citation. The time interval until DUI recidivism is 3 years, measured in months.</p>	<p>Offenders who completed MASEP have significantly lower DUI recidivism over a 3 year period than people who did not enroll. Non-completers recidivated at the highest rate.</p>	<p>↗ Non-completers vs control group: relative hazard ratio = 1.30</p> <p>Completers vs control group: relative hazard ratio = 0.71</p>
Robertson et al., 2013	<p>The purpose of this quasi-experimental study is to evaluate the effectiveness of the 'Mississippi Alcohol Safety Education Program' (MASEP) in reducing DUI recidivism. The purpose of this study is to measure the effectiveness of the programme as a whole and to examine whether the most recent programme revisions have led to improvements in reducing DUI recidivism.</p>	<p>The Cox proportion hazards model was used to estimate the effects of covariates on DUI recidivism data. Model 1 estimated the effects of the programme</p>	<p>Non-completers versus people never referred for treatment</p> <p>Completers versus people never referred for treatment</p>	<p>DUI recidivism was defined differently depending on whether the participant enrolled in MASEP. Participants who enrolled in the course were counted</p>	<p>Compared to those who did not complete or did not enrol in MASEP, offenders who completed the programme had significantly lower DUI recidivism at 12 months and at 36 months.</p>	<p>↗ Non-completers vs control group: relative hazard ratio = 0.123</p> <p>Completers vs control group: relative hazard ratio = 0.099</p>

	<p>Individuals were grouped into one of three categories: timely completers (n=12975), noncompleters (n=955) and nonenrollers (n=8797)</p>	<p>completion status on the hazard of DUI recidivism for the entire sample, while Model 2 assessed the effectiveness of the MASEP programmes on the hazard of DUI recidivism for the subsample of participants who completed the MASEP curriculum.</p>		<p>as having recidivated if they had another DUI arrest after the date in which they enrolled in the course. Participants who never enrolled in the course were considered to have recidivated if they had a DUI arrest anytime after their first guilty DUI conviction.</p>			
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3.4 OBSERVED EFFECTS

Studies reporting the percentages of recidivism in treatment vs. control

Author(s), Year	Groups defined	Outcome measure	Percentage treatment group	Percentage control group	Other important variables
Ma et al., 2015	No BOT – EduBOT on time – EduBOT late – FullBOT on time – FullBOT late	Recidivism	NoBOT = 8.5% NoBOT = 8.5% EduBOT on time = 5.4% EduBOT late = 7.2%	EduBOT on time = 5.4% EduBOT late = 7.2% FullBOT on time = 3.9% FullBOT late = 5.8%	age
Ekeh et al., 2008	Participants of the Drive alive programme – control group (a random selection of individuals in the same age range who committed similar offenses, received standard court sentencing and who did not attend the programme)	Recidivism 6m Recidivism 12m Recidivism 18m Recidivism 24m Recidivism 30m	28% 54.7% 68.1% 76.1% 79.1%	42% 53.8% 72.7% 76.8% 82.7%	Moving violations, alcohol violations
Crew & Johnson, 2011	Participants of the Victim Impact Panel – control group	New DUI conviction Any new conviction	12.3% 22.2%	8.4% 18.2%	Prior convictions
Vaucher et al., 2016	7hourlecture – 4hourlecture – 2hourlecture – control group (no lecture)	DUI recidivism 0-2 years	Difference between 7hourlecture and control group = 47.0% (no separate percentages mentioned).		

Studies calculating odds ratio

Author(s), Year	Groups defined	Outcome measure	Result	Other important variables
Beadnell et al., 2015	DEEP: non completers, standalone programme, programme and treatment Standard Care: non completers, standalone programme, programme and treatment	Rearrest during the 3 years after the intervention or after DUI-arrest	Non completers: DEEP vs Standard care = OR 1.05' (n.s.) Standalone: DEEP vs Standard care = OR 0.73* Programme and treatment: DEEP vs Standard care = OR 0.80**	age
Mills et al., 2008	Participants of the Sober Drive Program and control group	Recidivism over a period of 2 years	All participants: OR=0.57 Completers: OR = 0.47	
Crew & Johnson, 2011	Participants of the Victim Impact Panel – control group	New DUI conviction Any new conviction	DUI conviction OR=1.16 (n.s.) Any conviction: OR = 0.992 (n.s.)	Earlier DUI conviction, supervision type (parole or not)

Studies using Cox Regression

Author(s) , Year	Groups defined	Outcome measure	Result	Other important variables
Vaucher et al., 2016	7hourlecture – 4hourlecture – 2hourlecture – control group (no lecture)	DUI recidivism 0-2 years DUI recidivism 2-5 years DUI recidivism 5-10 years	4hourlecture vs 7hourlecture: hazard ratio = 0.53 2hourlecture vs 7hourlecture: hazard ratio = 0.75 4hourlecture vs 7hourlecture: hazard ratio = 1.06 2hourlecture vs 7hourlecture: hazard ratio = 1.03 4hourlecture vs 7hourlecture: hazard ratio = 1.78 2hourlecture vs 7hourlecture: hazard ratio = 1.11	
Bouffard & Richardson, 2007	Drug court: methamphetamine – non methamphetamine – DUI – non DUI Prison sentence: methamphetamine – non methamphetamine – DUI – non DUI	Re-arrest	Methamphetamine, drug court vs prison sentence: hazard ratio = 0.345 (n.s.) Non methamphetamine, drug court vs prison sentence: hazard ratio = 0.472* DUI, drug court vs prison sentence: hazard ratio = 0.590(n.s.) Non DUI, drug court vs prison sentence: hazard ratio = 0.205*	
Robertson et al., 2009	Alcohol Safety Education Program: completers and non-completers Control group (not enrolled)	A subsequent DUI citation within a 3-year time period	Non completers vs non enrollers: hazard ratio = 1.30 Completers vs non enrollers: hazard ratio = 0.71	
Robertson et al., 2013	Alcohol Safety Education Program: completers and non-completers Control group (not enrolled)	DUI arrest up until 36 months after arrest/program	Non completers vs non enrollers: hazard ratio = 0.123 Completers vs non enrollers: hazard ratio = 0.099	Version of the program

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Age-based screening of elderly drivers

Martensen, H.



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1 Summary

1.1 COLOUR CODE

Red: Although studied by a number of good quality studies, age based screening of all elderly drivers for fitness to drive has not been found to reduce fatalities. At the same time there are indications that it might increase fatalities among elderly pedestrians and the average risk per licensed (elderly) driver.

1.2 KEY WORDS

Fitness to drive assessment; elderly drivers; old drivers; senior, screening; motor vehicle; licensing policies, relicensing, licence renewal

1.3 ABSTRACT

Due to the increased numbers and mobility of elderly drivers in most industrialised countries, there has been a growing concern to assure the fitness of elderly drivers. Therefore many countries have introduced additional re-licensing requirements like vision tests, medical check-ups, or on-road driving tests for all drivers from a certain age on (most often 70 years). From a scientific point of view there is no indication that age-based screening of elderly drivers improves road safety. Although a good number of studies from Europe, Canada, and Australia have investigated this effect in the last decade, no effect of increased safety was found. On the contrary there are implications that the measure might have two unwanted side-effects: (1) increased accident risk per licensed driver, and (2) increase of pedestrian fatality rate. However, studies from the United States indicate that obliging drivers to appear in person for licence renewal, rather than allowing re-licensing on-line or per mail has a beneficial effect on the number of fatal crashes involving elderly drivers.

1.4 BACKGROUND

The measure discussed is the *age-based* screening of elderly drivers. This means a fitness to drive assessment is scheduled by *chronological age* rather than concrete indications of reduced driving fitness.

- *Why do many countries screen elderly drivers at regular intervals?*

In an ageing society, the proportion of elderly drivers has been increasing and will do so for the next decades (OECD, 2001). The risk for severe crashes has been shown to increase for drivers from 75 years onwards (for an overview see DaCoTA, 2012). A number of functions important for driving show an age-related decline (e.g., vision, speed of perception and decision making). In addition to 'normal' age-related degeneration, many people of older age have one or more recorded illnesses, which can also compromise their fitness to drive.

- *What are the arguments against screening?*

Age-related decline of fitness to drive does not concern everyone at the same age, and it can mostly be compensated for by changes in driving behaviour: the elderly drive more carefully, at less busy times, and avoid darkness, as well as complex and/or unknown situations (Meng & Siren, 2012). The greatest risk for elderly drivers is related to illness and impairments, which certainly become more frequent at higher age but can affect younger drivers as well.

A fitness to drive assessment should be tailored to the reason for initiating the procedure – the referral diagnosis or the functional impairment felt by the driver or the passengers. A general standardised

testing procedure must necessarily be superficial. For every candidate who is justly prohibited from driving, there are many who should give up, but go undetected, and many who have to give up driving but would never have had an accident. For undetected unfit drivers, the test results can act as a boost of confidence and therefore undermine above-mentioned compensation strategies. Physicians who doubt the fitness to drive of their patients will moreover be more hesitant to take action, if the candidate has been 'approved' by the official authorities (Mikkonen, 2014). For those drivers who lose their driving licence, driving cessation has severe consequences on the social, emotional and also physical well-being (CONSOL, 2012). Moreover, road users who have lost their driver's licence walk more and are consequently exposed to a higher injury and fatality risk than they were as a car-driver (Siren & Meng, 2012).

- *What are alternatives to age-based screening?*

Advising against age-based screening does not mean that it is not necessary to pay attention to the fitness of elderly drivers. A staged system of screening, that starts with a simple self test and /or a visit to the primary care physician is an alternative to mass screening. If the primary caretaker doubts the patient's fitness to drive, she can refer them to a specialist for a more thorough examination, which should be focused on maintaining mobility, e.g. by issuing a limiting licence (e.g. day-time only), adjusting medication, or possibly adjusting the vehicle (EC, 2017).

- *How is the effect of age-based screening measured?*

For the evaluation of individual assessment tools see SafetyCube Synopsis *Medical Referrals* (Boets, 2017). To evaluate the procedural aspects (age-based vs. medical referrals) the most common designs are between country / state comparisons (e.g., Langford et al., 2004; 2008; McGwin, 2008); before-after comparisons (e.g., Siren & Meng, 2012), and panel analyses across several states and several years (e.g., Tefft, 2013; Sharp & Johnson, 2005; Tay, 2012; Grabowski, et al., 2004). The dependent variable is often the fatal-crash involvement rate. For most studies the fatality rates are calculated with respect to the population of the age-segment in question. This is suboptimal, because age-based screening could reduce the number of licensed drivers. Only the Australian studies have based their rates on different baselines: population, licensed drivers, km driven, time spent in traffic (Langford et al., 2004a; 2004b; 2008).

1.5 OVERVIEW OF RESULTS

Generally, studies from Europe, Australia, and Canada do not find an effect, while studies from the US tend to do so. Seven studies from Europe, Australia, and Canada have found no change in the fatality rate due to stricter requirements for licence renewal for elderly drivers. On the contrary, those (Australian) studies that calculated risk-rates *per licensed driver* (rather than per population) even found an *increased* risk per elderly driver for the states with age-based screening. Two studies also found a negative effect of age-based screening on pedestrian fatality rates.

Studies from the US tend to find a reduced fatality rate associated with vision tests upon licence renewal for elderly drivers. However, according to two more recent studies, (Tefft, 2013; Grabowski, 2004) the aspect that affects fatality-rates is to oblige candidates to come for licence renewal *in person* as opposed to giving them the opportunity to do so by (e-)mail or online. There is also an effect of a vision test, but only for those states where renewal by mail is possible. These results suggest that the most important aspect of the whole procedure is to ask people to come and *personally* see someone for the renewal – be that the officer at the licensing authority or their local optician.

2 Scientific overview

2.1 THEORETICAL BACKGROUND

Objective of age-based screening for elderly drivers

Due to the ageing of societies and increased mobility in elderly people, a growing number of drivers is part of this demographic group: the elderly. More than two decades ago researchers started to worry about the accident rate in elderly drivers. Due to an age-related decline in perceptual, cognitive, and physical functions and an increase in chronic diseases, there is a general decline in fitness to drive in the elderly population. And indeed, it was found that although the absolute number of accidents is declining with age, this is due to a reduction in population and in mileage while the risk for accidents per kilometre driven is increasing from an age of 75 on (OECD, 2001; Vaa, 2003; DaCoTA, 2012).

There are two reasons for the increased risk per kilometre in elderly drivers that have nothing to do with a possible regression of their fitness to drive. The most important reason for the increased risk is probably the frailty of elderly drivers due to which they become severely injured or even die of the consequences in an accident that would be much less harmful for a younger person (Li, Braver, & Chen, 2003; DaCoTA, 2012). Moreover elderly drivers typically have a lower mileage than younger ones, and the risk per kilometer is higher for all drivers who drive shorter routes, mainly attributed to the type of road that short routes are driven on (Langford, 2006). Nevertheless, accident causation data suggest that not only does the risk of getting injured or killed increase with age but also the risk of causing accidents (Statistisches Bundesamt, 2012).

Although it is clear that there are great differences in how people age and at what moment their fitness is too compromised to keep driving a car, the need for monitoring the fitness of elderly drivers has been perceived, especially as not all drivers are aware to what extent their functioning is compromised. As a consequence, 12 European countries have a mandatory screening procedure for elderly drivers who want to renew their licence (CONSOL, 2013).

Contra-indications to age-based screening

Age-based screening is, however, far from being undisputed. In general it has been concluded that no positive effect of a screening procedure can be demonstrated (Haustein & Siren, 2015, Vlakveld & Davidse, 2011). Elderly people are generally careful drivers and mostly take measures themselves to compensate for a regressing fitness to drive by either adapting their driving patterns (not driving in darkness, during rush-hour, or on routes unknown to them) or by stopping driving altogether (Meng & Siren, 2012). It is also argued that even with scientifically validated tests, many drivers who would never have an accident are prohibited from driving (Martin, Marottoli, & O'Neill, 2013). Forced driving cessation is associated with an increased chance of depression and with being unable to continue living independently (Windsor, Anstey, Butterworth, Luszcz, & Andrews, 2007; Ragland, Santariano, & MacLeod, 2005). Additionally a substantial proportion of older people relies on driving a car for mobility, and they are left with unfulfilled mobility needs when they stop driving (CONSOL, 2013; GOAL, 2013). Moreover, drivers who lose their licence will (hopefully) tend to increase the number of trips made walking. In this unprotected transportation mode, elderly road users have an even higher risk.

Additionally, a screening procedure might boost the confidence of some drivers who have passed the test. A study by a Finnish insurance company found that elderly drivers had more crashes and fines directly after they had passed the screening test, as compared to right before it. Based on anecdotal evidence, the authors also raised the concern that physicians who doubted their patients' fitness to

drive might rather avoid the uncomfortable task of telling them so, if they assume that the problem will be taken care of in the licence renewal procedure (Mikkonen, 2014)

Age-based screening versus medical referral

The measure discussed here is age-based screening, which means that independent of their medical condition everybody is tested from a certain age on. Advising against age-based screening does not mean that it is not necessary to assess the fitness of elderly drivers. The question is rather whether it should be done routinely from a certain age on or whether it should be initiated by concrete indications either from the drivers and their family themselves or per referral from the physician.

For a population wide screening, the costs of this procedure must be kept relatively low. At the same time, the efficiency of fitness to drive assessment tools depends on the target group. Given a particular diagnosis (e.g., cognitive impairment, Parkinson's disease, Vascular diseases) testing should be focused on different functional aspects and thus different tools are needed, which is impossible for a routine check-up that has to be applied to everyone (see Synopsis on Medical Referrals, Boets et al., 2017). An important question is consequently what to do with the test results of more general screening tests. Using the test results directly to decide on driving prohibition is associated with a high error rate. This means there will be many drivers who are not fit to drive, but can continue, as well as many drivers who are actually fit to drive but will be forced to stop.

In practice, it is more important to focus the diagnostic effort on those drivers with reasonable doubt with respect to their fitness to drive. The decision does not necessarily have to be black and white. Restricting the licence to situations that the candidate can still handle (e.g. only day-time driving or a general limit of 80 km/h) has been shown to be respected by the drivers in question and to lead to a decrease in crashes (Nasvadi & Wister, 2009; Kulikov, 2011). However, to determine which situations a candidate can still handle, a detailed diagnostic process is needed. This process can be much better tailored to the candidate, if testing is initiated by the diagnosis of a physician or concrete problems noticed by the drivers or their social environment (e.g. relatives or friends).

Evaluating the effect of screening elderly drivers

To evaluate the effect of screening, typically three types of studies have been conducted:

- (1) Beforeafter comparisons: upon introduction of a new (element in the) screening procedure, the crash-rate before the introduction is compared to the one after. A general trend in crash numbers is usually taken into account by conducting the same analysis on a group of younger drivers not subjected to the procedure. The papers reviewed here did not however account for other possible influences specifically affecting elderly fatalities.
- (2) Comparisons between two countries/ states/ provinces that differ with respect to the licensing policies for elderly people. This approach can be combined with (1), to have pre-/post-comparisons in both countries. Seeing a change for elderly drivers only in the country with screening (but not for the younger ones and for neither age-group in the country without screening) increases the confidence that the observed pattern is actually due to the licensing policy.
- (3) Comparing several states/ provinces/ countries with respect to different aspects of their licensing policies for elderly drivers and taking those into account in their crash rates. Statistically, these are the most advanced studies that enable researchers to distinguish different aspects of the screening procedure and at the same time correct for possible confounds with other variables.

2.2 INCLUDED STUDIES

Table 1: Information on sample and design of coded studies (sorted by recency)

Author(s) , Year	Sample and study design	Method of analysis	Outcome	Confounds/ corrections	Main result	
Tefft, 2013 USA	The effect of different aspects of licensing requirements on fatal crash involvement rates of elderly motorists is analysed in 46 US states.	Negative binomial regression analysis / panel analysis	Fatal-crash rate per population	Possible differences in elderly mobility as drivers are not taken into account.	States requiring licence renewal to be requested in-person had a lower crash involvement of drivers 85+ than those who did not. For those states where licence renewal can be requested on-line or per e-mail, a vision test was associated with lower fatality rates for drivers 85+	(-)
Tay, 2012 - Canada	The stringency of licensing requirements (rated by experts) in five Canadian provinces is related to the respective vehicle collision rates for ageing drivers.	Negative binomial regression analysis	Fatal-crash rate per population	Results are corrected for share of elderly drivers as well as a number of economic factors.	No significant effect was found, but states with stricter licensing policies towards elderly drivers tend to have even higher vehicle collision rates for elderly drivers.	-
Siren, 2012 - Denmark	Comparing fatal motor vehicle crashes before and after inclusion of cognitive testing into mandatory screening procedure in Denmark.	Chi-square	Fatal-crash rate per population: car drivers / pedestrians and cyclists	Possible differences in elderly mobility and other changes concurrent with measure are not taken into account.	No significant changes in crash-frequency were found for car drivers (neither for elderly nor for younger ones). For pedestrians and cyclists there was a significant increase for elderly but not for younger persons.	↘
McGwin, 2008 USA	Comparing fatal motor vehicle crashes before and after introduction of visual acuity standards in Florida.	Relative risk	Fatal-crash rate per population	The decrease in elderly fatalities started one year before the first drivers had been tested. This could be an indication that the decrease in elderly fatalities was caused by something other than the law.	For elderly drivers 80+, the risk on motor vehicle crashes was lower after the law as compared to before. For all drivers together (independent of age) the difference was non-significant but in tendency the other way around.	↗

Langford, 2008 Australia	Comparing fatality rates for elderly drivers in Victoria (no screening) to those in New South Wales (NSW - screening).	Relative risk	Fatal-crash rate per population and per licensed driver for: (1) driver, (2) passenger, (3) person outside vehicle	Fatalities per population analysis gave similar results to fatalities per driver analysis	No significant differences between Victoria and NSW concerning fatality rates for the drivers themselves, for passengers, or for persons outside the vehicle.	—
Sharp, 2005 USA	The effect of different aspects of licensing requirements on fatal crash involvement rates of elderly motorists is analysed in 46 US states.	Logistic regression (mixed effects)	Fatal-crash rate per population	States with vision tests and on-road driving tests have lower crash-rates	No comparison to younger age-groups. No differentiation between vision/driving test requirements and 'in-person' renewal.	↗
Grabowski; 2004 USA	The effect of different aspects of licensing requirements on fatal crash involvement rates of elderly motorists is analysed in 46 US states.	Negative binomial regression.		Corrected for number licensed drivers and effects on younger drivers	For 85+ 'in-person' renewal reduces the fatality rate. No other significant effects.	—
Keall, 2004 New Zealand	Analysed crash-records of individual elderly drivers (80+) tested in on road driving exams for licence renewal. Drivers who passed the test right away with drivers who needed more than one attempt.	Logistic regression	Crash history (yes/no)		Each time the test is failed the probability for crash involvement during two years after the test increases by 33%.	↗
Langford, 2004 Australia	Comparing crash rates for elderly drivers in Melbourne (no screening) to those in Sydney (screening).	Poisson regression with different off-sets	Crashes per population, license, distance driven, time driven	Corrected for elderly mobility	Fatal crash rates per licence and per time spent driving were significantly higher in Sydney (screening) as compared to Melbourne (no screening)	↘
Langford, 2004 Australia	Comparing fatality/serious injury rates for elderly drivers in Victoria (no screening) to those in other states (different licensing procedures).	Poisson regression with different off-sets	Fatal & serious crashes per population, license, time driven	Corrected for elderly mobility	Elderly driver crash rates (fatal & severe) per licence and per time spent driving in Victoria (no screening) were significantly lower than in other states.	↘

2.3 RESULTS

At the European level, the evaluation of including a test for cognitive impairment into the Danish screening program (Siren & Meng, 2012) suggests that stricter screening rules do not lead to lower crash-rates. It should be noted that two studies not coded for SafetyCube (Mitchel, et al., 2008 reporting only graphic results and Hakamies-Blomquist, 1996) confirmed this null-effect. This is also confirmed in studies from Australia (where Melbourne and Victoria, with no aged based screening were compared to other cities and states with screening). The Australian studies also investigated the risk *per licensed driver* (rather than per population). This risk is even higher in those states that have elderly screening procedures implemented. Only in the United States, the comparison of crash-rates before and after the introduction of a screening programme in Florida indicated decreasing crash-rates for elderly drivers. It must be noted however, that the largest decrease occurred in the year *before* the first driver was tested, which introduces reasonable doubt whether this effect has anything to do with the screening procedure.

A number of older US-American studies (and one that coded for this review, Sharp & Johnson, 2015) have found a positive effect of mandatory vision tests at licence renewal. Two more recent studies give an interesting insight how this apparent contradiction with the rest of the world might come about (Tefft, 2013; Grabowski, 2004). In these two studies, different aspects of a screening procedure were investigating: simply obliging candidates to come in-person for renewal, having their vision tested, having their knowledge tested, and undergoing a practical driving test. The general design of both studies is very similar, with some improvements of statistical modelling and more recent data in the second one. Both studies lead to the same conclusion: for the oldest age-group (85+), the aspect that seems to have an effect on fatality-rates is to oblige candidates to come for licence renewal in person as opposed to giving them the opportunity to do so by (e-)mail or online. There is also an effect of a vision test, but *only* for those states where renewal by mail is possible. It seems that the most important aspect of the whole procedure is to ask people to come and *personally* see someone for the renewal – be that the officer at the licensing authority or their local optician.

Another interesting case is New Zealand. From 1999 to the end of 2006, older drivers aged 80 plus were subject to an on-road driving test every two years. The test had some validity in terms of safety: each test failure was associated with a 33% increase in the odds of subsequent crash involvement (Keall & Frith, 2004). But the test was criticised because it was experienced as stressful and often exceeded the driving demands that older drivers normally faced; the regime was also very costly to maintain. So in 2007, the requirement of an on-road driving test for licence renewal among 80+ was removed. Nevertheless, the numbers of casualties arising from crashes involving drivers aged 80 plus compared to drivers aged 70-79 showed no evidence of change (Keall, 2013).

2.4 CONCLUSION

Seven studies of satisfactory quality have failed to show a positive effect of screening the fitness of elderly drivers purely on the base of their age. On the contrary, two studies have shown an increased risk per licensed driver and one study has shown a negative effect, in the sense that screening has led to an increased number of pedestrian fatalities among the elderly. Three US-American studies suggest, however, that a requirement to come in-person for the renewal of their driver's licence might have a beneficial effect on the crash rate among elderly drivers.

The results thus emphasise the need for rising awareness among elderly drivers of the need to consider their fitness to drive, but at the same time indicate that routine-testing from a certain age on is not an adequate measure to achieve this.

Supporting document

2.5 LITERATURE SEARCH STRATEGY

The literature research for this synopsis was based on the literature review by Siren and Haustein (2015). Study selection for coding up to 2012 was based on the studies reviewed by Siren and Haustein. 10 studies were removed from Siren & Haustein’s list (2015).

- Criterion: 2004 and later
 - 6 excluded
- Criterion: effect estimate in statistical analysis
 - 2 excluded
- Criterion: studies that evaluated the effect on administrative units (country, state, province) rather than on individual driver
 - 2 excluded

This left 9 studies to code for review. Additionally a search from 2013 on was conducted using the same search terms and database (Google Scholar) as Siren and Haustein.

2.5.1 Research terms and hits

Database: Google Scholar

Date: 21st and 22nd April, 2017

Limitations/ Exclusions:

- Published: 2013 to current
- Document Type: Published articles

	search terms / operators / combined queries	hits
Search results sorted by relevance	('old' OR 'elderly' OR 'senior' OR 'age') AND ('license' OR 'licence') AND ('assessment' OR 'testing' OR 'screening' OR 'renewal') AND ('driving' OR 'driver').	115,000
Screened results	Google sorts hits by relevance. All 9 titles relevant for the present search were found within the first 16 hits. The next 54 hits were screened, but no more relevant titles were found. Clearly relatedness to the topic was declining quickly, implying that hits were related to (successively smaller) subsets of the entered search terms only .	70
Selected for abstract review	Titles irrelevant for topic were discarded.	9
Selected for coding	Based on principles below.	1

2.6 PRIORITISATION

The following principles were applied for study selection among the 9 relevant abstracts. These – except for the publication year --were also respected in the studies selected from Haustein and Siren (2015).

Principles

- 2013 and later

- Studies that evaluated the effect on administrative unit (country, state, province) rather than on individual drivers

Excluded

- Effects of driving cessation
- Prevalence of functional impairments (e.g. reduced acuity)
- Risk of functional impairments
- Evaluation of individual tools (-> Synopsis Medical Referrals)
- Practical issues of test-applications

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Fitness to drive assessment tools for medical referrals



Boets, S., Tant, M., Martensen, H., June 2017



Please refer to this synopsis as:

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1 Summary

1.1 COLOUR CODE

Light green: A number of the evaluated off-road tests appear to have some potential for predicting driving performance, and for identifying drivers who do not require an “on-road fitness to drive” assessment. These require further research. Most of the studied tests are not sufficiently accurate to predict on-road performance as a replacement for on-road assessment.

1.2 KEY WORDS

Fitness to drive, assessment, evaluation, screening, prediction, on-road driving performance, older drivers, referred drivers, cognitive impairment, sensitivity, specificity, psychometrics.

1.3 ABSTRACT

The overall aim of fitness to drive assessment is to determine whether a driver with functional impairments will be able to drive a car, and where limitations are detected, determine how these can be compensated for. This overview reviews studies evaluating whether off-road assessment tools can replace on-road testing (at least partly) in this process. None of the evaluated tests (N=14) perfectly predicts driving performance. Thus none would be able to fully replace on-road driving assessment. Drive-Safe/DriveAware and SMC Tests have the highest reported sensitivity and specificity. These have the potential to eliminate the need for on-road testing for a substantial proportion of the tested drivers. However, replication studies are required, particularly because the results depend on the composition of the tested group.

1.4 BACKGROUND

Why and how is fitness to drive assessed?

The aim of determining fitness to drive is to achieve a balance between minimising any driving-related road safety risk for the individual and the community, posed by the driver’s permanent or long-term injury, illness or disability, and maintaining the driver’s lifestyle and employment-related mobility independence. The minimum standards of physical and mental fitness for driving a power-driven vehicle concern vision, hearing, locomotor abilities and cognitive functions (EC, 2016).

On-road assessments are considered the gold standard for evaluating fitness to drive. However, they are very time consuming and expensive, and preferably not required for all drivers with suspected or confirmed impairments.

For some time, there has been considerable international interest in developing stepwise assessment systems, to avoid large numbers of people having to undergo unnecessary and expensive medical fitness tests in order to drive (e.g. AGILE, 2004; Austroads, 2004; EC, 2017).

The currently accepted best practice (EC, 2017) suggests the following **multi-step procedure**:

- (i) Referral by a General Practitioner (GP) or due to self-screening.
- (ii) Assessment of fitness to drive using validated off-road screening tools with acceptable sensitivity and specificity measures, mostly administered by professionals (occupational therapists, psychologists)
- (iii) Referral to expert medical advisory boards for final assessment by expert medical advisors (usually including on-road driving assessment).

Within each step a triage is formed into yes (fit to drive), no (not fit), and unclear (further testing necessary). By referring just the “unclear” cases to the next step, the diagnostic effort can be focused on the cases where it is needed most.

What is the predictive power of a fitness to drive screening tool?

The effectiveness of a test is mostly described in terms of sensitivity and specificity. **Sensitivity** is the ability of the test to identify correctly those who are not fit to drive. **Specificity** of the test reflects the probability that the screening test result will be negative (i.e. safe) among those who are fit to drive. These parameters are qualities of the test and are dependent on the cut-off point chosen. A cut-off point that identifies more true positives also increases the risk of identifying more false positives.

Which factors determine the choice of a test

Tests in phase (i) and (ii) should identify individuals more likely to have a certain condition and in need of further evaluation. Therefore, these tests need to be very sensitive but do not have to be so specific (missing problematic cases would be more severe than false alarms). In phase (iii), a false alarm means that a fit driver would be forced to give up driving. Here a high *specificity* is important.

The predictive value of a test depends in part on its technical parameters, including the sensitivity and specificity, but also on the prevalence of the condition in the tested population. Therefore, it is important to test for those conditions that are likely given the referral diagnosis. This also means that study results for a particular target group (e.g. patients with mild cognitive impairment) cannot be transferred to another target group.

Overview of results

The present synopsis is mainly based on an overview study (Kay et al, 2012) and was further completed with newer studies evaluating tests or batteries in their ability to predict on-road driving assessment.

No single test or battery has optimal sensitivity and specificity and could thus replace on-road performance. Moreover, the results change by target population. However, a number of test-batteries show potential and would deserve more extensive testing. Generally, it should be noted that multi-test batteries perform better than single tests.

DriveSafe/DriveAware assesses the awareness of driving environment using images of an intersection. Additionally, driving ability is assessed with a questionnaire (Kay et al., 2009). Using an upper (safe – fit) and a lower (unsafe – not fit) cut-off value, this test has the potential to eliminate the need for on-road testing for 50% of the referred drivers (mixed diagnoses including cognitive impairment).

The computerised sensorimotor and cognitive tests (**SMC Tests**) include three visuo-perceptual tests (Visual Resolution, Static Perception, and Dynamic Perception), four visuo-motor tests (Ballistic Movement, Footbrake Reaction, Footbrake and Clutch Reaction, and Hand Control reaction), and three eye-arm tracking tests (Sine Tracking, Random Tracking and Step Tracking), which involve the use of a steering wheel and/or foot pedals (Innes et al, 2007). It has the potential to predict on-road performance, but was tested with only a small sample of drivers with mixed conditions.

These test batteries have the potential to predict on-road performance accurately, but since the research on these tests is rather limited, replication studies are required before deciding whether either can predict on-road performance accurately enough to minimise the need for on-road assessment. The other 12 tests can be useful as a supplement to on-road testing and for some tests, different cut-off points can be chosen based on the specific outcome required (e.g. assessment step with emphasis on high sensitivity or on high specificity).

2 Scientific overview

2.1 THEORETICAL BACKGROUND

Aim and methods of off-road FDA and screening tools

It is widely accepted that the success of the private and personal life of people with a disability or long-term medical condition, depends directly on their mobility. Driving a car plays a key role in allowing access to employment, education, medical facilities, and many of the requirements for daily living. Lack of mobility can result in social isolation and the high social cost of maintaining people who have become housebound. Expectations of personal mobility have increased dramatically in recent decades (CONSOL, 2013).

The overall aim of fitness to drive assessment is to determine if a driver with functional impairments will be able to drive a car, and where limitations are detected, determine how these can be compensated for (AGILE, 2004). Fitness to drive has to be differentiated from driving ability, competence, or skill; these are considered to be mostly a question of training. The 3rd European Driving License Directive lays down the minimum requirements for the maintenance of a driving license and does that for reasons of road safety. After knowledge, skills, and behaviour, it stresses the importance of standards of physical and mental fitness. This means that 'health' in general is considered to be a crucial aspect of having a driver's license and hence being awarded the privilege to drive a car.

Fitness to drive is not merely the absence of a medical problem prescribed by statute, such as epilepsy or poor eyesight, important though these are. The process of determining fitness to drive for people with a medical condition or disability is a clinical process. This attempts to assess the impact of any medical condition or disability on the ability to drive, and to provide clear professional advice to a novice or experienced driver, their professional advisers and/or the licensing authority, on whether it is possible to start, continue or resume driving. A large number of professionals, medical and paramedical, might be involved in the decision making process: medical practitioners (GPs and other specialists), optometrists, occupational therapists, psychologists, physiotherapists, alcohol and drug addiction counsellor, etc.

Fitness to drive assessment tools

On-road driving test

The most well-known tool to assess fitness to drive is the on-road driving test, or practical driving assessment. It has frequently been considered as the gold standard in fitness to drive evaluations, although recently its status has been debated. This is primarily for practical reasons due to costs, and also the danger to which it exposes candidates and examiners (EC, 2017). Conversely, its clinical purpose must be considered. It is a tool for appreciating and evaluating impairment-related driving, and any practical consequences. It has a high face validity and is consequently well accepted. Ideally it is not a pass/fail test, but an assessment by pragmatism, which looks for both problems and solutions. Hence, it is not always a (double) blind evaluation. Ideally it integrates background medical information with an objective evaluation of physical, visual, and cognitive function and an in-car demonstration of a disabled person's ability and skill to drive, using any compensatory aids, mechanisms or actions if required (Hunter et al., 2009).

Staged procedure

There is wide variation in the process of establishing fitness to drive within Europe, with substantial differences in the structures involved and the resources available. The differences in driving assessment procedures are particularly marked, with some countries offering no facilities and others

having developed complex processes for medical, psychological and practical on-road assessment. In light of the limited resources and the vast level of complexity of the fitness to drive decision there is currently a movement to a 'stepwise fitness to drive decision system'. The idea here is that the right resources should be allocated to the right people. An efficient screening system applies simple screening methods to a large population. In redirecting and efficiently referring only 'problematic drivers' to the following stage, more sophisticated and specific tools can be applied to fewer drivers. GPs or other professionals in first line health care should make a first tier and direct the driver into 'stop driving', 'continue without any problem' (clear cases 'no' and 'yes'), and finally 'more investigation needed'. This latter 'grey group' should then be referred to experts or specialists in the second line: psycho-geriatrics, neurologists, etc. These experts conduct the same triage, namely yes-no-further referral. The highest level of resources, expertise and decision making can then be applied in the third line, where only a small quantity of candidate drivers is examined at specialized fitness to drive centres. The decisions in the final phase are often not simply a yes or a no. Restricted or conditional licenses for those shown to be marginally at risk, but who require personal mobility for basic medical and social activities, have proven beneficial (Nasvadi & Wister, 2009; Kulikov, 2011). Common restrictions include driving in daylight only, in a restricted well-known area, or at limited speed. The diagnostic decision also concerns the retest frequency (e.g. after one year).

The aim of the staged system is for the level of expertise and complexity to be inversely proportional to the number of drivers tested. This clearly has consequences for the characteristics of the (assessment) tools used at each level.

Off-road assessment tools

Stage 1: GPs are usually willing to be the primary point of contact for initiating an assessment of a person's fitness to drive. However, they often acknowledge the lack of details on specific assessment criteria to use. Therefore, educational programs for GPs and easy-to-use tools to assist in this process are recommended (EC, 2017). Moreover, self-assessment tools could be made available to assist individuals and their family members in this process, such as online self-assessment tools (e.g., AAFTS, 2013; BRSI, 2014).

Stage 2: More advanced off-road tests or tools, mostly administered by professionals (e.g. GPs, specialists such as neurologists, geriatricians, occupational therapists, (neuro-) psychologists, etc.) could be used to identify safe and at-risk drivers, and to separate drivers who require an on-road assessment from those who don't (Korner-Bitensky & Sofer, 2009).

Stage 3: The tools used in this phase are tailored to the referral condition. Each discipline has its proper toolset. For example, an ophthalmologist will use letter charts, and automated or manual perimeters to determine visual acuity and visual field respectively. Typically, this will be complemented by measurements of contrast- and glare sensitivity, eye motility, etc. All of these ocular functions are measured by specific and different tools. The expert is free to decide which specific tool will be used. Cognitive disability tends to be quantified by neuropsychological or cognitive tests. All aspects of attention (selective, sustained, divided), executive function, visuo-spatial function, general cognitive efficiency, and problem solving are examples of cognitive functions considered to be important for the fitness to drive decision. The expert has to choose the test in function of the possibilities of the patient. Usually different aspects or components of cognitive function have to be tested. To evaluate the extent to which a person can compensate for certain disabilities, an on-road driving assessment will usually be included. In this phase, all expertise is to be shared and combined, requiring multi-disciplinarity to be a key element in the final decision making process.

2.2 EVALUATING THE PREDICTIVE POWER OF FDA-SCREENING TOOLS

Study designs in the evaluation of FDA-screening tools

The vast majority of studies in this field apply a prospective or retrospective quasi-experimental design with a specific target group (most: older drivers and cognitively-impaired drivers), use an on-road assessment to validate the FDA (screening) test/tool and define sensitivity and specificity levels (or provide results based on which sensitivity/specificity can be calculated).

How is the predictive power of a FDA-screening tool investigated?

The effectiveness of any test can be expressed in several ways. At the most general level, the 'clinical' effectiveness is expressed as 'validity'. The validity is the ability of a test to indicate which individuals have the disease (in this case are unfit to drive) and which do not.

Quantitatively, results are mostly described in terms of sensitivity and specificity, sometimes with varying levels related to different possible cut-off points. Sensitivity is the ability of the test to identify correctly those who are unfit to drive. Hence the sensitivity of the test reflects the probability that the (screening) test will be positive (unsafe) among those who are unfit. Specificity is the ability of the test to identify correctly those who are fit to drive. Hence, the specificity of the test reflects the probability that the screening test will be negative (safe) among those who are fit. Both sensitivity and specificity are characteristics of the test itself.

The effectiveness or predictive power of FDA tests/tools can be evaluated against different possible outcome measures, of which in this case an on-road assessment (mostly dichotomised as pass/fail) is commonly used. Dichotomising means deciding to let subjects or patients pass or fail by means of a cut-off point. The cut-off points determine how many subjects will be considered unfit to drive. As a consequence, different cut-off points yield different sensitivities and specificities. A cut-off point that identifies more true negatives will also identify more false negatives. And a cut-off point that identifies more true positives will also identify more false positives.

The following table shows the matrix for determining sensitivity and specificity.

Table 1: Matrix for determining sensitivity and specificity

Screening test results	Actual driving performance	
	Unsafe	Safe
Unsafe (fail test)	a (true positive)	b (false positive)
Safe (pass test)	c (false negative)	d (true negative)
Note: Sensitivity = $a/(a + c)$; specificity = $d/(b + d)$		

Alternative measures related to sensitivity and specificity are the positive predictive value (PPV) and negative predictive value (NPV) of a test. The former (PPV) is the proportion of patients who test positive (unsafe) who have the disease (unfit). The latter is (NPV) is the proportion of patients who test negative (safe) who are free of the disease (fit).

In clinical practice the PPV and NPV are more commonly used, because the high or low prevalence is also considered. However, these are not fixed characteristics of the test, but also depend on the prevalence of the condition evaluated. If a person tests positive on any test, the probability that he or she actually has the disease depends not only on the validity of the test (sensitivity and specificity), but also on the prevalence of the disease. (Parikh, et al., 2008).

In principle, an ideal test should have 100% sensitivity and 100% specificity, i.e. it would be error-free. In practice, this is rarely the case and choices have to be made regarding the characteristics of the test (the best test under reasonable conditions). Screening tests are usually not considered to be diagnostic, but are meant to identify individuals more likely to have a certain condition. Participants

who test positive typically require further evaluation with subsequent diagnostic tests or procedures. Therefore, a high sensitivity (few misses) is more important than a high specificity (few false alarms). (Maxim, et al., 2014)

Limitations of FDA and screening tools and challenges of evaluation

As an outcome measure for evaluating off-road FDA tools, on-road assessment is considered the gold standard. However, this assessment can rarely be used on its own, as medical and paramedical issues are additionally to be taken into account when taking the final fitness to drive decision. The practical assessment of fitness to drive involves the integration of background medical information with an objective evaluation of physical, visual, and cognitive function. The driver is allowed and encouraged to use any compensatory aid or action if required. Further, for clinical purposes the on-road assessment is rarely performed 'blindly'. The assessor actually needs the background information to interpret any negative events. Results for research purposes should be interpreted accordingly.

Other possible outcome measures are: a driving simulator test or accident/violation statistics. Driving simulator results can definitely have their merits, but only for specific research questions and traffic situations. It is well-known that most simulators lack ecological validity. Traffic accidents and violations are (fortunately) low-frequency events. Consequently, they are difficult to use for statistical purposes in these usually low-sample studies. Typically, these parameters are based on self-reporting, with the inherent limitations.

Biases and transferability

A complete specification of a screening test includes the intrinsic test characteristics (sensitivity, selectivity and ultimately financial cost), characteristics of the subject population (including opportunities for segmenting the population to identify high risk groups), the key derived quantities (PPV and NPV) and the consequences of false positives and negatives.

The predictive value of the test depends in part on the technical parameters of the test, including the sensitivity and specificity, but also on the prevalence of the disease in the population. For this reason, it is necessary to be able to identify criteria to define a population group or subgroup with a high disease incidence at the outset.

This means that changing one of the parameters changes the complete specification of the test. As a result, test A for target group A cannot be applied to target group B without changing the specification set. Moreover, in a staged procedure as described above, the test characteristics should be tailored to the phase they are used in, because in such a procedure the prevalence should increase in each phase. Note that this is why assessment of asymptomatic populations is not always appropriate and could do more harm than good.

Sensitivity and specificity (although less relevant in clinical practice) do not depend on the prevalence of the condition tested. This is the reason why the review below is focused on these two psychometric properties. Note, however, that they do depend on the cut-off point chosen.

2.3 OVERVIEW OF RESULTS

The review of studies is based on a review by Kay et al. (2012), which was chosen because of its focus on psychometric properties and predictive power for a driving test, combined with the description of practical aspects (15 studies). Three more recent papers were added.

The table in Section 3.2 of the supporting document gives an overview of the main outcomes in terms of sensitivity and specificity for specific off-road FDA and screening tools, including diagnostic group, outcome measure and conclusion on predictive power (to replace an on-road assessment). Kay et al. (2012) set the acceptable level of both sensitivity and specificity at 90% for the purpose of replacing on-road testing for some drivers. It should be noted that if the purpose were to supplement on-road testing, much lower sensitivity and specificity levels of FDA tools would be acceptable.

2.4 CONCLUSION

No single test or battery of tests has perfect sensitivity and specificity. Two of the 14 considered off-road FDA-screening tests meet the criteria of minimally 90% sensitivity and specificity, which is the requirement for the tool to be used in replacement of a driving test. However, these criteria still allow a non-negligible percentage of safe drivers to be misclassified as unsafe, and vice-versa. Moreover, the findings on these two tests are single-study based and should be replicated.

Since driving itself is a complex task, a task of similar complexity is required to adequately predict its performance level. Therefore, the quality of single test predictions will always be worse than those of comprehensive test batteries. There is a large number of clinical diagnoses and an even larger number of clinical manifestations of individual diagnoses. Section 3.3 of the supporting document gives an overview of the main medical reasons for referral to fitness to drive assessment. It is not reasonable to expect that one single test (battery) is able to measure everything for each different medical condition. Moreover, if an individual lacks insight into their own disability, even a good performance on the most relevant clinical or office-based tests does not necessarily predict an adequate driving performance. This is because sickness insight (appreciating and taking into account one's own possibilities and state of mind) is a strong mediating factor.

In conclusion, there is no currently available screening instrument that can replace an on-road driving assessment, or form (by itself) the basis for the decision as to whether a person is fit to drive a motor vehicle.

However, there are two important functions of FDA-screening tools, related to different phases of a staged assessment procedure. (1) In a screening phase, tests with a high sensitivity can reduce the number of persons having to be referred for more thorough testing and (2) in an advanced assessment stage, the practical assessment of fitness to drive has to integrate background medical information with an objective evaluation of physical, visual, and cognitive function. Therefore, each tool must contribute information that has to be integrated by a multidisciplinary team of experts.

3 Supporting documents

3.1 LITERATURE SEARCH STRATEGY

Literature search was conducted in December 2016. It was carried out in three databases and a complementary free internet search. The queried databases were

- Scopus: a large abstract and citation database of peer-reviewed literature
- TRID: a large online bibliographic database of transportation research

Database: Scopus

Date: 21st an 22nd December 2016

Limitations/ Exclusions:

- Search field: TITLE-ABS-KEY or TITLE
- Published: 1990 to current
- Document Type: ALL

	search no.	search terms / operators / combined queries	hits
Fitness to drive – medical referrals	Not selected	(TITLE-ABS-KEY (diagnos* OR "fitness to drive" OR test* OR screen* OR assessment) AND TITLE-ABS-KEY (driv* OR crash OR accident OR traffic OR road OR safety)) AND PUBYEAR > 1989	771,391
	Not selected	(TITLE-ABS-KEY (diagnos* OR "fitness to drive" OR test* OR screen* OR assessment) AND TITLE-ABS-KEY (driv* OR "road safety" OR "traffic accident" OR "road crash" OR "road accident" OR "accident risk" OR "crash risk" OR "road fatalities" OR traffic)) AND PUBYEAR > 1989	300,511
	Not selected	(TITLE-ABS-KEY (diagnostic OR "fitness to drive" OR testing OR screening OR assessment) AND TITLE-ABS-KEY (driv* OR "road safety" OR "traffic accident" OR "road crash" OR "road accident" OR "accident risk" OR "crash risk" OR "road fatalities" OR traffic)) AND PUBYEAR > 1989	150,273
	Not selected	(TITLE-ABS-KEY (diagnostic OR "fitness to drive" OR testing OR screening OR assessment) AND TITLE-ABS-KEY ("road safety" OR "traffic accident" OR "road crash" OR "road accident")) AND PUBYEAR > 1989	12,106
	Not selected	(TITLE-ABS-KEY (diagnostic OR "fitness to drive" OR testing OR screening OR assessment) AND TITLE-ABS-KEY ("road safety")) AND PUBYEAR > 1989	1,187
	#1	(TITLE-ABS-KEY ("fitness to drive") AND TITLE-ABS-KEY ("road safety")) AND PUBYEAR > 1989	35
	#2	(TITLE-ABS-KEY ("fitness to drive") AND TITLE-ABS-KEY (evaluation OR assessment OR screening)) AND PUBYEAR > 1989	426

Database: TRID

Date: 27th December 2016

Limitations/ Exclusions:

- Published: 1990 to 2016
- Document source: ALL, Document Type: ALL, Subject area : ALL
- Language: English and French

	search no.	search terms / operators / combined queries	hits
Fitness to drive	#1	"Fitness to drive" AND (assessment OR evaluation OR screening)	407

3.1.1 Results Literature Search

Database	Hits – Fitness to drive
Scopus	461
TRID	407
Total number of studies to screen title	868

3.1.2 Prioritizing

Among the retrieved studies, 15 review articles were considered for their suitability to present a quantitative overview of test-properties. The paper chosen as point of departure was: Kay, L.G.; Bundy, A.C.; Clemson, L.; Cheal, B.; Glendenning, T. (2012) Contribution of off-road tests to predicting on-road performance: a critical review of tests; Australian Occupational Therapy Journal, 59 (1), p. 89-97.

The paper was chosen because it is relatively recent (2012) and because the selection criteria were closely aligned with those of the present synopsis. It includes tests that have been used in research since 2000, and excluded:

- tests created specifically for one diagnostic group only
- neuropsychological test batteries that had generated comparatively little research
- studies with an outcome measure of on-road assessment on closed circuit routes because they do not involve a full range of driving conditions
- tests where the sensitivity and specificity were not reported or could not be calculated from the data

All papers considered by Kay et al. (2012) were coded. Five papers could not be retrieved and were coded on the basis of the information given by Kay et al. The same criteria were applied to the more recent studies resulting from above search. Three additional papers were identified and coded.

3.2 OVERVIEW OF RESULTS: TABLE

Table 2: Summary of coded study results regarding FDA and screening tools (sorted by test, most studied tests first)

Test name Test description (original citation*)	Research references	Diagnostic sample	Sample size	Outcome measures	Sensitivity (%) fail test + fail drive	Specificity (%) pass test + pass drive	Utility in predicting on-road performance
Useful Field of View (UFOV) alone or in CALTEST							Limited face validity Inconsistent results across different diagnostic groups Not sufficiently accurate to predict on-road performance
A computer-administered and scored test of visual attention to determine the visual field over which a driver can process rapidly presented visual information, including speed of processing, selective and divided attention tasks (Ball & Owsley, 1993)*	Austrorads, 2004 (In CALTEST)	Older drivers	106	On-road assessment	92+	71‡	
	George & Crotty, 2010 (In CALTEST)	CVA	43	On-road assessment	86 (Subset 2)	69 (Subset 2)	
					43 (Subset 3)	89 (Subset 3)	
	Myers et al., 2000 (alone)	Mixed	43	On-road assessment	78	56	
Hoffman et al., 2005 (alone)	Older drivers	155	Simulator	85	Not reported		
Cognitive Behavioural Driver's Inventory (CBDI)							Limited face validity Inconsistent results Not sufficiently accurate to predict on-road performance
27 psychological tests of cognitive and visual processing skills, WAIS and Trail Making A and B, tests of vision and reaction time (Engum et al., 1988)*	Austrorads, 2004	Older drivers	284	On-road assessment	69+	55‡	
	Bouillon et al., 2006	Mixed CNS	172	On-road assessment	62	81	

	Duquette et al., 2010	CVA, TBI	187	On-road assessment	51	85-88	
DriveABLE							<p>Some items have face validity Limited replication of results Not sufficiently accurate to predict on-road assessment Has potential to eliminate the need for on-road testing of 46% of drivers referred</p>
Six computer-based tests: motor speed and control, span of attentional field, spatial judgment and decision making, speed of attentional, shifting, executive functions, and identification of hazardous driving situations (Dobbs, 2013)	Austrroads, 2004	Older drivers	300	On-road assessment	65+	58‡	
	Korner-Bitensky & Sofer, 2009	Varied diagnoses & ages	52	On-road assessment	76	90	
	Dobbs, 2013**	Referred drivers with suspected or confirmed cognitive impairment	3662	On-road assessment (DriveABLE On-Road Evaluation)	Upper cut-off (safe drivers) 95+	Lower cut-off (unsafe drivers) 63‡	
Motor-free Visual Perceptual Test (MVPT)							<p>No face validity Results not replicated Not sufficiently accurate to predict on-road performance</p>
Person identifies correctly completed diagram from a series of options when shown an incomplete	Korner-Bitensky et al., 2000	CVA	269	On-road assessment	61	64	

diagram (Calarusso & Hammill, 1972)	Oswanski et al., 2007	Older drivers with various conditions	232	On-road assessment	60	83	
Clock Drawing Test							No face validity Results not replicated Not sufficiently accurate to predict on-road performance
Pen and paper task to draw a clock face with the hours and hands pointing to a specified time (Critchley, 1953)*	Freund, et al., 2005	Impaired drivers	109	Driving simulator (STISIM)	64 (Note: using cut-off score 4)	98 (Note: using cut-off score 4)	
	Oswanski et al., 2007	Older drivers	232	On-road assessment	70	65	
DriveSafe / DriveAware							Face validity Results not replicated Has potential to eliminate the need for on-road testing of 50% of drivers referred
Assesses awareness of driving environment using images of an intersection & driving ability using a questionnaire (fully revised & updated)	Kay et al., 2009	Mixed diagnoses with cognitive impairment	96	On-road assessment	Upper cut-off (safe drivers)	Lower cut-off (unsafe drivers)	
					93 (Subset 1)	97 (Subset 2)	
					95 (Subset 2)	96 (Subset 2)	
Fitness-to-Drive Screening Measure (FTDS)							Face validity Results not replicated Not sufficiently

Online proxy-screening test in which caregivers who have driven with the driver in the last 3 months can rate a driver's difficulties with 54 driving items + driver demographics, driver habits and driving history	Classen et al., 2015**	Older drivers	200	On-road assessment	81 (Note: using cut-off score 73,465)	60 (Note: using cut-off score 73,465)	accurate to predict on-road performance
Web-based Bern Cognitive Screening Test (wBCST)							Some face validity Results not replicated Not sufficiently accurate to predict on-road performance
Web-based computer test for driving-relevant cognitive functions (five subtests): eye-hand coordination, selective attention, divided attention, executive function, distance judgment and speed regulation	Nef et al., 2013**	Older drivers: mixed healthy and cognitively impaired	80	Driving simulator	83 (Note: using cut-off score 0,75)	70 (Note: using cut-off score 0,75)	
Multidomain Tests							Limited face validity Results not replicated Not sufficiently accurate to predict on-road performance
Three tests of vision, cognition, motor and balance (colour choice, reaction time, postural sway & motion sensitivity); plus self-report of driving exposure (i.e. number of kilometres driven)	Wood et al., 2008	Older drivers	270	On-road assessment	91	70	
Visual Slide Recognition Test (VRST)							Face validity Replicated in revised

Assesses awareness of driving environment	Kay et al., 2008	Mixed diagnoses with cognitive impairments	838	On-road assessment	81	89	format as DriveSafe Not sufficiently accurate to predict on-road performance
Computerised sensorimotor and cognitive tests (SMC Tests)							Some items have face validity Results not replicated Has potential to predict on-road performance accurately
Computer-based tests with car controls to assess visual perception; visual motor, eye-arm tracking; divided, complex attention; visual search; decision-making; planning; impulse control	Innes et al., 2007	Mixed	50 with medical conditions	On-road assessment	97	89	
			12 healthy controls				
Maze Test							No face validity Results not replicated Not sufficiently accurate to predict on-road performance
Pen and paper mazes	Snellgrove, 2005	MCI	115	On-road assessment	78	82	
CALTEST							Some items have face validity but are not associated with driving Results not replicated Not sufficiently accurate to predict on-road performance
Computer-based (touch screen) test including: autotrails, UFOV and modified Hazard Perception Test (HPT) (Janke, 1994; Janke & Eberhard, 1998)*	Austrroads, 2004	Older drivers	286	On-road assessment	56†	72‡	

Trail Making Test B in GRIMPS							No face validity Results not replicated Not sufficiently accurate to predict on-road performance
Pen and paper task to connect alternating consecutive numbers and letters (Reitan, 1958)*	Austrroads, 2004	Older drivers	278	On-road assessment	30†	81‡	

Primary source: Kay et al., 2011

*If earlier than 2000.

**Added to references in Kay et al., 2012.

†Reported results re-calculated for failing test / failing driving performance.

‡Reported results re-calculated for passing test / passing driving performance.

3.3 MAIN MEDICAL REASONS FOR REFERRAL TO FITNESS TO DRIVE ASSESSMENT

Annex III of the European Driving License directive (EC, 2006) states the minimum standards of physical and mental fitness for driving a power-driven vehicle. It has chapters on 'sight', 'hearing', 'locomotor disabilities', 'cardio vascular disease', 'diabetes', 'neurological disorders', 'mental conditions', 'alcohol', 'drugs and medicinal products', and 'renal disorders'.

Sometimes a fitness to drive decision will be made purely on medical grounds, for example in the case of epilepsy (neurological condition). However, in many cases the seriousness of the condition and its impact on everyday life activity, including driving, has to be considered. For example, in the case of a cerebrovascular accident (CVA, also a neurological condition), besides locomotor consequences, neuropsychological and ophthalmological consequences will have to be considered. Many different ways and methodologies exist for quantification. Most likely, due to the complexity of both the human mind and that of the driving task, it will involve a battery of tests incorporating different aspects or components of cognitive function. It must be kept in mind that a test of higher cognitive function can identify and measure the nature and extent of the cognitive deficiency or disorder, but not the extent to which the rest of the person's brain can compensate for it.

Other conditions that have received a lot of attention in relation to fitness to drive, are traumatic brain injury (TBI), forms of dementia (including mild cognitive impairment (MCI) and more generally, old age.

Dementia refers to serious loss of global cognitive abilities, beyond what might be expected from normal aging. This cognitive decline interferes with daily functioning. Affected areas of cognition may be memory, attention, language, visuospatial abilities, and problem solving, and can thus have a major impact on fitness to drive. However, dementia is a broad, nonspecific concept. Dementias have a wide variety of causes, including neurodegeneration (e.g., Alzheimer's disease, dementia with Lewy bodies, Parkinson's disease), cerebrovascular pathology (vascular dementia), infections (e.g., dementia associated with HIV), toxic and metabolic processes (e.g., Wernicke-Korsakoff syndrome), brain traumas, and brain tumours. A diagnosis of dementia is often given when the cognitive impairments are still mild. In later stages of dementias with a progressive course, large parts of the brain are affected, resulting in numerous cognitive impairments and comparable symptoms between patients. However, in early stages of dementias, specific patterns of cognitive and behavioural dysfunctions may be detectable. This variation is increased by the various aetiologies underlying dementia. As a result, patients with dementia differ regarding their cognitive impairments and consequently with respect to their fitness to drive (Piersma et al., 2016; Chee et al., 2017).

In addition to patients with a diagnosis of dementia, there are patients with mild *cognitive impairment* (MCI), which is generally considered to be a state between normal cognition and dementia. In this group, daily functioning is still preserved or only minimally impaired. Similar to dementia, MCI also includes various cognitive impairments and a wide variety of causes.

Traumatic brain injury (TBI) is often caused by road traffic accidents. Other causes are domestic falls, assaults, occupational injuries, and recreational injuries. Estimates made in the United States and Western-Europe before 1980 indicate some 10 new cases of TBI every year per 1000 inhabitants, showing its high prevalence. When considering only cases severe enough for hospital admittance, estimations for the same period are 2/1000, but it appears that in the aforementioned countries figures have decreased to approximately 1/1000 in the last decades of the 20th century, probably because of improved crash protection measures. Most victims have sustained closed head injuries (CHI) with initial durations of disturbed consciousness (coma and posttraumatic amnesia). Initial recovery after TBI is fast, but after a period of 6 months to 1 year,

the situation has usually stabilized in terms of persistent impairments. Diffuse and focal damage in TBI often results in acquired impairments of perceptual, cognitive, and motor processes that are important for safe driving (Brouwer et al., 2002).

A *Cerebro Vascular Accident* (CVA) or stroke occurs when poor blood flow to the brain results in cell death in the brain or cerebrum. There are two main types of stroke: ischemic, due to lack of blood flow, and haemorrhagic, due to bleeding. They result in parts of the brain not functioning properly, resulting in apparent symptoms. Strokes remain one of the leading causes of mortality and morbidity worldwide. According to World Health Organization estimates, there are 15 million incidences of stroke each year, of which approximately 10 million survive. Although mortality as a result of stroke has reduced since 2011, it remains a major health problem and a leading cause of long-term disability. The symptoms of a stroke can be permanent, numerous, and varying in the level of disability: an altered smell, taste, hearing, or vision (total or partial), weakness of ocular muscles or inability to move or feel on one side of the body, dysarthria, altered reflexes, sensation, and balance, vertigo, aphasia, apraxia, visuo-spatial neglect, memory deficits, disorders of attention, problem solving, planning, and anosognosia. These sequelae can lead to unsafe driving (Devos, et al., 2014; Ranchet et al., 2016). If symptoms last less than one to two hours, it is known as a transient ischemic attack (TIA) or mini-stroke.

The issue of aging drivers is discussed in the synopsis "Screening elderly drivers". The issue is mentioned here, because many of the above mentioned conditions have a higher incidence among older people. Nevertheless, age in itself cannot be considered a disease or a medical challenge and should therefore be omitted from this discussion on medical disorders.

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Effectiveness of Road Safety Campaigns



Kaiser, S. & Aigner-Breuss, E., June 2017

1 Summary

1.1 COLOUR CODE

Light green

There is some indication that campaigns are beneficial for road safety on various levels. Meta-analyses show an association with accident reduction, increased safe behaviours and risk awareness. However, for other outcome variables such as drink-driving or safety relevant attitudes, no such effect was found. Furthermore, meta-analysed studies vary strongly, mainly regarding the design of the evaluated campaigns.

1.2 KEYWORDS

Road safety campaign, awareness raising, campaign effectiveness, campaign evaluation.

1.3 ABSTRACT

Road safety communication campaigns aim at informing, persuading and motivating people to change attitudes and behaviour and ultimately at improving road safety.

Two meta-analyses on campaigns with various road safety themes showed an association with a reduction of accident occurrence (9%) as well as a favourable change in (observed and self-reported) seat belt use (+25%), yielding behaviour (+37%), speeding behaviour (-16%) and risk comprehension (+16%). No significant changes are indicated, however, for drink-driving behaviour, favourable road safety attitudes and knowledge. Often, when road safety campaigns are implemented, they are accompanied by increased enforcement. Accounting for this factor, a decrease in accidents can still be found in a meta-analysis due to campaigns solely, however, a smaller one (10% vs. 13% for campaigns combined with enforcement).

1.4 BACKGROUND

From 2006 to 2009, the EU Project CAST "Campaigns and Awareness-Raising Strategies in Traffic Safety" was carried out by 19 partners from 15 European countries. This project identified essential parameters of campaigns and was aimed at enhancing the effectiveness of communication strategies in road safety (Delhomme et al., 2009).

How is 'campaign' as a road safety measure defined?

The EU project CAST provides the following definition of campaigns in the field of road safety: "Road safety communication campaigns can be defined as purposeful attempts to inform, persuade, or motivate people in view of changing their beliefs and/or behaviour in order to improve road safety as a whole or in a specific, well-defined large audience, typically within a given time period by means of organised communication activities involving specific media channels often combined with interpersonal support and/or supportive actions such as enforcement, education, legislation, enhancing personal commitment, rewards, etc." (Elliott, 1993, Rice & Atkin, 1994, Vaa et al., 2008, as cited in Delhomme et al., 2009). While this is an accepted definition, it has to be noted that the combination of campaigns with e.g. enforcement makes it difficult to assess the effectiveness of the campaign as a single measure.

When designing a campaign it is crucial to follow these main steps:

- Define specific road safety problem
- Define target audience
- Define message and communication strategy

The media to transport the message are manifold and have to be tailored to the target group. Commonly used channels are broadcastings on TV, radio, newspaper, posters, leaflets, billboards, internet advertisement and social media.

How do campaigns affect road safety?

Campaigns target the following aims, as Delhomme et al. (2009, p. 17) point out:

- "(1) to provide information about new or modified laws.
- (2) to improve knowledge and/or awareness of new in-vehicle systems, risks, etc., and the appropriate preventive behaviours.
- (3) to change underlying factors known to influence road-user behaviour.
- (4) to modify problem behaviours or maintain safety-conscious behaviours.
- (5) to decrease the frequency and severity of accidents."

So the effect of a campaign can be increased information, knowledge, raised awareness, changed attitude, and changed behaviour to the extent that eventually the frequency of accidents is reduced. However, since accident occurrence is multicausal and highly influenced by chance there is rarely a direct link from a campaign to accident reduction. Campaigns influence the "mediators" in cognition of humans, which are knowledge, awareness, and attitudes. Many campaigns are combined with enforcement and new legislation. It is difficult to attribute the effect to a single element of this combination. Campaigns can also be used to establish favourable preconditions in the public for new legislation.

Which factors influence the effect of a campaign on road safety and which are the modifying conditions?

Important factors for an effective campaign are clearly defined road safety problems and target groups, as well as a corresponding tailored message. Furthermore, it is necessary to use theoretical psychological models that explain the risk behaviour or safety problem (Delhomme et al., 2009). These models help to define the campaign's aim, the campaign strategy and message. It is important to note that communication has to be based on the cultural codes used in the target community (national, regional, sub-groups etc.). That means that a successful campaign might not be as effective in another country or community. A controversial issue when designing a campaign message is whether or not fear-based information is effective. While this kind of approach was used widely in the past, more recent research indicates that information campaigns that focus on positive consequences are more effective, especially among males and young groups, than confronting campaigns (SWOV, 2015). Other influencing factors are the duration and intensity of a campaign. Also, other situational factors such as simultaneous competing events (e.g. tragic accident reported in media) can have an impact on the campaign effects.

How is the effect of a campaign on road safety measured?

The following measures are used to assess the effectiveness of campaigns:

- Accident occurrence
- Observed behaviour such as seat belt usage, mean speed, headway distance etc.
- Behaviour and intended behaviour reported in questionnaires and interviews
- Attitudes, opinions, norms, knowledge, behavioural beliefs, risk perception reported in questionnaires and interviews
- Observations of other road users reported in questionnaires and interviews

The vast majority of studies in this field apply a before-after design to measure the campaign effect. In a few cases, the effects are put into the context of accident statistics since crashes are multicausal events.

1.5 OVERVIEW OF RESULTS

Two meta-analyses (Phillips et al., 2009 and 2011) calculated the effect of road safety campaigns in general and for various additional campaign themes such as drink-driving or speeding.

Phillips et al. (2011) reported an overall decrease of crashes of 9% as well as 8% for injury crashes and 11% (non-significant) for fatal crashes. Differentiating by theme, drink-driving campaigns are especially associated with accident reduction (see also synopsis 'Awareness raising and campaigns – Driving under the influence') while speeding campaigns did not lead to a significant change.

Regarding (observed and self-reported) behavioural changes Phillips et al. (2009) reported a significant increase in seat belt usage (25%) and yielding behaviour (37%) as well as a 16% significant reduction in speeding. However, no significant change in drink-driving behaviour was found. Also risk comprehension was found to be positively influenced (16% increase), while no impact was observed for favourable road safety attitudes and knowledge.

Only Phillips et al. (2011) made a further differentiation between campaigns which were accompanied by increased enforcement activities and campaigns solely. Both groups resulted in a significant reduction of accidents. However, the decrease is higher for campaigns combined with enforcement (13% vs. 10%).

It has to be noted that the individual studies which were considered in the two meta-analyses vary widely in terms of campaign specifics (exact activities, media, length, target group, underlying theoretical model as foundation for design etc.).

2 Scientific overview

2.1 THEORETICAL BACKGROUND

Aim and methods of awareness raising measures and campaigns

The main purpose of awareness raising measures and communication campaigns is to encourage road users to engage in safe behaviour in traffic. The underlying concept of campaigns in road safety is social marketing.

Social marketing is defined as “the use of marketing principles and techniques to influence a target audience to voluntarily accept, modify or quit behaviour for the benefit of individuals, groups or society as a whole, and marketing strategy factors which includes marketing mix” (Kotler et al, 2002, as cited in Delhomme et al., 2009, p. 87). Social marketing aims at influencing and changing social behaviours, which are in the interest of a target audience or of the society as a whole. That is the case if e.g. a campaign promotes the idea that drink-driving is against the social norm of the peer group.

Social marketing can also be targeted at raising knowledge and changing attitudes respectively in order to influence the behaviour (Delhomme et al., 2009). As an example, campaigns can inform a target group about the correct behaviour like the correct use of child restraints.

When developing a campaign, it is crucial to conduct a detailed analysis of the **road safety problem** that is targeted and to clearly identify the **target group** of the campaign. It is less effective to spread information all over the public. Segmentation of the audience means focusing on those who show the problematic behaviour. This can be done by means of statistics, databases, observations and surveys.

For developing the **campaign’s message**, it is also necessary to know as much as possible about the target group. What are the deficits in knowledge? Is there a lack of awareness of the problem? Are the people not able to resist the problem behaviour? Why? Is it a planned behaviour or is it a habit? What could motivate the target group to adapt their behaviour? In this respect, theoretical models are very helpful: their use for the development of the campaign message has been found to increase the effectiveness of campaigns (Delany et al., 2004). There are several psycho-social theories, which are applied to explain road user behaviour. For evidenced-based campaigns the following models are most often used (Robertson & Pashley, 2015):

- Theory of planned behaviour (TPB)
- Health belief model
- Protective motivation theory
- Transtheoretical model of change
- Social norms theory
- Elaboration likelihood model

A description of these models can be found in SafetyCube’s Deliverable 4.2 (Theofilatos et al., 2017).

Besides developing the message, the **campaign strategy** has to be defined. Campaigns may use an information approach or use emotions, especially fear to draw the target audience’s attention to the message. There are still controversial discussions on this topic (see e.g. Castillo-Manzano et al., 2012). Phillips et al. (2011) analysed road safety campaigns in 12 countries from the years 1975 to 2007. The authors found weak methodologies and therefore could not draw conclusions on whether fear appeals should be used or not. More studies with robust methodologies are needed.

To evaluate whether or not the message of the campaign can influence the behaviour of the target group as intended, a **pre-test of message** and slogan should be conducted before the campaign is finalised and released (Delhomme et al., 2009, Hoekstra & Wegman, 2011).

The following **types of media** are generally used for road safety campaigns: television, radio, newspaper/magazines, cinema, web/online, social media, billboards, flyers/leaflets/posters, message signs and events involving face to face communications. An overview of the advantages and disadvantages of different types of media for road safety campaigns can be found in Delhomme et al. (2009).

Campaign effects and influencing factors

Awareness raising activities and campaigns can positively influence a number of road safety relevant constructs such as favourable attitudes, knowledge and perceptions as well as safe behaviour and therefore, also accident rates. However, there are various factors to be considered to maximise impact.

Phillips et al. (2011) carried out a meta-regression (model of predictor variables) based on 119 individual campaign effects to identify the relative importance of factors influencing the effectiveness of road safety campaigns. They identified the following factors of campaigns to be associated with accident reduction:

- Personal communication
- Road side delivery (billboards, message signs)
- Drink-driving theme
- Combination with enforcement
- Short campaign duration (0-29 days)

Vaa et al. (2004) conducted a meta-regression considering various outcome variables, not only accident reduction (e.g. self-reported behaviour or attitudes) and found the same factors to be beneficially influencing campaign outcomes.

Snyder & Hamilton (2004) discuss the impact of the factor 'behavioural baseline' on health campaign outcomes. If a favourable behaviour such as seat belt wearing is already widespread, the impact of a campaign will obviously be diminished. But having very few people engaging in a certain behaviour can also be disadvantageous as a starting point for a campaign, since there are not enough role models in the target group yet. Thus, in general a moderate baseline rate leads to the highest impact.

Limitations of campaigns and challenges of evaluation

In the past, evaluations of campaigns were rarely carried out for various reasons. For one, sometimes there is a lack of awareness regarding the benefit of evaluating, or there may be budget and time constraints. Uncertainties in terms of methodological application are also a barrier ("How can I clearly see and measure if this effect was created by the campaign?"). However, by understanding the mechanisms of certain attitudes and behaviours and describing them by psychological theories (see above), it is feasible to define measurable dimensions.

As previously described, the effectiveness of road safety campaigns can be measured by various means. The ultimate outcome measure is a reduction in crashes. It is difficult though to link an accident reduction to a campaign, while controlling for all other possible contributing factors. The defined outcome measures to account for campaign effects are therefore often 'indirect' like intended behaviour or attitudes etc. Even though there is evidence concerning the influence of these constructs on actual behaviour, there are also always other determining factors (e.g. situational factors) that cannot be accounted for.

A before-after-design ideally includes a meaningful reference group to control for confounding factors (e.g. a similar geographical region where there is no exposure to the contents of the campaign), which is however rarely the case.

Next to a lack of (systematical and valid) evaluation of effects, often, campaigns are combined or conducted simultaneously with enforcement measures and implementation of new legislation respectively. If an effect (improvement) is measured then, it remains unclear to which of the single

components it is attributable, and to what extent. Furthermore, even though research indicates a generally positive effect of an additional enforcement strategy on road safety, this might not be the case for specific topics such as speeding (Hoekstra & Wegmann, 2012).

2.2 CODED STUDIES

The literature search was carried out in three databases (Scopus, TRID and a KfV-internal literature database) with separate search strategies (for a detailed description see the section "Supporting documents"). Additionally, a free web-based search was conducted via Google.

Below, first information on the characteristics of coded studies is given and subsequently the main research methods used for evaluating campaigns and awareness raising measures is provided.

Description of studies

There is only a very small number of meta-analyses on the effectiveness of road safety campaigns. The most recent meta-analysis using accidents as outcome variable was published in 2011. Phillips et al. (2011) investigated 67 studies on road safety campaigns from 12 different countries over the time period 1975 to 2007 and extracted 119 estimates. They allowed for publication bias and heterogeneity of effects and then found a weighted average effect of road safety campaigns of 9% in accident reduction (with 95% confidence that the weighted average is between -12 and -6%). In order to better understand the variability of results the authors collected information on campaign characteristics and evaluation design associated with each effect. A model of seven campaign factors was developed and tested by a meta-regression (e.g. theme of the campaign, nature of campaign message and how message was delivered, if there was a pretest with a sample of the target group and if a psychological/social marketing model was used). After having identified this list of possible contributors, the factors were inspected by statistical analyses.

Phillips et al. (2011) state that the meta-analysis of "119 individual estimates of the effect of campaigns on accidents using a fixed-effect model gave a combined estimate" (p. 1210). To characterise the campaigns, subgroups were analysed.

The authors reported that it was difficult to find studies dated after 2000 and a "thorough search failed to find any campaign evaluations based on accident effects that were published between 2008 and 2010". Furthermore, "according to a fixed effects (regression) model, a drink-drive theme, shorter campaign duration (<30 d), use of personal communication, roadside delivery, and enforcement are each uniquely associated with greater accident reductions" (p.1213).

Phillips et al. (2009) focused the meta-analysis on various outcome measures and road safety themes (e.g. seat belt use, speeding, drink-driving, yielding to pedestrians, attitudes, risk comprehension and knowledge) including 437 individual campaign effects from the last 30 years in 14 countries. Weighted average effects were calculated after accounting for publication bias. 202 campaign effects were taken from campaigns accompanied by increased enforcement. More than half of the studies did not employ a control group.

Table 1: Information on sample and design of coded meta-analyses, sorted by authors

Author(s), year, country	Measure description	Evaluation design	Research conditions
Phillips et al, 2009, international	Road safety campaigns in 14 countries in the last 30 years; campaign media: TV, radio, newspaper, leaflet, posters, cinema, billboard, personal communication, website, variable and fixed message signs	Meta-analysis of 180 studies	A weighted average was calculated from 437 individual campaign effects.

Author(s), year, country	Measure description	Evaluation design	Research conditions
Phillips et.al, 2011, international	Road safety campaigns in 12 countries (1975-2007), campaign media: TV, radio, newspaper, leaflet, cinema, billboard, personal communication	Meta-analysis of 67 studies	A weighted average was calculated from 119 individual campaign effects.

Description of the main research methods

The two coded meta-analyses mainly comprised studies with a before-after design with various outcome variables. While Phillips et al. (2011) focused on crashes (all, fatal and injury), Phillips et al. (2009) also considered observed and self-reported road safety behaviour. Most of the evaluation studies included a control group. Both meta-analyses were adjusted for publication bias and used weighted average effects.

2.3 OVERVIEW OF RESULTS

The following table presents information on the main outcomes of the coded studies (Table 2). A description of coded studies on the topics fatigue, visibility and protective clothing as well as helmets can be found in the section "Supporting Documents" together with the corresponding main results.

Table 2: Summary of meta-analyses results

Author(s), year, country	Exposure variable	Dependant / outcome type	Effects on road safety	Main outcome – description
Phillips et.al, 2009, international	Road safety campaigns on seat belt use	Seat belt use (observed, 119 effects and self-reported, 14 effects)	↑ Percent change = 0.25 CL: 95%, CI: 0.18 - 0.31	Road safety campaigns on seat belt use are linked to a significant 25% increase of seat belt usage.
	Road safety campaigns on speeding	Speeding (observed, 21 effects and self-reported, 7 effects)	↑ Percent change = -0.16 CL: 95%, CI: -0.25 - -0.06	Road safety campaigns on speeding are linked to a significant 16% decrease in speeding behaviour.
	Road safety campaigns on drink-driving	Drink-driving (observed, 4 effects and self-reported, 19 effects)	– Percent change = -0.17 CL: 95%, CI: -0.46 - 0.28	Road safety campaigns on drink-driving are linked to a non-significant 17% decrease of drink driving behaviour.
	Road safety campaigns on considerate behaviour	Yielding to pedestrians (observed, 11 effects and self-reported, 2 effects)	↑ Percent change = 0.37 CL: 95%, CI: 0.14 - 0.65	Road safety campaigns on considerate behaviour are linked to a significant 37% increase of yielding to pedestrians.
	Road safety campaigns	Favourable road safety attitudes	– Percent change = 0.05	Road safety campaigns are linked to a non-significant 5% increase of favourable road safety attitudes.

		(self-reported, 39 effects)		CL: 95%, CI: 0.00 - 0.11	
		Risk comprehension (self-reported, 24 effects)	↗	Percent change = 0.16 CL: 95%, CI: 0.04 - 0.30	Road safety campaigns are linked to a significant 16% increase of risk comprehension.
		Knowledge (self-reported, 17 effects)	—	Percent change = 0.44 CL: 95%, CI: -0.10 - 1.32	Road safety campaigns are linked to a non-significant 44% increase of road safety knowledge.
Phillips et al., 2011, international	Road safety campaigns	Crashes	↗	Percent accident reduction = 0.09 CL: 95%, CI: 0.12 - 0.06	Road safety campaigns are linked to a significant 9% accident reduction.
		Injury Crashes	↗	Percent accident reduction = 0.08 CL: 95%, CI: 0.13 - 0.02	Road safety campaigns are linked to a significant 8% injury accident reduction.
		Fatal Crashes	—	Percent accident reduction = 0.11 CL: 95%, CI: 0.22 - -0.01	Road safety campaigns are linked to a non-significant 11% fatal accident reduction.
	General road safety campaigns on mixed topics	Crashes	↗	Percent accident reduction = 0.14 CL: 95%, CI: 0.25 - 0.01	General road safety campaigns on mixed topics are linked to a significant 14% accident reduction.
	Road safety campaigns on speeding	Crashes	—	Percent accident reduction = 0.04 CL: 95%, CI: 0.10 - -0.01	Road safety campaigns on speeding are linked to a non-significant 4% accident reduction.
	Road safety campaigns on drink driving	Crashes	↗	Percent accident reduction = 0.18 CL: 95%, CI: 0.23 - 0.12	Road safety campaigns on drink driving are linked to a significant 18% accident reduction.
	Road safety campaigns on other topics	Crashes	↗	Percent accident reduction = 0.07 CL: 95%, CI: 0.12 - 0.01	Road safety campaigns on other topics are linked to a significant 7% accident reduction.
	Road safety campaigns with enforcement	Crashes	↗	Percent accident reduction = 0.13 CL: 95%, CI: 0.16 - 0.09	Road safety campaigns with enforcement are linked to a significant 13% accident reduction.

Road safety campaigns without enforcement	Crashes	↗	Percent accident reduction = 0.10 CL: 95%, CI: 0.16 - 0.03	Road safety campaigns without enforcement are linked to a significant 10% accident reduction.
Road safety campaigns with law changes	Crashes	–	Percent accident reduction = 0.09 CL: 95%, CI: 0.17 - 0.00	Road safety campaigns with law changes are linked to a non-significant 9% accident reduction.
Road safety campaigns without law changes	Crashes	↗	Percent accident reduction = 0.12 CL: 95%, CI: 0.16 - 0.07	Road safety campaigns without law changes are linked to a significant 12% accident reduction.

*Effects on road safety are coded as significant positive (↗), significant negative (↘) or non-significant (–).

Phillips et al. (2009, 2011) analysed the overall effect of road safety campaigns – with additional effect calculations for various campaign themes e.g. drink-driving, speeding. They thereby considered the results of previous meta-analyses.

Phillips et al. (2011) reported an overall decrease of crashes of 9% as well as 8% for injury crashes and 11% for fatal crashes. The latter however was not significant. Considering different campaign themes it proved that especially drink-driving campaigns are yielding effects. Whereas, campaigns with a drink-driving theme resulted in a significant accident reduction (18%) anti-speeding campaigns led to no significant change.

Regarding behavioural changes, Phillips et al. (2009) reported a significant increase in seat belt usage (25%) and yielding behaviour (37%) as well as a 16% significant reduction in speeding. However, no significant change in drink-driving behaviour was found. It should be noted that behavioural outcomes refer to observed and self-reported behaviour.

Road safety campaigns also positively influence risk comprehension (16% increase), while no impact was found for favourable road safety attitudes and knowledge.

It is important to consider that both meta-analyses calculated effects of campaigns with and without enforcement components. Phillips et al. (2011) reported results adjusted for accompanied enforcement measures. The reduction for campaigns accompanied by enforcement is higher (13%) than campaigns only (10%). Both effects are significant, though.

Modifying Conditions

Phillips et al. (2011) carried out a meta-regression (model of predictor variables) based on 119 individual campaign effects to identify the relative importance of factors influencing the effectiveness of road safety campaigns. They identified the following factors of campaigns to uniquely be associated with accident reduction:

- Personal communication
- Road side delivery (billboards, message signs)
- Combination with enforcement
- Short campaign duration (0-29 days)

Phillips et al. (2009) outlined conclusions on a meta-regression by Vaa et al. (2004). They considered various outcome variables, not only accident reduction (e.g. self-reported behaviour or attitudes) and found the same factors as listed above to be beneficially influencing campaign outcomes.

2.4 CONCLUSION

There is some indication that campaigns are beneficial for road safety on various levels. Meta-analyses show an association with accident reduction, increased safe behaviours and risk awareness. However, for other outcome measures such as drink-driving behaviour or safety relevant attitudes, no such effect was found. Furthermore, meta-analysed studies vary strongly. Accounting for the factor that campaigns are often combined with enforcement activities, there is still a decrease in accidents, however, a smaller one.

Biases and transferability

Most campaign evaluations included in the meta-analyses were carried out soon after the campaign ended. Hardly any long term effects are available. Therefore, sustainable changes in behaviour due to campaigns remain unclear. Meta-analysed studies were quite different regarding exposure variables (different aims and means of campaigns).

Studies reporting on campaigns supported by enforcement activities were included in the meta-analyses. Only for the overall crash reduction was a differentiation between combined measures and campaign only made. For most other reported outcomes, only the combined effects of campaigns and enforcement are known.

The authors themselves urge that the results are interpreted with caution, since the set of individual effects vary considerably. Furthermore, it was not possible to control for quality in terms of measurement accuracy, specificity of effect, regression to the mean or accident migration of single studies (Phillips et al., 2011).

3 Supporting documents

3.1 LITERATURE SEARCH STRATEGY

This synopsis deals with the effectiveness of road safety campaigns in general. Campaigns for specific topics such as speeding are documented in separate synopses. However, for the topics of fatigue, distraction, visibility, protective clothing and helmets the number of codable studies was not sufficient for a stand-alone synopsis. Therefore, the identified studies are included and documented at this point – subsequent to the section 'general'.

3.1.1 Campaigns in general

The literature search was conducted in December 2016 and carried out in the following three databases:

- Scopus: a large abstract and citation database of peer-reviewed literature
- TRID: a large online bibliographic database of transportation research
- DOK-DAT: KfV-internal literature database

Database: Scopus

Date: 16th of December 2016

No.	search terms, logical operators, combined queries	Hits
#1	"Campaign" OR "safety Campaign" OR "awareness" OR "public information"	248,963
#2	"road safety" OR "traffic safety"	12,033
#3	#1 AND #2	697
#4	Limited to Europa, Russland, USA, Kanada, Australien und Neuseeland	436

Table 3: Used search terms, logical operators, and combined queries of literature search (Scopus).

Detailed search terms, as well as their linkage with logical operators and combined queries are shown in table above. Using search fields title, abstract and keywords (TITLE-ABS-KEY), and a general limitation to studies which were published from 2006 to current, led to 697 studies.

In a further reduction step results were limited to European countries, as well as Russia, USA, Canada, Australia and New Zealand. This led to a final sample of 436 studies of literature search in database Scopus (Table 3).

Database: DOK-DAT

Date: 7th of December 2016

Search no.	Search terms, operators, combined queries	Hits
#1	"Werbung" (advertisement) AND "Sicherheit" (safety)	467
#2 (within #1)	"Wirksamkeit*" (effectiveness) OR "Evalu*" (evaluation) OR "Bewertung*" (assessment)	278

Table 4: Used search terms, logical operators, and combined queries of literature search (DOK-DAT).

German search fields 'Titel', 'ITRD Schlagworte' and 'freie Schlagworte' were used. Hits were only limited to the years 1990 to 2016 and got 278 more potential studies (Table 4).

Database: TRID

Date: 20th of December 2016

Search no.	Search terms, operators, combined queries	Hits
#1	"safety" AND "campaign" AND "evaluation"	240

Table 5: Used search terms, logical operators, and combined queries of literature search (TRID).

Search terms were "safety", "campaigns" and "evaluation". Hits were limited to the years 2000 to 2016 and got 240 potential studies with various campaign themes.

Results Literature Search

Database	Hits
Scopus (remaining papers after several limitations/exclusions)	436
DOK-DAT	278
TRID database	240
Total number of studies to screen title/ abstract	954

Table 6: Results of databases and free search after limitations

In all, the literature search lead to 954 potential studies for screening.

Screening

Total number of studies to screen title/ abstract	954
Exclusion criteria: no campaign/evaluation or topic not or not sufficiently covered or duplicates	925
Studies to obtain full-texts	29

Table 7: Screening of abstracts

After screening the titles and abstracts 29 studies remained for screening the full-text.

Total number of studies to screen full-text	29
Full-text could be obtained	29
Reference list examined Y/N	Partly
Eligible papers	29

Table 8: Papers obtained for full-text screening

Screening of the full texts

Total number of studies to screen full paper	29
Studies covered by another topic	3
Studies excluded because no evaluation or quantitative effects reported	9
Studies covered by meta-analysis	7
Not relevant	8
Remaining studies	2

Table 9: Screening of full-texts

Studies are presented by author's name; meta-analyses are mentioned first.

No.	Publication	Coded Yes/No	Reason
1.	Delaney, A., Lough, B., Whelan, M. & Cameron, M. (2004). A Review of Mass Media Campaigns in Road Safety. Victoria: Monash University, Accident Research Centre.	N	Study covered in a meta-analysis
2.	Elliott, B. (1993). Road Safety Mass Media Campaigns: A Meta Analysis. Federal Office of Road Safety, Canberra (CR 118).	N	Study covered in a more recent meta-analysis
3.	Phillips, R.O., Ulleberg, P. & Vaa, T. (2009). Do road safety campaigns work? A meta-analysis of road safety campaign effects. In: Forward, S. & Kazemi, A., 2009. A theoretical approach to assess road safety campaigns. Evidence from seven European countries. 25-45.	Y	
4.	Phillips, R.O., Ulleberg, P. & Vaa, T. (2011). Meta-analysis of the effect of road safety campaigns on accidents. <i>Accident Analysis and Prevention</i> 43, 1204-1218.	Y	
5.	Adamos, G., Nathanail, E., & Kapetanopoulou, P. (2012). Does the theme of a road safety communication campaign affect its success? <i>Transport and Telecommunication</i> 13(4), 294-302.	N	Study coded within another synopsis
6.	Backer, T., Rogers, E. & Sopory, P. (1992). <i>Designing Health Communication Campaigns: What Works</i> . Sage: Newbury Park.	N	No evaluation or quantitative effects reported
7.	Carey, R.N. & Sarma, K.M. (2016). Threat appeals in health communication: Messages that elicit fear and enhance perceived efficacy positively impact on young male drivers. <i>BMC Public Health</i> 16(1).	N	Thematically not relevant
8.	Castillo-Manzano, J.I., Castro-Nuno, M. & Pedregal, D.J. (2012). How many lives can bloody and shocking road safety advertising save? The case of Spain. <i>Transportation Research Part F</i> 15(2), 174-187.	N	Thematically not relevant
9.	Delhomme, P. (2002). Some Criteria for Running Successful Campaigns. PRI Road Safety Forum 2002. PRI. Lisbon. A summary of the findings from the GADGET project.	N	No evaluation or quantitative effects reported
10.	Delhomme, P., Vaa, T., Meyer, T., Goldenbeld, C., Jaermark, S., Christie, N. & Rehnova, V. (1999). Deliverable 4: Evaluation of road safety media	N	Study covered in a meta-analysis

No.	Publication	Coded Yes/No	Reason
	campaigns: An overview of 265 evaluated campaigns and some meta-analysis on accident. GADGET project contract no. RO-97-SC. 2235.		
11.	Elvik, R., Høy, A., Vaa, T. & Sørensen, M. (2009). The handbook of road safety measures. 2 nd Ed. Bingley: Emerald Group Publishing.	N	Relevant effects covered in a meta-analysis
12.	Fry, T.R.L. (1996). Advertising wearout in the Transport Accident Commission road safety campaigns. <i>Accident Analysis & Prevention</i> 28(1), 123-129.	N	Thematically not relevant
13.	Haid, K. (2002). Opportunities and limitations in road safety information. A literature study. On behalf of the Swedish Road Administration. Vienna: Austrian Road Safety Board.	N	No evaluation or quantitative effects reported
14.	Hoekstra, T. Wegman, F. (2011). Improving the effectiveness of road safety campaigns: Current and new practices, <i>IATSS Research</i> , 34 (2), 80–86.	N	No evaluation or quantitative effects reported
15.	Hutchinson, T.P. & Wundersitz, L.N. (2011). Road safety media campaigns: Why are the results inconclusive and what can be done? <i>International Journal of Injury Control and Safety Promotion</i> 18(3), 235-241.	N	No evaluation or quantitative effects reported
16.	Johnston, R. & Brady, H.E. (2006). Capturing campaign effects. The University of Michigan Press.	N	Thematically not relevant
17.	Kuratorium für Verkehrssicherheit (1992). 5 Jahre Aktion 'Minus 10%' in Österreich. Wien: Kuratorium für Verkehrssicherheit	N	Thematically not relevant
18.	Robertson, R.D. & Pashley, C.R. (2015). Road Safety Campaigns. What the research tells us. TIRF. http://turf.ca/wp-content/uploads/2017/01/2015_RoadSafetyCampaigns_Report_2.pdf	N	No evaluation or quantitative effects reported
19.	Rohrmann, B. (1992). The evaluation of risk communication effectiveness. <i>Acta Psychologica</i> 81(2), 169-192.	N	Thematically not relevant
20.	Sävenhed, H., Brude, U., Nygaard, B., Petterson, H.-E. & Thulin, H. (1996). Heja Halland. Utvärdering av en trafiksäkerhetskampanj. (Heja Halland. An evaluation of a traffic safety campaign). VTI Meddelande 779, Linköping.	N	Study covered in a meta-analysis
21.	Segui-Gomez, M., Lopez-Valdes, F.J., Tsirigoti, A. & Ntinapogias, A. (2008). Message 1: "Be a safe driver" - Message 2: "Be a safe road user." <i>Archives of Hellenic Medicine</i> 25(1), 11–18.	N	Thematically not relevant
22.	Snyder, L.B. & Hamilton, M.A. (2004). A meta-analysis of the effect of mediated health communication campaigns on behavior change in the United States. <i>Journal of Health Communication</i> 9(1), 71-96.	N	Study coded within another synopsis
23.	Vaa, T., Assum, T., Ulleberg, P. & Veisten, K. (2004). Effects of information on behaviour and road accidents: Conditions, evaluation and cost-effectiveness (TØI-report 727/2004). Oslo: Institute of Transport Economics.	N	Study covered in a meta-analysis
24.	Wakefield, M.A., Loken, B. & Hornik, R.C. (2010). Use of mass media campaigns to change health behaviour. <i>The Lancet</i> 376, 1261–1271.	N	No evaluation or quantitative effects reported

No.	Publication	Coded Yes/No	Reason
25.	Whittam, K.P., Dwyer, W.O., Simpson, P.W. & Leeming, F.C. (2006). Effectiveness of a Media Campaign to Reduce Traffic Crashes Involving Young Drivers. <i>Journal of Applied Social Psychology</i> 36(3), 614-628.	N	Study covered in a meta-analysis
26.	Wiik, J., Kopjar, B. & Bulajic-Kopjar, M. (1995). Trends in bicycle-related injuries in Norway, 1990-1993. Does prevention yield effects? In: Van Weperen, W. (Ed.). 3rd International Conference on Product Safety Research. Amsterdam, March 1995	N	Not relevant (too many measures combined)
27.	Wundersitz, L.N., Hutchinson, T.P. & Woolley, J.E. (2010). Best practice in road safety mass media campaigns: A literature review. Centre for Automotive Safety Research. Adelaide, Australia.	N	No evaluation or quantitative effects reported
28.	Wundersitz, L. & Hutchinson, T.P. (2011). What can we learn from recent evaluations of road safety mass media campaigns? <i>Journal of the Australasian College of Road Safety</i> 22(4), 40-50.	N	No evaluation or quantitative effects reported
29.	Zampetti, R., Messina, G., Quercioli, C., Vencia, F., Genco, L., Di Bartolomeo, L. & Nante, N. (2013). Nonfatal road traffic injuries: Can road safety campaigns prevent hazardous behaviour? An Italian experience. <i>Traffic Injury Prevention</i> 14, 261-266.	N	Study coded within another synopsis

3.1.2 Fatigue, distraction, visibility, protective clothing and helmets

The literature search for the topics fatigue, distraction, visibility, protective clothing and helmets was conducted in December 2016. It was carried out in the following three databases:

- Scopus: a large abstract and citation database of peer-reviewed literature
- TRID: a large online bibliographic database of transportation research
- DOK-DAT: a KfV-internal literature database

Database: Scopus

Date: 16th of December 2016

No.	Search terms, logical operators, combined queries	Fatigue	Distraction	Visibility, protective clothing	Helmets
#1	"Campaign" OR "safety Campaign" OR "awareness" OR "public information"	248,963	248,963	248,963	248,963
#2	"fatigue*" OR "sleep*" OR "tired*" OR "drowsy" OR "drowsiness" OR "alert*" OR "monoton*" OR "mental* fatigue*" OR "mental* tired*", "Sleep disorde*" OR "narcolepsy" OR "apnea" OR "apnea" OR "rest" OR "break"	67,572			
	"Distract*" OR "cell phone" OR "mobile phone" OR "smart phone" OR "phone use" OR "text*" OR "navigation" OR "IVIS" OR "handheld" OR "hands-free"		616,048		
	"Protective clothing" OR "cycling" OR "motorcycling" OR "pedestrian" OR "visibility"			144,207	
	"Helmet"				7,188
#3	"road safety" OR "traffic safety"	12,033	12,033	12,033	12,033

#4	#1 AND #2 AND #3	18	65	96	37
#5	Limit to Europa, Russland, USA, Kanada, Australien and Neuseeland	-	52	62	-

Table 10: Used search terms, logical operators, and combined queries of literature search (Scopus).

Detailed search terms, as well as their linkage with logical operators and combined queries are shown in the table above. Search fields title, abstract and keywords (TITLE-ABS-KEY) and a general limitation to studies which were published from 2006 to current were used.

In a further reduction step, results were partly limited to European countries, as well as Russia, USA, Canada, Australia and New Zealand. This led to a final sample of 18, 52, 62 and 37 studies, respectively, for the literature search in database Scopus (Table 10).

Database: DOK-DAT

Date: 7th of December 2016

Search no.	Search terms, operators, combined queries	Hits
#1	"Werbung" (advertisement) AND "Sicherheit" (safety)	467
#2 (within #1)	"Wirksamkeit*" (effectiveness) OR "Evalu*" (evaluation) OR "Bewertung*" (assessment)	278

Table 11: Used search terms, logical operators, and combined queries of literature search (DOK-DAT).

German search fields 'Titel', 'ITRD Schlagworte' and 'freie Schlagworte' were used. Hits were only limited to the years 1990 to 2016 and got 278 more potential studies (Table 11).

Database: TRID

Date: 20th of December 2016

Search no.	Search terms, operators, combined queries	Hits
#1	"safety" AND "campaign" AND "evaluation"	240

Table 12: Used search terms, logical operators, and combined queries of literature search (TRID).

Search terms were "safety", "campaigns" and "evaluation". Hits were limited to the years 2000 to 2016 and got 240 potential studies with various campaign themes.

Results literature search

Database	Fatigue	Distraction	Visibility, protective clothing	Helmets
Scopus (remaining papers after several limitations/exclusions)	18	52	62	37
DOK-DAT	278	278	278	278
TRID database	240	240	240	240
Total number of studies to screen title/ abstract	536	570	580	555

Table 13: Results of databases and free search after limitations

In all, the literature search lead to 536, 570, 580 and 555 potential studies for screening, respectively.

Screening

Total number of studies to screen title/ abstract	Fatigue	Distraction	Visibility, protective clothing	Helmets
	536	570	580	555
Exclusion criteria: no campaign/evaluation or topic not or not sufficiently covered or duplicates	531	566	576	549
Studies to obtain full-texts	5	4	4	6

Table 14: Screening of abstracts

After screening the titles and abstracts 31 studies remained for screening the full-text.

Total number of studies to screen full-text	Fatigue	Distraction	Visibility, protective clothing	Helmets
	5	4	4	6
Full-text could be obtained	5	4	4	6
Reference list examined Y/N	1	Partly	Partly	Partly
Eligible papers	6	4	4	6

Table 15: Papers obtained for full-text screening

Screening of the full texts

Total number of studies to screen full paper	Fatigue	Distraction	Visibility, protective clothing	Helmets
	6	4	4	6
Studies covered by another topic or measure category		2	1	3
Studies excluded because no evaluation or quantitative effects reported		1	1	2
Effects covered by meta-analysis or other included study	3			
Not relevant	2	1		
Remaining studies	1	0	2	1

Table 16: Screening of full texts

Studies are sorted by authors' names.

No.	Publication	Coded Y/N	Reason
Fatigue			
1.	Adamos, G. & Nathanail, E. (2016). Predicting the effectiveness of road safety campaigns through alternative research designs. <i>Journal of Safety Research</i> , 59, 83-95.	N	Included in other study
2.	Adamos, G., Nathanail, E. & Kapetanopoulou, P. (2013). Do road safety communication campaigns work? <i>Transportation Research Record</i> , 2364, 62-70.	Y	
3.	Adamos, G., Nathanail, E. & Kapetanopoulou, P. (2014). Cluster modeling of driving behavior under fatigue <i>Transportation Research Record</i> , 2465, 24-32.	N	Included in other study
4.	Fletcher, A., McCulloch, K., Bault, S.D. & Dawson, D. (2005). Countermeasures to driver fatigue: a review of public awareness campaigns and legal approaches. Australian and New Zealand. <i>Journal of Public Health</i> , 29(5), 471-476.	N	Not relevant, no campaign
5.	Nathanail, E. & Adamos, G. (2010). Impact assessment of a mass media campaign on fatigue. 24 th ARRB Conference, Australia, 2010.	N	Included in other study
6.	Popp, R. & Geisler, P. (2015). Daytime sleepiness and road safety: Prevention and countermeasures to sleepiness in sleep medicine. <i>Somnologie</i> , 19(3), 171-177.	N	Not relevant, no campaign
Distraction			
1.	Chaudhary, N.K., Casanova-Powell, T.D., Cosgrove, L., Reagan, I., & Williams, A. (2012). Evaluation of NHTSA distracted driving demonstration projects in Connecticut and New York. Report No. DOT HS 811 635. Washington, DC: National Highway Traffic Safety Administration.	N	Focus on enforcement
2.	Cosgrove, L., Chaudhary, N. & Roberts, S. (2010). High Visibility Enforcement Demonstration Programs in Connecticut and New York Reduce Hand-Held Phone Use. Research Note DOT HS 811 376. Washington, DC: National Highway Traffic Safety Administration.	N	Focus on enforcement
3.	Florida Department of Highway Safety and Motor Vehicles (2016). Distracted Driving Campaign Evaluation Report. Retrieved from: https://www.flhsmv.gov/pdf/distracted/distracteddrivingreport_2016.pdf	N	No measures of effectiveness reported
4.	Wandtner, B. (2016). Die Wirkung von Verkehrssicherheitsbotschaften im Fahrsimulator – eine Machbarkeitsstudie. Bericht der Bundesanstalt für Straßenwesen, <i>Mensch und Sicherheit</i> , M 266.	N	Other topic, not relevant
Visibility, protective clothing			
1.	Roge, J., El Zufari, V., Vienne, F. & Ndiayne, D. (2015). Safety messages and visibility of vulnerable road users for drivers. <i>Safety Science</i> , 79, 29-38.	Y	No measure of effectiveness
2.	Tales of the Road campaign (2011) http://webarchive.nationalarchives.gov.uk/20120606112243/http://assets.dft.gov.uk/publications/think-research/talesoftheroad-evaluation-2011.pdf	N	No measure of effectiveness
3.	TNS (2014). THINK! Cycling 'Safety Tips' campaign evaluation. Retrieved from http://think.direct.gov.uk/cycling.html	N	Considered within other topic

No.	Publication	Coded Y/N	Reason
4.	UK Department of Transport (2014). THINK! Motorcycle safety campaign 2014 evaluation presentation. Retrieved from https://www.gov.uk/government/publications/think-motorcycle-safety-campaign-2014-evaluation	Y	
Helmets			
1.	Kazemi, A. & Forward, S. (2008). Evaluation of the Swedish Bicycle Helmet Wearing Campaign 2008. In S. Forward & A. Kazemi (Eds.): A theoretical approach to assess road safety campaigns. Evidence from seven European countries, p. 47-72.	N	Focus on education
2.	Farley, C., Laflamme, L. & Vaez, M. (2003). Bicycle helmet campaigns and head injuries among children. Does poverty matter? <i>Journal of Epidemiol Community Health</i> , 57, 668-672.	N	Focus on education
3.	Furian, G. & Gruber, M. (1999). Die österreichische Radhelminitiative 1992-1998. Institut SICHER LEBEN, Kuratorium für Schutz und Sicherheit, Wien 1999.	Y	
4.	Hunt, S. (2006). Development of a bike helmet safety program. <i>Air Medical Journal</i> , 25(5), 194-195.	N	No measures of effectiveness
5.	Parkin, P.C., Spence, L.J., Hu, X., Kranz, K.E., Shortt, L.G. & Wesson, D.E. (1993). Evaluation of a Promotional Strategy to Increase Bicycle Helmet Use by Children. <i>Pediatrics</i> , 91(4), 772-777.	N	Focus on education
6.	Wiik, J., Kopjar, B. & Bulajic-Kopjar, M. (1995). Trends in bicycle-related injuries in Norway, 1990-1993. Does prevention yield effects? <i>International Journal of Consumer Safety</i> , 3, 67-77.	N	No measures of effectiveness for single measure

3.1.3 Studies on fatigue, visibility and protective clothing and helmets

For some of the topics the number of identified codable studies was not sufficient to draw conclusions and create a separate synopsis. Thus, it was decided to incorporate the study results at this point.

Author(s), year, country	Measure description	Evaluation design	Research conditions
Adamos et al., 2013, Greece	Road safety campaign on fatigue of professional and non-professional drivers (2008, 2009): television spot, a radio spot, leaflets, posters, and insertions in national newspapers	Before-after questionnaire: Before=November 2008 After=June 2009	n before=2,000 n after=996
Department of transport, 2015, UK	Think! Motorcycle campaign to increase visibility of PTW (2014): TV, outdoor posters, radio, online, petrol station, cinema	Before-after questionnaire: Before=September 2014 After=October 2014	n=500 riders

Author(s), year, country	Measure description	Evaluation design	Research conditions
Roge et al., 2015, France	Safety messages concerning the vulnerability of PTW and pedestrians: film	Before-after simulator study, detection task	Randomised sample including control group, n test group=17 n control group=17
Furian & Gruber, 1999, Austria	Cycle helmet campaign (1995-1997): posters, pamphlets, festivals/activities, school programmes, company programmes, retailer actions	Before-after observations of helmet wearing of children, adolescents and adults: Before=1994 After=1998	n before=36,000 n after=22,500

Table 17: Summary of coded study results regarding fatigue, visibility and protective clothing as well as helmet use

Author(s), Year, Country	Exposure variable	Dependant / outcome type	Effects on Road Safety		Main outcome - Description
Adamos et al., 2013, Greece	Fatigue driving campaign	Self-reported behaviour, stop and rest	↗	Kruskal-Wallis test, p=0.003	Significant increase of reported behaviour to stop and rest when tired among non-professional drivers
		Self-reported behaviour, not driving at all	—	Kruskal-Wallis test, p=0.055	No difference between before and after campaign for reported behaviour to not driving at all when tired among non-professional drivers
		Self-reported behaviour, stop and rest	↗	Kruskal-Wallis test, p=0.001	Significant increase in self reported behaviour to stop and rest among professional drivers
		Self-reported behaviour, not driving at all	↘	Kruskal-Wallis test, p<0.001	Significant decrease in self reported behaviour in not driving at all when tired among professional drivers
Department of Transport, 2015, UK	Think! Motorcycle campaign	Self-reported, wearing protective gear	/	Percent change = 0.01	Increase of wearing protective gear of 1% (no test for significance reported)
		Self-reported, wearing bright reflective clothing	/	Percent change = -0.03	Decrease of wearing bright reflective clothing of 3% (no test for significance reported)
Roge et al. 2015, France	Safety message concerning VRU presented via film	Detection of VRU in simulator (visibility distance in meters)	↗	Fischer LSD test, p=0.0002	Significant increased visibility distance of VRU in the test group after watching the film. There is no difference between test and control group after the safety message.
Furian & Gruber, 1999, Austria	Cycle helmet campaign	Helmet wearing rate	↗	Percent change = 0.057	Significant increase of overall helmet wearing rate between 1994 and 1998 by 5.7%
		Helmet wearing rate, children	/	Percent change = 0.236	Increase of children's helmet wearing quote between 1994 and 1998 by 23.6%

Author(s), Year, Country	Exposure variable	Dependant / outcome type	Effects on Road Safety		Main outcome - Description
		Helmet wearing rate, adolescents	/	Percent change = 0.073	Increase of adolescents' helmet wearing quote between 1994 and 1998 by 7.3%
		Helmet wearing rate, adults	/	Percent change = 0.037	Increase of adults' helmet wearing quote between 1994 and 1998 by 3.7%

* Effects on road safety are coded as: significant positive (↗), significant negative (↘), non-significant (→) or no test for significance reported (↯)

3.2 REFERENCES

Meta-analyses

Phillips, R., Ulleberg, P. & Vaa, T. (2009). Do road safety campaigns work? A meta-analysis of road safety campaign effects. In S. Forward & A. Kazemi (Ed.), *A theoretical approach to assess road safety campaigns* (pp. 25-45). Evidence from seven European countries.

Phillips, R., Ulleberg, P. & Vaa, T. (2011): Meta-analysis of the effect of road safety campaigns on accidents. *Accident Analysis and Prevention*, 43, 1204–1218.

List of additional coded studies (campaigns on fatigue, protective clothing, helmet use)

Adamos, G., Nathanail, E. & Kapetanopoulou, P. (2013). Do road safety communication campaigns work? *Transportation Research Record*, 2364, 62-70.

Furian, G. & Gruber, M. (1999). Die österreichische Radhelminitiative 1992-1998. Institut SICHER LEBEN, Kuratorium für Schutz und Sicherheit, Wien 1999.

Roge, J., El Zufari, V., Vienne, F. & Ndiayne, D. (2015). Safety messages and visibility of vulnerable road users for drivers. *Safety Science*, 79, 29-38.

UK Department of Transport (2014). THINK! Motorcycle safety campaign 2014 evaluation presentation. Retrieved from <https://www.gov.uk/government/publications/think-motorcycle-safety-campaign-2014-evaluation>

List of studies included in Phillips et al., 2009

Agent K.R., Green E.R. & Langley R.E. (2002). Evaluation of Kentucky's "You Drink and Drive. You Lose." Campaign. KTC-02-28/KSP1-02-2F University of Kentucky College of Engineering, Kentucky Transportation Center. Kentucky, USA.

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Awareness raising and campaigns – Seatbelts



Aigner-Breuss, E., Eichhorn, A., June 2017

1 Summary

1.1 COLOUR CODE

Green: Results consistently show that seatbelt campaigns increase seatbelt use. As seatbelt use reduces injury severity significantly, this countermeasure has a positive impact on road safety.

1.2 KEY WORDS

Campaign, evaluation, impact, effectiveness, awareness raising, seatbelt, safety belt, seatbelt use, buckle up, occupant protection.

1.3 ABSTRACT

The main purpose of seatbelt campaigns is to encourage car occupants to use seatbelts. Meta-analyses evaluating mainly studies from the 1980s or early 1990s showed a significant positive average effect on road safety (+15%-25%). Studies, conducted in recent years, indicate a minor increase of general observed seatbelt usage (+1.8%-6.4%). This can be attributed to an already high baseline rate.

Furthermore, it should be noted that all analysed seatbelt campaigns were accompanied by strong enforcement activities or law changes. Therefore, it is not clear to what extent the effects are attributable to the campaign itself. Moreover, transferability to European countries might not be possible as most coded studies were carried out in the USA.

1.4 BACKGROUND

This synopsis focuses on the specific issues of campaigns addressing seatbelt use, specifically. For more details on campaigns and awareness raising in general, please also see the synopsis "Effectiveness of Road Safety Campaigns".

How is 'campaign' as a road safety measure defined?

The EU project CAST¹ provides the following definition of campaigns in the field of road safety: "Road safety communication campaigns can be defined as purposeful attempts to inform, persuade, or motivate people in view of changing their beliefs and/or behaviour in order to improve road safety as a whole or in a specific, well-defined large audience, typically within a given time period by means of organised communication activities involving specific media channels often combined with interpersonal support and/or supportive actions such as enforcement, education, legislation, enhancing personal commitment, rewards, etc." (Elliott, 1993; Rice & Atkin, 1994; Vaa et al., 2008, as cited in Delhomme et al., 2009, p.16).

How are awareness-raising and campaigns regarding seatbelts affecting road safety?

The effect of a campaign can be increased information, knowledge, raised awareness, changed attitude, and changed behaviour to the extent that eventually the frequency or severity of accidents is reduced. However, since accident occurrence is multicausal and highly influenced by chance, there is rarely a direct link from a campaign to accident reduction. Many seatbelt campaigns are combined with enforcement and new legislation. It is difficult to attribute the effect to a single element of this combination.

¹ From 2006 to 2009, the EU Project CAST "Campaigns and Awareness-Raising Strategies in Traffic Safety" was carried out by 19 partners from 15 European countries. This project identified essential parameters of campaigns and effectiveness.

Which factors influence the effect of a seatbelt campaign on road safety and which are the modifying conditions?

Important factors for an effective campaign are clearly defined road safety problems and target groups, as well as a corresponding tailored message. Furthermore, it is necessary to use theoretical psychological models that explain the risk behaviour or safety problem (CAST, 2009). It is important to note that communication has to be based on the cultural codes used in the target community (national, regional, sub-groups etc.). Other influencing factors are the duration and intensity of a campaign. Also, other situational factors such as simultaneous competing events (e.g. tragic accident reported in media) can have an impact on the campaign effects.

How is the effect of a seatbelt campaign on road safety measured?

The following measures are used to assess the effectiveness of seatbelt campaigns:

- Observed seatbelt usage
- Behaviour and intended behaviour reported in questionnaires and interviews
- Attitudes, opinions, norms, knowledge, behavioural beliefs, risk perception reported in questionnaires and interviews

The vast majority of studies in this field apply a before-after design to measure the campaign effect. Accident statistics are seldom the means for evaluation because behaviour of road users is multicausal.

1.5 OVERVIEW OF RESULTS

Two meta-analyses on the effectiveness of seatbelt campaigns have been considered (Phillips et al., 2009; Snyder et al., 2004). The outcomes show that the respective campaigns on seatbelt use had a significant positive average effect on road safety (+15-25%). However, it should be noted that the majority of the studies included, were carried out in the 80s or early 90s, as the main peak of seat belt campaigns and corresponding evaluation studies was in this period.

Additionally, results from single campaign evaluations conducted in recent years are presented (Agent et al., 2004; Chaudhary et al., 2005; Nichols et al., 2009; Solomom et al., 2007; Tamis, 2009, Vasudevan et al., 2009). These show an increase of general observed seatbelt usage between 1.8% and 6.4%, though some of the effects were not statistically tested.

However, all studies had at least minor limitations. All of the evaluated single campaigns were accompanied by enforcement activities, some lacked reported significance testing or measured only short-term campaign effects.

2 Scientific details

2.1 THEORETICAL BACKGROUND

Aim and methods of awareness raising measures and campaigns

The main purpose of awareness raising measures and communication campaigns is to encourage road users to engage in safe behaviour in traffic. The underlying concept of campaigns in road safety is social marketing, which aims at influencing and changing social behaviours.

When developing a campaign, it is crucial to conduct a detailed analysis of the **road safety problem** and the **target group**. Furthermore, psychological theoretical models are very helpful in the development of the campaign message to increase the effectiveness (Robertson & Pashley, 2015). A description of these models – such as the Theory of planned behaviour (TPB) – can be found in Theofilatos et al. (2017).

Besides developing the message the **campaign strategy** has to be defined. Campaigns may use an information approach or emotions, especially fear, to draw the target audience's attention to the message. There are still controversial discussions regarding the effectiveness of fear-based messages (see e.g. Castillo-Manzano et al., 2012).

To evaluate whether or not the message of the campaign can influence the behaviour of the target group as intended, a **pre-test of message** and slogan should be conducted (Delhomme et al., 2009; Hoekstra & Wegman, 2011).

For road safety campaigns the following **type of media** is generally used: television, radio, newspaper/magazines, cinema, web/online, social media, billboards, flyers/leaflets/posters, message signs and events involving face to face communication. An overview of advantages and disadvantages of different types of media for road safety campaigns can be found in Delhomme et al. (2009).

Campaign effects and influencing factors

Awareness raising activities and campaigns can positively influence a number of road safety relevant constructs such as favourable attitudes, knowledge and perceptions as well as safe behaviour and therefore also accident rates. However, there are various factors to be considered to maximise impact. According to Phillips et al. (2011) the following factors of campaigns are associated with accident reduction:

- Personal communication
- Road side delivery (billboards, message signs)
- Drink-driving theme
- Combination with enforcement
- Short campaign duration (0-29 days)

Snyder & Hamilton (2004) discuss the impact of the factor '**behavioural baseline**' on health campaign outcomes. If a favourable behaviour such as seatbelt wearing is already widespread, the impact of a campaign will obviously be diminished. But if very few people engage in a certain behaviour it can also be disadvantageous as a starting point for a campaign since there are not enough role models in the target group yet. Thus, in general a moderate baseline rate leads to the highest impact.

Limitations of campaigns and challenges of evaluation

In the past, evaluations of campaigns were rarely carried out rarely for various reasons. For one, sometimes there is a lack of awareness regarding the benefit of evaluating, or there may be budget and time constraints. Also, uncertainties in terms of methodological application are a barrier. As previously described, the effectiveness of road safety campaigns can be measured by various means. The most important **outcome measure** is a reduction in crashes or accident severity. It is

difficult though to link an accident reduction to a campaign while controlling for all other possible contributing factors. The defined outcome measures to account for campaign effects are therefore often 'indirect' like intended behaviour or attitudes etc. Even though there is evidence concerning the influence of these constructs on actual behaviour, there are also always other determining factors (e.g. situational factors) that cannot be accounted for.

A before-after-design ideally includes a **meaningful reference group** to control for confounding factors (e.g. a similar geographical region where there is no exposure to the contents of the campaign), which is however rarely the case.

Next to a lack of (systematical and valid) evaluation of effects, often, campaigns are **combined or conducted simultaneously** with enforcement measures and implementation of new legislation respectively. If an effect (improvement) is measured then, it remains unclear to which of the single components it is attributable and to what extent.

2.2 METHODOLOGY

The literature search was carried out in three databases (Scopus, TRID and a KfV-internal literature database) with separate search strategies (for a detailed description see "Supporting documents"). Additionally, a free web-based search was done via Google.

Below, first information on the characteristics of coded studies is given, and subsequently the main research methods used for campaigns and awareness raising measures for seatbelt usage is provided.

Description of studies

Table 1 provides further description of the background characteristics of the coded studies that deal with campaigns on seatbelt usage (sorted by authors, meta-analyses first).

Table 1: Information on sample and design of coded studies (sorted by author(s), meta-analyses first)

Author(s), year, country	Measure description	Evaluation design	Research conditions
Snyder et. al, 2004, US	Mass media campaigns for increasing seatbelt use in the USA (before 1995).	Meta-Analysis of 5 studies	An average effect size was calculated for seatbelt usage
Phillips et.al, 2009, international	Road safety campaigns on seatbelt use in 14 countries	Meta-Analysis of 74 studies	A weighted average was calculated from 133 effects
Agent et al., 2004, US	"Buckle up Kentucky" media & enforcement campaign (TV, radio and printed stories) focused on drivers and passengers to increase seatbelt use (2004)	Before-after observation: Before=April 2004 After=May/June 2004	21 sample locations
Chaudhary et al., 2005, US	Night-time safety belt media & enforcement campaign (PR and events, radio, round table discussion for local radio program, pamphlets) focused on drivers and passengers to increase seatbelt use (2004)	Before-after observation with control group: Before=August 2004 After=October 2004	20 observation sites in Reading (test group, n=12,924) and Bethlehem (comparison group, n=10,713)
Nichols et al., 2009, US	"Buckle Up in Your Truck" media& enforcement program focused on 18-34 years old drivers and passengers to increase seatbelt use in 4 states (2006 & 2007)	Before-after observation: Before=April 2006 After=June 2007	Observation sites in Iowa=100; Kansas=120; Missouri=42; Nebraska=201

Author(s), year, country	Measure description	Evaluation design	Research conditions
Solomon et al., 2007, US	"Click it or ticket" media & enforcement program (TV, radio and advertisement) focused on drivers and passengers to increase seatbelt use in 50 states (2004)	Before-after observation: Before=May 2003 After=June 2004 Questionnaire= Before=April 2004 After=June 2004	Survey samples were representative of the national population (n≈1,000)
Tamis, 2009, Netherlands	Dutch seatbelt media & enforcement campaign (billboards and TV and radio spots) focused on drivers and passengers to increase seatbelt use (2008)	Before-after observation: Before=March 2008 After=June 2008	76 observation sites on local and provincial roads (n=31,555)
Vasudevan et al., 2009, US	"Click it or ticket" media & enforcement program focused on 18-34 years old drivers and passengers to increase seatbelt use in Nevada (2005)	Before-after observation: Before= March/April 2005 After=June/August 2005	50 observation sites across Nevada

Description of the main research methods

In order to evaluate the effectiveness of seatbelt campaigns mainly before/after designs are used. Evaluations of seatbelt campaigns focus mainly on outcomes of observational data. Additionally, in some cases a questionnaire survey was conducted to gain insight into attitudes and opinions on seatbelt usage. Two meta-analyses calculated (weighted) average effects. Only one (Phillips et al., 2009) accounted for publication bias².

For the majority, it is not clear from the evaluation studies whether or not a theoretical psychological model was the basis for designing the respective campaigns.

2.3 OVERVIEW RESULTS

The following tables present information on the main outcomes of all coded studies. Table 2 gives an overview of two meta-analyses, while single coded studies can be found in Table 3.

Meta-Analyses

Table 2: Summary of meta-analyses results

Author(s), Year, Country	Exposure variable	Dependant / outcome type	Effects on Road Safety	Main outcome - Description
Snyder et al., 2004, US	Media & enforcement campaigns on seatbelt use	Seatbelt usage	↗ Percent change=0.15 CL: 95%	Seatbelt campaigns led to a positive average behaviour change (seatbelt usage increased on average by 15%)
Phillips et al., 2009, international	Road safety campaigns on seatbelt use	Observed and self-reported seatbelt use	↗ Percent change=0.25 CL: 95%, CI: 0.18-0.31	Road safety campaigns on seatbelt use are linked to a significant 25% increase of seatbelt usage.

* Effects on road safety are coded as: positive (↗), negative (↘), non-significant (–) or no test for significance reported (↯)

² Statistically significant results are more often published than non-significant findings. This publication bias should be accounted for in meta-analysis otherwise the results can be biased and effects of a measure overestimated.

Snyder et al. (2004) conducted a meta-analysis on health campaigns in the United States, while Philips et al. (2009) carried out a meta-analysis with the focus on overall effects of road safety campaigns. Both studies included campaigns on seatbelt use.

The outcomes show that the respective campaigns on seatbelt use had a significant positive average effect on road safety. Seatbelt usage increased by 15-25%. However, it has to be noted that the included studies were mostly carried out in den 80s or early 90s, so results have to be considered carefully.

Table 3: Summary of coded study results regarding seatbelt usage (sorted by author(s))

Author(s), Year, Country	Exposure variable	Dependant / outcome type	Effects on Road Safety		Main outcome - Description
Agent et al., 2004, US	Seatbelt campaign "Buckle up Kentucky"	Observed seatbelt usage	/	Percent change=0.06	A 6% increase of seatbelt usage during the enforcement phase of the campaign was shown (no significance was reported).
	Seatbelt campaign "Buckle up Kentucky"	Fatal crashes	/	Absolut accident change=13	An increase of fatalities (+13) compared to the previous three years was shown (no significance was reported).
	Seatbelt campaign "Buckle up Kentucky"	Injury crashes	/	Absolut accident change =-235	A decrease of injuries (-235) compared to the previous three years was shown (no significance was reported).
Chaudhary et al., 2005, US	Night-time safety belt campaign	Observed seatbelt usage at night - general	↗	Percent change=0.06	A significant 6% increase of seatbelt usage at night was reported.
	Night-time safety belt campaign	Observed seatbelt usage at night - driver	/	Percent change=0.05	A 5% increase of seatbelt usage at night was shown for drivers (no significance reported).
	Night-time safety belt campaign	Observed seatbelt usage at night - passenger	/	Percent change=0.09	A 9% increase of seatbelt usage at night was shown for passengers (no significance reported).
Nichols et al., 2009, US	Seatbelt campaign "Buckle up in your truck"	Observed seatbelt usage for Pick-ups	/	Percent change=0.08	An average 8% increase of seatbelt usage for Pick-up drivers was shown (no significance reported).
	Seatbelt campaign "Buckle up in your truck"	Observed seatbelt usage for Non-Pick-ups	/	Percent change=0.08	An average 8% increase of seatbelt usage for Non-pick-up drivers was shown (no significance reported).
Solomon et al., 2007, US	"Click it or ticket" campaign	Observed seatbelt usage - general	/	Percent change=0.024	A 2.4% increase of seatbelt rate from 2003 to 2004 was shown (no significance reported).
	"Click it or ticket" campaign	Self-reported seatbelt usage	/	Percent change=-0.01	A 1% decrease of self-reported seatbelt use was reported (no significance reported).

Author(s), Year, Country	Exposure variable	Dependant / outcome type	Effects on Road Safety		Main outcome - Description
	"Click it or ticket" campaign	Opinion: Important to enforce seatbelt law more strictly	/	Percent change=0.05	A 5% increase of the opinion that seatbelt law should be enforced more strictly was shown (no significance reported).
Tamis, 2009, Netherlands	Dutch seatbelt campaign	Observed seatbelt usage - general	↗	Percent change=0.018	A significant 1.8% increase in seatbelt use in total by all car occupants was reported.
	Dutch seatbelt campaign	Observed seatbelt usage – inside built-up areas	↗	Percent change=0.012	A significant 1.2% increase in seatbelt use inside built-up areas by all car occupants was reported.
	Dutch seatbelt campaign	Observed seatbelt usage – outside built-up areas	↗	Percent change=0.021	A significant 2.1% increase in seatbelt use outside built-up areas by all car occupants was reported.
	Dutch seatbelt campaign	Observed seatbelt usage - driver	↗	Percent change=0.015	A significant 1.5% increase in seatbelt use by drivers was reported.
	Dutch seatbelt campaign	Observed seatbelt usage – front passenger	↗	Percent change=0.023	A significant 2.3% increase in seatbelt use by front passengers was reported.
	Dutch seatbelt campaign	Observed seatbelt usage – rear passenger	–	Percent change=0.042	A non-significant change in seatbelt use by rear passengers was reported.
Vasudevan et al., 2009, US	"Click it or ticket" campaign	Observed seatbelt usage - general	↗	Percent change=0.064	A significant 6.4% increase of seatbelt usage for all occupants was reported.
	"Click it or ticket" campaign	Observed seatbelt usage - drivers	↗	Percent change=0.067	A significant 6.7% increase of seatbelt usage for all drivers was reported.
	"Click it or ticket" campaign	Observed seatbelt usage - passengers	↗	Percent change=0.059	A significant 5.9% increase of seatbelt usage for all passengers was reported.

* Effects on road safety are coded as: positive (↗), negative (↘), non-significant (–) or no test for significance reported (∅)

Additional studies on seatbelt usage

Speaking of campaigns with seatbelt topics in Europe a peak can be observed in the 80s and 90s. Later seatbelt campaign evaluations can mostly be found in the US. Predominantly, national programs like "Click it or ticket" or "Buckle up", which are combined media & enforcement activities, were conducted. So, results cannot be attributed to the media campaigns alone (see conclusion). With regard to general observed seatbelt usage Chaudhary et al. (2005), Tamis (2009) and Vasudevan et al. (2009) showed significant increases between 1.8% and 6.4%. Furthermore, they differentiated between drivers (1.5%-6.7%) and passengers (2.3%-5.9%). Tamis (2009) in addition gives information on seatbelt usage inside (+1.2%) and outside built-up areas (+2.1%). All other single campaign evaluations show an increase of seatbelt usage for different car occupants as well, though the effects often were not statistically tested. Nichols et al. (2009) reported an average 8% increase of seatbelt usage for Pick-up drivers, Solomon et al. (2007) a 2.4% increase and Agent et al. (2004) a 6% increase.

Additional to the observed or self-reported seatbelt use, only Agent et al. report effects on accidents. Although the seatbelt usage increased by 6%, a rise of the absolute numbers of fatalities was recorded (no significance tests provided), (Table 3).

Modifying conditions

Phillips et al. (2009) outlined conclusions on a meta-regression by Vaa et al. (2004). They identified the following factors of campaigns to be associated with accident reduction:

- Personal communication
- Road side delivery (billboards, message signs)
- Combination with enforcement
- Short campaign duration (0-29 days)

Seatbelt usage is also influenced by the type of seatbelt law in a state or in a country e.g. first and secondary seatbelt laws in the USA. Furthermore, for delivering the message of the campaign specific factors have to be taken into account, such as differentiating between drivers and passengers or differentiating between inside and outside built-up areas.

2.4 CONCLUSION

General

Examining the effects of seatbelt campaigns it can be seen that in recent years the seatbelt usage couldn't be increased like in the 1980's, where a moderate baseline rate lead to the highest impact. Now the baseline rate is quite high (e.g. 77% in high-income countries, WHO 2015), so the impact of a campaign will be rather low-level.

Main results

The outcomes of two meta-analyses (Phillips et al., 2011; Snyder, 2004) show that the respective campaigns on seatbelt use had a significant positive average effect on road safety. Seatbelt usage increased by 15-25%. However, as the studies were carried out in the 80's or early 90's, results have to be considered carefully.

Most single campaign evaluations from recent years show an increase of general observed seatbelt usage between 1.8% and 6.4%, though some of the effects were not statistically tested (Nichols et al., 2009; Solomon et al., 2007 & Agent et al., 2004).

Biases and transferability

All studies had at least minor limitations. Most of the evaluated campaigns were accompanied by strong enforcement activities or law changes. In that case, it is not clear to what extent the effects are attributable to the single measures. Only the meta-analysis of Phillips et al. (2009) differentiated for crash reduction. For most other reported outcomes, only the combined effects of campaigns and enforcement are known. All individual campaigns (exposure) were heterogeneous regarding design (exact target group, period, media etc.).

Moreover, many studies did not indicate whether or not significance was tested. Long term effects of the campaigns are not available. One study compared effects between two years as the campaign was launched a second time. Therefore, sustainable changes in behaviour due to campaigns remain uncertain.

Finally, most coded studies were carried out in the USA using a combined enforcement and media design, so effects might not be transferable to other countries.

3 Supporting documents

3.1 LITERATURE SEARCH STRATEGY

The literature search was conducted in December 2016. It was carried out in three databases and was complemented by a free internet search. The queried databases were

- Scopus: a large abstract and citation database of peer-reviewed literature
- TRID: a large online bibliographic database of transportation research
- DOK-DAT: a KfV-internal literature database.

Database: Scopus

Date: 16th of December 2016

Limitations: published: 2006 to present

Search no.	Search terms, logical operators, combined queries	Hits
#1	"Campaign" OR "awareness" OR "public information"	248,963
#2	"Seatbelt" OR "seatbelt use" OR "belt use" OR "buckle" OR "fasten your seatbelt"	5,329
#4	#1 AND #2	187
#5	Limited to Europe, Russia, USA, Canada, Australia and New Zealand	113

Table 4: Used search terms, logical operators, and combined queries of literature search (Scopus).

Detailed search terms, as well as their linkage with logical operators and combined queries are shown in Table 4. Using search fields title, abstract and keywords (TITLE-ABS-KEY), and a general limitation to studies which were published from 2006 to current, led to 187 studies.

In a further reduction step, results were limited to European countries, as well as Russia, USA, Canada, Australia and New Zealand. This led to a final sample of 113 studies for the literature search in database Scopus (Table 4).

Database: DOK-DAT

Date: 7th of December 2016

Search no.	Search terms / operators / combined queries	Hits
#1	"Werbung" (advertisement) AND "Sicherheit" (safety)	467
#2 (within #1)	"Wirksamkeit*" (effectiveness) OR "Evalu*" (evaluation) OR "Bewertung*" (assessment)	278

Table 5: Used search terms, logical operators, and combined queries of literature search (DOK-DAT).

German search fields 'Titel', 'ITRD Schlagworte' and 'freie Schlagworte' were used. Hits were only limited to the years 1990 to 2016 and got 278 more potential studies (Table 5).

Database: TRID database

Date: 20th of December 2016

Search no.	Search terms, operators, combined queries	Hits
#1	"safety" AND "campaign" AND "evaluation"	240

Table 6: Used search terms, logical operators, and combined queries of literature search (TRID).

Results Literature Search

Database	Hits
Scopus (remaining papers after several limitations/exclusions)	113
DOK-DAT	278
TRID database	240
Literature from reference lists and recommendations	3
Total number of studies to screen title/ abstract	634

Table 7: Results of databases after limitations

In all, literature search lead to 634 potential studies for screening.

Screening

Total number of studies to screen title/ abstract	634
Exclusion criteria: no campaign/evaluation or topic not or not sufficiently covered or duplicates	612
Studies to obtain full-texts	22

Table 8: Screening of abstracts

After screening the titles and abstracts 22 studies remained for screening the full-text.

Total number of studies to screen full-text	22
Full-text could be obtained	22
Reference list examined Yes/No	Y
Eligible papers	22

Table 9: Papers obtained for full-text screening

Screening of the full texts

Total number of studies to screen full paper	22
Studies covered by another topic	4
Program already covered in other considered study	2
Studies covered by meta-analyses	1
No before-after design	1
Not relevant	7
Remaining studies	7
Seatbelt effects coded within "campaigns general" (meta-analyses)	1

Table 10: Screening of full texts

List of references resulting from search strategy (sorted by authors)

No.	Publication	Coded Yes/No	Reason
1	Aitken, M. E., Mullins, S. H., Lancaster, V. E., & Miller, B. K. (2007). Cubs Click It for Safety A school-based intervention for Tween passenger safety. <i>Journal of Trauma - Injury, Infection and Critical Care</i> , 63(3 SUPPL.), S39–S43.	N	Study in other measures category
2	Agent, Kenneth R. and Green, Eric R., "Evaluation of Kentucky's "Buckle Up Kentucky: It's the Law and It's Enforced" 2004 Campaign" (2004). Kentucky Transportation Center Research Report. Paper 204.	Y	
3	Brijs, K., Daniels, S., Brijs, T., & Wets, G. (2011). An experimental approach towards the evaluation of a seatbelt campaign with an inside view on the psychology behind seatbelt use. <i>Transportation Research Part F: Traffic Psychology and Behaviour</i> , 14(6), 600–613.	N	No before-after design
4	Chaudhary, N. K., Tison, J., & Casanova, T. (2010). The effects of Maine's change to primary seatbelt law on seatbelt use and public perception and awareness. <i>Traffic Injury Prevention</i> , 11(2), 165–172.	N	Study in other measures category
5	Chaudhary, N. K., Alonge, M., and Preusser, D. F. (2005). Evaluation of the Reading, PA nighttime safety belt enforcement campaign: September 2004. <i>Journal of Safety Research</i> . 36: 321-326	Y	
6	Dissanayake, S., & Parik, A. (2007). Effect of seatbelt laws and other factors in increasing seatbelt usage rates. In <i>Proceedings, Annual Conference - Canadian Society for Civil Engineering</i> (Vol. 1, pp. 455–462). Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-36049035357&partnerID=40&md5=482913d13cbfe2e9ec81a49acb12a352	N	Not relevant
7	Dissanayake, S. (2009). Identification of focus areas for improving safety belt usage in the United States. In <i>Proceedings of the 14th HKSTS International Conference: Transportation and Geography</i> (Vol. 2, pp. 605–612). Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-84897599895&partnerID=40&md5=da721733473e715e6629865ae4b35884	N	Not relevant
8	European Road Safety Federation (ERSF) (1997). <i>European Platforms for Young Drivers & Multipliers</i> . Brussels, 18. November 1996. Copenhagen, 24. February 1997. Rome, 26. May 1997. European Road Safety Federation (ERSF), Brussels 1997, 187 S. + Anhang. "Young Greek Car Occupants Say Yes to Life: They Buckle up and Win"	N	Not relevant
9	Guria, J., 1999, An economic evaluation of incremental resources to road safety programmes in New Zealand., <i>Accident Analysis & Prevention</i> Vol.31 Nos.1/2, January/March 1999, S. 91-99.	N	Not relevant
10	Houston, M., Cassabaum, V., Matzick, S., Rapstine, T., Terry, S., Uribe, P. Moulton, S. (2010). Teen traffic safety campaign: Competition is the key. <i>Journal of Trauma - Injury, Infection and Critical Care</i> , 68(3), 511–514.	N	Study in other measures category
11	Kim, S., Depue, L., Spence, L., & Reine, J. (2009). Analysis of teenage seatbelt use: From the 2007 Missouri high school seatbelt survey. <i>Journal of Safety Research</i> , 40(4), 311–316.	N	Not relevant
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Awareness raising and campaigns – Child restraint



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1 Summary

1.1 COLOUR CODE

Light green: Results show that child restraint campaigns have significant positive effects on child restraint use. However, most campaigns do not indicate long-term effects. Furthermore, only a few studies on evaluations of child restraints could be found and the quality of some studies was not satisfactory.

1.2 KEYWORDS

Child restraint, child restraint use, passenger safety, campaign, evaluation, awareness raising, attitude

1.3 ABSTRACT

The main purpose of child restraint campaigns is to promote the safety of children in vehicles by using child restraints.

Results provide some indication that campaigns on child restraint usage have positive effects on road safety. Studies which measure observed child restraint use show a significant increase between 12% and 28%. Self-reported child restraint use increases between 23% and 30%. No clear statement can be drawn on influencing knowledge and attitudes as studies use different theoretical approaches and measurements. However, there are some indication that knowledge and some attitudes can be improved by campaigns.

Results should be considered carefully, as the methodology of some studies is quite poor. Furthermore, the identification of long term effects has not been adequately studied.

1.4 BACKGROUND

How is 'campaign' as a road safety measure defined?

The EU project CAST¹ provides the following definition of campaigns in the field of road safety: "Road safety communication campaigns can be defined as purposeful attempts to inform, persuade, or motivate people in view of changing their beliefs and/or behaviour in order to improve road safety as a whole or in a specific, well-defined large audience, typically within a given time period by means of organised communication activities involving specific media channels often combined with interpersonal support and/or supportive actions such as enforcement, education, legislation, enhancing personal commitment, rewards, etc." (Elliott, 1993; Rice & Atkin, 1994; Vaa et al., 2008; as cited in Delhomme et al., 2009).

How do awareness raising and campaigns regarding child restraints affect road safety?

The effect of child restraint campaigns can be increased information, knowledge and awareness, and changes in attitudes and behaviour to the extent that, eventually the severity of accidents is reduced. Most child restraint campaigns are combined with other activities like education. However, a clear distinction between awareness-raising activities and education is difficult.

Campaigns can also be used to establish favourable preconditions in the public for new legislation. Campaigns addressing the use of child restraints have positive effects on:

- Attitudes on child restraint use
- (Correct) child restraint usage

¹ From 2006 to 2009, the EU Project CAST "Campaigns and Awareness-Raising Strategies in Traffic Safety" was carried out by 19 partners from 15 European countries. This project identified essential parameters of campaigns and effectiveness.

Which factors influence the effect of child restraint campaigns on road safety and which are the modifying conditions?

Important factors for an effective campaign are clearly defined road safety problems and target groups, as well as a corresponding tailored message. Furthermore, it is necessary to use a theoretical psychological model that explains the risk behaviour or safety problem (CAST, 2009). It is important to note that communication has to be based on the cultural codes used in the target community (national, regional, sub-groups etc.). Other influencing factors are the duration and intensity of a campaign. Also, other situational factors such as simultaneous competing events (e.g. tragic accident reported in media) or increased enforcement can have an impact on the campaign effects.

How is the effect of a child restraint campaign measured?

The vast majority of studies in this field apply a before-after design to measure the campaign effect. Only a few studies give a comparison with a control group, as it is very difficult to find a suitable control group for nation-wide interventions.

The following measures are used to assess the effectiveness of child restraint campaigns:

- Observed behaviour such as child restraint use
- Behaviour and intended behaviour reported in questionnaires and interviews
- Attitudes, opinions, norms, knowledge, behavioural beliefs, risk perception reported in questionnaires and interviews

1.5 OVERVIEW OF RESULTS ON CHILD RESTRAINT CAMPAIGNS

Evaluations of child restraint campaigns from different countries all over the world were included in the analysis (Ausserer et al., 2009; Bryant-Stephens et al., 2013; Dabrowska-Lorac et al., 2008; Ebel et al., 2003; Howard et al., 2006; Lewis et al., 2016; Will et al., 2009) No meta-analysis was available for this topic.

The outcomes of the respective studies provide some indication that campaigns on child restraint usage have positive effects on road safety. Studies, which measure observed child restraint use, show a significant increase between 12% and 28% (Ebel et al., 2003, Bryant-Stephens et al., 2013, Will et al., 2009). Furthermore, self-reported child restraint use indicates positive effects of child restraint campaigns with increases between 23% (Howard et al., 2006) and 30% (Dabrowska-Lorac et al., 2008). No clear statement can be drawn for effects of child restraint campaigns on knowledge and attitudes as studies use different theoretical approaches and measurements. However, there are some indications that knowledge and some attitudes can be improved by campaigns (Ausserer et al., 2009; Howard et al., 2006; Lewis et al., 2016; Will et al., 2009).

It has to be noted that most of the evaluation studies were carried out soon after the campaign ended. Therefore, sustainable changes in behaviour due to campaigns remain uncertain. Moreover, the quality of most studies was not satisfactory. In particular, samples are small or non-representative, most studies do not consider long-term trends, and some of them lack of methodological details (about sample as well as statistical methods or even concrete results).

2 Scientific details

2.1 THEORETICAL BACKGROUND

Aim and methods of awareness raising measures and campaigns

The main purpose of awareness raising measures and communication campaigns is to encourage road users to engage in safe behaviour in traffic. The underlying concept of campaigns in road safety is social marketing which aims at influencing and changing social behaviours.

When developing a campaign, it is crucial to conduct a detailed analysis of the **road safety problem** and the **target group**. Furthermore, psychological theoretical models are very helpful in the development of the campaign message to increase the effectiveness (Robertson & Pashley, 2015). A description of these models – such as the Theory of Planned Behaviour (TPB) – can be found in Theofilatos et al. (2017).

Besides developing the message, the **campaign strategy** has to be defined. Campaigns may use an information approach or emotive, especially using fear to draw the attention of the target audience to the message. However, there are still controversial discussions regarding the effectiveness of fear-based messages (see e.g. Castillo-Manzano et al., 2012).

To evaluate whether or not the message of the campaign can influence the behaviour of the target group as intended, a **pre-test of message** and slogan should be conducted (Delhomme et al., 2009; Hoekstra & Wegman, 2011).

For road safety campaigns the following **type of media** is generally used: television, radio, newspaper/magazines, cinema, web/online, social media, billboards, flyers/leaflets/posters, message signs and events involving face to face communication. An overview of advantages and disadvantages of different types of media for road safety campaigns can be found in Delhomme et al. (2009).

Campaign effects and influencing factors

Awareness raising activities and campaigns can positively influence a number of road safety relevant constructs, such as favourable attitudes, knowledge and perceptions as well as safe behaviour and therefore also accident rates. However, there are various factors to be considered to maximise impact. According to Phillips et al. (2011) the following factors of campaigns are associated with accident reduction:

- Personal communication
- Road side delivery (billboards, message signs)
- Drink-driving theme
- Combination with enforcement
- Short campaign duration (0-29 days)

Snyder & Hamilton (2004) discuss the impact of the factor '**behavioural baseline**' on health campaign outcomes. If a favourable behaviour such as seat belt wearing is already widespread, the impact of a campaign will obviously be diminished. But if very few people engage in a certain behaviour, it can also be disadvantageous as a starting point for a campaign since there are not enough role models in the target group yet. Thus, in general a moderate baseline rate leads to the highest impact.

Limitations of campaigns and challenges of evaluation

In the past, evaluations of campaigns were rarely carried out for various reasons. For one, there is sometimes a lack of awareness of the benefit of evaluating, or there may be budget and time constraints. Uncertainties in terms of methodological application are also a barrier.

As previously described, the effectiveness of road safety campaigns can be measured by various means. The most important **outcome measure** is a reduction in crashes. It is difficult though, to link

an accident reduction to a campaign while controlling for all other possible contributing factors. The defined outcome measures to account for campaign effects are therefore often 'indirect', like intended behaviour or attitudes etc. Even though there is evidence concerning the influence of these constructs on actual behaviour, there are always other additional determining factors (e.g. situational factors) that cannot be accounted for.

A before-after-design ideally includes a **meaningful reference group** to control for confounding factors (e.g. a similar geographical region without exposure to the contents of the campaign), which is however rarely the case.

Next to a lack of (systematical and valid) evaluation of effects, campaigns are often **combined or conducted simultaneously** with enforcement measures and implementation of new legislation. If an effect (improvement) is measured then, it remains unclear to which of the single components it is attributable, and to what extent.

2.2 CODED STUDIES

Description of studies

Table 1 provides further descriptions of the background characteristics of the coded studies that deal with campaigns and awareness-raising regarding child restraint usage (sorted by author).

Table 1. Characteristics of coded studies that deal with campaigns and awareness raising regarding child restraint usage

Author, year, country	Measure description	Evaluation Design	Research Conditions
Ausserer et al., 2009, Austria	Austrian Euchires campaign – European public awareness campaign, focused on the use of seat belts and child restraints (2006-2008)	Before-after quasi-experimental comparison of attitudes, habits and intentions; 2 experimental groups + one control	375 pupils (8-12) and 225 parents (25-54)
Bryant-Stephens et al., 2013, US	Community- delivered marketing campaign to promote belt-positioning booster seat (October/November 2008)	Before-after observations of belt-positioning child restraint use, quasi-experimental Before =September 2008 After=April 2009	Children (4-7) 822 observations (test group=377, comparison group=343)
Dabrowska-Lorac et al, 2008, Poland	Polish Euchires campaign - European public awareness campaign, focused on the use of seat belts and child restraints (2005-2007)	Before-after survey (drivers, passengers) on seat belt and child restraint use Before=2005 After=2007	
Ebel et al, 2003, US	Community booster seat campaign in increasing observed booster seat use among child passengers in motor vehicles (2000-2001)	Before-after observation of child restraint use in intervention and control communities Before=Jan 2000 After=March 2001	Children (4-8) Intervention: 1,299 observations Control: 2,259 observations
Howard et al., 2006, Canada	Safe Kids Week Booster seat campaign on promoting booster seat use (May 2004)	Nationally representative random telephone survey: Before-after questionnaires on knowledge and child restraint use Before=one week before the campaign After=one week after the campaign	Survey sample: 265 parents pre-test, 260 parents post-test
Lewis et al., 2016, Australia	TV-advertisement on appropriate use of child restraints	Randomised online survey: Comparison of attitudes, norms, intentions between intervention and control group, experimental	384 parents test group 223 parents control group

		Parents of children (0-7)	
Will et al., 2009, US	Video-intervention on encouraging child restraint use using a high-threat message	Before-after survey of caregivers and observation of restraint use, quasi-experimental	226 caregivers (100 test, 126 control), 3,382 (1,925 test, 1,457 control) observations

Description of main research methods

In order to evaluate the effectiveness of child restraint campaigns before-after designs are used. There are two main approaches: questionnaires and observations. Questionnaires are used for assessing changes in attitudes, opinions and self-reported behaviour. With observations, the actual child restraint usage can be observed. Campaigns on child restraint usage focus mainly on parents or caregivers.

By the majority of the evaluation studies, it is not clear from the publication whether or not a theoretical psychological model was the basis for designing the respective campaigns.

2.3 OVERVIEW OF RESULTS

Evaluations of child restraint campaigns from different countries all over the world were included in the analyses.

Observations of actual child restraint usage are a valid indication for the effectiveness of child restraints campaigns. The coded studies, which observed child restraint use, show a significant increase between 12% and 28% (Ebel et al., 2003; Bryant-Stephens et al., 2013; Will et al., 2009). Furthermore, self-reported child restraint use indicates positive effects of child restraint campaigns with increases between 23% (Howard et al., 2006) and 30% (Dabrowska-Lorac et al., 2008). Often campaigns aim at effecting knowledge and attitudes, which are important factors influencing the correct use of child restraints. The effects are surveyed by different kinds of questionnaires. Therefore results cannot be summarised. However, there are some indications that knowledge and some attitudes can be improved by campaigns (Ausserer et al., 2009; Howard et al., 2006; Lewis et al., 2016; Will et al., 2009).

Table 2 presents information on the main outcomes of coded studies on campaigns dealing with child restraint (sorted by author).

Table 2: Main outcomes on coded studies that deal with awareness raising and campaigns for using child restraints

Author, Year, Country	Exposure variable	Outcome variable	Effects on Road Safety		Main outcome description
Ausserer et al., 2009, Austria	Child restraint campaign	Feeling of inconvenience when wearing a seatbelt	–		Overall, there was no significant effect on pupil's feeling of inconvenience.
	Child restraint campaign	Correctly buckled up in the car	–	Percent change = 0.05	In the after study 10% are not always buckled up correctly (compared to 15% before).
	Child restraint campaign	Correctly buckled up in the car	–	Percent change = 0.06	In the after study 82% are always buckled up correctly when in a hurry (compared to 76% before).

Author, Year, Country	Exposure variable	Outcome variable	Effects on Road Safety		Main outcome description
	Child restraint campaign	Remind others	–	Percent change = 0.04-0.11	There is no significant change in reminding others if they are not wearing a seatbelt in the control group and the group with information materials without intervention.
	Child restraint campaign	Remind others	↗	Percent change = 0.18	The percentage of pupils, who remind parents to buckle themselves up significantly changed positive in the intervention group.
	Child restraint campaign	Using child restraints in another car	–	Percent change = 0.01	There is no change in usage of child restraints in other people's car.
	Child restraint campaign	Behavioural beliefs	↗	Percent change	In the after study more parents of the intervention group believed that holding a child in one's arm when travelling by car is unsafe.
	Child restraint campaign	Normative beliefs	↗	Percent change	Fewer parents of the control group believe that the partner expects them to be buckled-up, when driving a car.
Bryant-Stephens et al., 2013, US	Child restraint Campaign	Child restraint prevalence	↗	Percent change = 0.285	6 months after the campaign the intervention community experienced a significant increase in child restraint use. There was no significant change in the comparison group.
Dabrowska-Lorac et al, 2008, Poland	Child restraint campaign	Self-reported child seat use	↗	Percent change = 0.30	A significant change of self-reported child seat use between the before period and after three years campaign duration could be shown.
Ebel et al, 2003, US	Community booster seat campaign	Change in booster seat use	↗	Percent change = 0.128; adjusted for child age, driver sex, seat belt use	Campaign significantly increased booster seat use (from 13.3% to 26.1%) among booster eligible children and compared to the control group.
Howard et al., 2006, Canada	National Booster seat campaign	Self-reported booster seat use	↗	Percent change = 0.23	Exposed respondents were significantly more likely to report using a booster seat for their child than before the campaign (47% vs 24%) and compared to the control group.
		knowledge	↗	Percent change = 0.08	Exposed respondents were significantly more likely to correctly identify at least one correct criterion for proper seat belt fit (22% vs 14%) than before the campaign and compared to the control group.
Lewis et al., 2016, Australia	TV advertisement	Intention to self-check restraints	–	Absolute difference = -1.87 (t-tests)	There is a trend for the intervention group to respond with higher intentions to self-check their child restraints.

Author, Year, Country	Exposure variable	Outcome variable	Effects on Road Safety		Main outcome description
	TV advertisement	Perceived behavioural control	↗	Absolute difference = -2.83 (t-tests)	There is a significant effect of the advertisement on the perceived behavioural control.
	TV advertisement	Attitudes	–	Absolute difference	There was no significant change in attitudes towards child restraint usage.
	TV advertisement	norms	–	Absolute difference	There was no significant change in subjective norms, group norms, and descriptive norms.
Will et al., 2009, US	Video intervention	Knowledge and attitudes	↗	Absolute difference = 12.25 (t-tests)	Significant increase of child passenger safety knowledge, risk reduction attitudes, behavioural intentions related to booster seats.
	Video intervention	Perception of threat and efficacy	↗	Absolute difference = 4.64 (t-tests)	The video significantly increased parents' overall sense of threat related to hazard.
	Video intervention	Sense of efficacy related to recommended behaviours	↗	Absolute difference = 8.08 (t-tests)	The video significantly increased parents' sense of efficacy related to the recommended behaviours.
	Video intervention	Booster seat use	↗	Absolute difference = 0.16 (t-tests)	A significant increase in booster seat use (4-8 year olds) was observed in the intervention group.

*Effects on road safety are coded as: significantly positive (↗), significantly negative (↘) or non-significant (–)

Modifying conditions

Factors that might influence child restraint usage and the correct use of child restraints have to be taken into account when evaluating child restraint campaigns. The age of the children is one of the crucial factors, older children are less often buckled up in child restraints than toddlers (e.g. Pitcher, 2015; Ebel et al., 2003). Furthermore, seat belt use and education of parents also seem to have an effect (Ebel et al., 2003).

2.4 CONCLUSION

Main results

There is some indication that campaigns on child restraint usage have positive effects on road safety. Three evaluation studies from the United States show a significant increase of observed child restraint usage (Ebel et al., 2003; Bryant-Stephens et al., 2013; Will et al., 2009). Studies using self-reported child restraint use also report a significant increase (Howard et al., 2006; Dabrowska-Lorac et al., 2008).

Concerning the effects of child restraint campaigns on knowledge and attitudes, the evaluations show mixed results. It seems that knowledge and some of the relevant attitudes can be improved by campaigns (Ausserer et al., 2009; Howard et al., 2006; Lewis et al., 2016; Will et al., 2009). However, these studies use different theoretical approaches and measurements.

Biases and transferability

Most campaign evaluations were carried out soon after the campaign ended. Hardly any long term effects are available. Therefore, sustainable changes in behaviour due to campaigns remain uncertain. Furthermore, some evaluation studies based on nation-wide interventions lack control

groups, while others were carried out on small scale and the results cannot be reliably transferred to different conditions. Moreover, the quality of most studies was not satisfactory as e.g. methodological details were missing. All individual campaigns (exposure) were heterogeneous regarding design (exact target group, period, media etc.). Finally, some studies combined awareness-raising and educational activities. In that case, it is not clear to which extent the effects are attributable to the single measures.

3 Supporting documents

3.1 LITERATURE SEARCH STRATEGY

The literature search was conducted in November and December 2016. It was carried out in three databases with separate search strategies. The first one was performed in 'Scopus' which is a large abstract and citation database of peer-reviewed literature. The second literature search was conducted in a KfV-internal literature database ('DOK-DAT'), and the third in the integrated TRID database, a large online bibliographic database of transportation research. Additionally, free web-based search was done via Google.

Database: Scopus **Date:** 2nd of December 2016

Search no.	Search terms, logical operators, combined queries	Hits
#1	"Campaign" OR "awareness" OR "public information"	248,963
#2	"Child restraint" OR "booster seat"	708
#3	#1 AND #2	74
#4	Limited to Europe, Russia, USA, Canada, Australia and New Zealand	49

Table 3: Used search terms, logical operators, and combined queries of literature search (Scopus).

Detailed search terms, as well as their linkage with logical operators and combined queries are shown in Table 3. Using search field titles, abstract and keywords (TITLE-ABS-KEY) and a general limitation to studies which were published from 2006 to current lead to 74 studies (Table 3).

Results were limited to "article" and "review" and in a further step to the languages 'English' and 'German'. As on study scope we only considered studies from Europe, Russia, USA, Canada, Australia and New Zealand. This led to a final sample of 49 studies of literature search in database Scopus.

Database: DOK-DAT **Date:** 7th of December 2016

Search no.	Search terms, operators, combined queries	Hits
#1	"Werbung" (advertisement) AND "Sicherheit" (safety)	467
#2 (within #1)	"Wirksamkeit*" (effectiveness) OR "Evalu*" (evaluation) OR "Bewertung*" (assessment)	278
#3 (within #2)		109

Table 4: Used search terms, logical operators, and combined queries of literature search (DOK-DAT).

German search fields 'Titel', 'ITRD Schlagworte' and 'freie Schlagworte' were used. Hits were only limited to the years 1995 to 2016 and got 109 more potential studies (Table 4).

Database: TRID database **Date:** 20th of December 2016

Search no.	Search terms, operators, combined queries	Hits
#1	"safety" AND "campaign" AND "evaluation"	240

Table 5: Used search terms, logical operators, and combined queries of literature search (TRID).

Search terms were "safety", "campaigns" and "evaluation". Hits were limited to the years 2000 to 2016 and got 240 potential studies (Table 5).

The literature search strategy, querying three databases, didn't result in a sufficient number of evaluated awareness raising measures. Based on the expertise of the consortium, it became evident that some evaluation studies are not published in scientific journals (grey literature, conference papers etc.). Therefore, it was decided to complement the results with a non-standardised, free search with the internet search engine Google. In a first step, relevant road safety campaigns were

identified. In a second step, the aim was to find according evaluation papers of these campaigns. The following search terms were used in different combinations: campaign, evaluation, effectiveness, awareness raising, child restraint, booster seat.

Results Literature Search

Database	Hits
Scopus (remaining papers after several limitations/exclusions)	49
DOK-DAT	109
TRID database	240
Unstandardized Search via Google & recommended literature	5
Total number of studies to screen title/ abstract	403

Table 6: Results of literature search after limitations

All in all, this literature search led to 403 potential studies for screening.

Screening

Total number of studies to screen title/ abstract	403
Exclusion criteria: not or other topic, no evaluation	378
Studies to obtain full-texts	25

Table 7: Screening of abstracts

After screening the titles and abstracts 25 studies remained for screening the full-text.

Total number of studies to screen full-text	25
Full-text could be obtained	-1
Reference list examined Yes/No	Y
Eligible papers	24

Table 8: Papers obtained for full-text screening

Screening of the full texts

Total number of studies to screen full paper	24
Other topic (e.g. education) - excluded	3
Studies with no codable data - excluded	2
No campaign (evaluation)	9
Effects coded in other studies	2
Studies not available in English - excluded	1
Remaining studies	7

Table 9: Screening of full texts

Prioritising Coding

- Prioritising Step A (meta-analysis first)
- Prioritising Step B (best fitting in coding scheme, in particular quantitative data)
- Prioritising Step C (published more recently)
- Prioritising Step D (Central-European countries before others)

Studies are presented in the following table sorted by authors' name.

No.	Publication	Coded Yes/No	Reason
1	Aitken, M.E., Mullins, S. H., Lancaster, V. E., & Miller, B. K. (2007). "Cubs Click It for Safety": A school-based intervention for Tween passenger safety. <i>Journal of Trauma - Injury, Infection and Critical Care</i> , 63(3 SUPPL.), S39-S43.	N	Other topic (education)
2	Anund, A. & Sörensen, G. (2001). Child safety restraints: an evaluation of a traffic safety campaign among parents in the south of Sweden. Swedish National Road and Transport Research Institute (VTI) Linköping.	N	Not available in English
3	Ausserer, K., Haupt, J. & Risser, R. (2009). Evaluation of a child restraint campaign in Austria. In Forward, S. & Kazemi, A. (Editors). A theoretical approach to assess road safety campaigns. Evidence from seven European countries. Belgian Road Safety Institute, 137-210.	Y	
4	BMRB Social Research (2006). THINK! Road safety campaign evaluation - Post Child Restraints and Pre Mobiles.	N	No codable data
5	Bryant-Stephens, T., Garcia-Espana, J.F., & Winston, F. K. (2013). Boosting Restraint Norms: A Community-Delivered Campaign to Promote Booster Seat Use. <i>Traffic Injury Prevention</i> , 14(6), 578-583.	Y	
6	Dabrowska-Lorac, M. & Wacowska-Slezak, J. (2008). Children safety in road transport European Project Euchires. <i>Journal of KONES Powertrain and Transport</i> , 15 (2).	Y	
7	Ebel, B.E., Koepsell, T.D., Bennet, E.E. & Rivara, F.P. (2003). Use of Child Booster Seats In Motor Vehicles Following a Community Campaign. <i>JAMA The Journal of the American Medical Association</i> 289(7), 879-84.	Y	
8	Ehiri, J.E., Ejere, H.O., Magnussen, L., Emusu, D., King, W. & Osberg, J.S. (2006). Interventions for promoting booster seat use in four to eight year olds traveling in motor vehicles. <i>Cochrane Database Syst Rev</i> (1):CD004334.	N	Other topic (education)
9	Elder, R.W. (2014). Combination of mass media health campaigns and health-related product distribution is recommended to improve healthy behaviors. <i>American Journal of Preventive Medicine</i> , 47(3), 372-374.	N	No campaign evaluation
10	Gielen, A.C., Dannenberg, A.L., Ashburn, N. & Kou, J. (1996). Teaching safety: evaluation of a children's village in Maryland. <i>Injury Prevention</i> , 1996; 2 (1): 26-31.	N	Other topic (education)
11	Golonka, R.P., Dobbs, B.M., Rowe, B.H., & Voaklander, D. (2016). Prevalence and predictors of booster seat use in Alberta, Canada. <i>Canadian Journal of Public Health</i> , 107(2), 155-160.	N	No campaign
12	Gunn, V.L., Phillippi, R.M., & Cooper, W.O. (2007). Improvement in booster seat use in Tennessee. <i>Pediatrics</i> , 119(1), 131-136.	N	No campaign
13	Howard, A., Beben, N., Rothman, L., Fiissel, D., & MacArthur, C. (2006). Evaluation of safe kids week 2004: Age 4 to 9? It's booster seat time! <i>Injury Prevention</i> , 12(5), 316-319.	Y	
14	Jacob, V., Chattopadhyay, S.K., Elder, R.W., Robinson, M.N., Tansil, K.A., Soler, R.E., & Mercer, S.L. (2014). Economics of mass media health campaigns with health-related product distribution: A community guide systematic review. <i>American Journal of Preventive Medicine</i> , 47(3), 348-359.	N	No codable data

No.	Publication	Coded Yes/No	Reason
15	Johnston, B.D., Ebel, B., Bennett, E., Gonzalez-Walker, D., & Blue, B. (2006). Making head start a safe start: Boost Kids! Child Passenger Safety project. <i>Journal of Trauma - Injury, Infection and Critical Care</i> , 60(6), 1383–1384.	N	No campaign evaluation
16	Klassen T, Mackay M, Moher D, Walker A. & Jones A. (2000). Community - Based Injury Prevention (The future of children). <i>Unintentional Injuries in Childhood</i> , 10, 83-110.	N	No campaign
17	Lewis, I., Ho, B., & Lennon, A. (2016). Designing and evaluating a persuasive child restraint television commercial. <i>Traffic Injury Prevention</i> , 17(3), 271–277.	Y	
18	Mytton, J., & Pilkington, P. (2007). Evaluation of booster seat campaign. <i>Injury Prevention: Journal of the International Society for Child and Adolescent Injury Prevention</i> , 13(1), 70.	N	Comment at Howard et al. (coded)
19	O'Neil, J., Slaven, J. E., Talty, J., & Bull, M. J. (2014). Are parents following the recommendations for keeping children younger than 2 years rear facing during motor vehicle travel? <i>Injury Prevention</i> , 20(4), 226–231.	N	No campaign
20	Pankratz, C., Warda, L., & Piotrowski, C. (2016). Challenges in the accurate surveillance of booster seat and bicycle helmet usage by children: Lessons from the field. <i>International Journal of Environmental Research and Public Health</i> , 13(7)	N	No campaign evaluation
21	Randle, S., Alatini, M., Bolton, P., Bennett, S. & Carter, W. (2012). Child motor vehicle passenger safety: using research to build a campaign. <i>Australasian Road Safety Research Policing Education Conference, New Zealand</i>	N	No campaign
22	Robinson, M.N., Tansil, K.A., Elder, R.W., Soler, R.E., Labre, M.P., Mercer, S.L. & Rimer, B.K. (2014). Mass media health communication campaigns combined with health-related product distribution: A community guide systematic review. <i>American Journal of Preventive Medicine</i> , 47(3), 360–371.	N	Effects already coded in Ebel et al.
23	Sheese, J., Talty, J., McCreary, L. & Bull, M. (1997) The Front Versus the Back Seat: Is the Message Affecting Practice? <i>Society Of Automotive Engineers, Inc. (SAE): Child Occupant Protection 2nd Symposium Proceedings. Orlando, Florida</i> , 283.	N	No campaign
24	Will, K.E., Sabo, C.S. & Porter, B.E. (2009). Evaluation of the Boost'em in the Back Seat Program: Using fear and efficacy to increase booster seat use <i>Accident Analysis & Prevention</i> , 41 (1), 57-65.	Y	

3.2 REFERENCES

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- Pitcher, M. (2015). Are Parents and Carers Fitting Child Car Seats Correctly? TRL presentation at the Harrogate International Nursery Fair, March 2015.
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- Robertson, R.D. & Pashley, C.R. (2015). Road safety campaigns – what the research tells us. Traffic Injury Reserach Foundation, Ottawa, Canada.
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Awareness raising and campaigns – Driving under the influence



Eichhorn, A., Kaiser, S., June 2017

1 Summary

1.1 COLOUR CODE

Light green: There is some indication that drink-driving campaigns have a positive impact on attitudes towards drink-driving and even related accident occurrence. There is less evidence of the effectiveness of designated driver programmes.

1.2 KEY WORDS

Campaign, evaluation, impact, effectiveness, awareness raising, driving under the influence, drunk driving, drink-driving, impaired driving, drugged-driving, alcohol, designated driver, heroin, LSD, ketamine, cocaine, ecstasy, cannabis

1.3 ABSTRACT

The main purpose of DUI (Driving Under the Influence) campaigns is to raise awareness regarding impaired driving as well as to promote sober driving.

Results provide some indication that drink-driving campaigns can have positive effects on road safety. One out of two meta-analyses showed an association with crash reduction. A further meta-analysis and other individual studies with indirect outcome measures showed mixed results. While self-reported drink-driving behaviour did not considerably change, attitudes towards drink-driving were favourably influenced to some extent. Designated driver programmes seem to have lower potential to prevent drink-driving. However, most of the coded individual studies focus on young drivers and to some extent on passengers aged up to 34 years. Thus, conclusions can only be drawn regarding this age group. Furthermore, it should be noted that some analysed DUI campaigns were accompanied by enforcement activities. Therefore, it is not clear to what extent the effects are attributable to the campaign itself.

1.4 BACKGROUND

This synopsis focuses on the effectiveness of campaigns addressing specifically driving under the influence. For more detailed information on campaigns and awareness raising in general, please also see the synopsis "Effectiveness of road safety campaigns".

How is 'campaign' as a road safety measure defined?

The EU project CAST¹ provides the following definition of campaigns in the field of road safety: "Road safety communication campaigns can be defined as purposeful attempts to inform, persuade, or motivate people in view of changing their beliefs and/or behaviour in order to improve road safety as a whole or in a specific, well-defined large audience, typically within a given time period by means of organised communication activities involving specific media channels often combined with interpersonal support and/or supportive actions such as enforcement, education, legislation, enhancing personal commitment, rewards, etc." (Elliott, 1993; Rice & Atkin, 1994; Vaa et al., 2008, as cited in Delhomme et al., 2009, p.16).

How do campaigns affect road safety?

The effect of a campaign can be increased information, knowledge, raised awareness, changed attitude and changed behaviour to the extent that eventually the frequency of accidents is reduced. However, since accident occurrence is multicausal and highly influenced by chance, there is rarely a direct link from a campaign to accident reduction. Many campaigns are combined with enforcement

¹ The EU-project CAST "Campaigns and Awareness-Raising Strategies in Traffic Safety" was carried out from 2006 to 2009 by 19 organisations from 15 European countries. This project identified essential parameters of campaigns effectiveness.

and new legislation. It is difficult to attribute the effect to a single element of this combination. Campaigns can also be used to establish favourable preconditions in the public for new legislation.

Which factors influence the effect of a campaign on road safety and which are the modifying conditions?

Important factors for an effective campaign are clearly defined road safety problems and target groups, as well as a corresponding tailored message. Furthermore, it is necessary to use theoretical psychological models that explain the risk behaviour or safety problem (Delhomme et al., 2009). It is important to note that communication has to be based on the cultural codes used in the target community (national, regional, sub-groups etc.). Other influencing factors are the duration and intensity of a campaign. Other situational factors such as simultaneous competing events (e.g. tragic accident reported in media) can also have an impact on the campaign effects.

How is the effect of campaigns on DUI measured?

The following measures are used to assess the effectiveness of DUI-campaigns:

- Self-reported and intended behaviour
- Attitudes, opinions, perceived norm, knowledge, behavioural beliefs
- Accident occurrence

The vast majority of studies in this field apply a before-after design to measure the campaign effect. Accident statistics are seldom the means of evaluation because behaviour of road users is multicausal.

1.5 OVERVIEW OF RESULTS

Four meta-analyses on the effectiveness of drink-driving campaigns have been considered (Yadav & Kobayashi, 2015; Phillips et al., 2009 and 2011; Ditter et al., 2005). They show mixed results regarding the effects on road safety. Phillips et al. (2011) found a significant accident reduction due to drink-driving campaigns. Yadav & Kobayashi (2015) on the other hand reported non-significant effects on accident reduction. A meta-analysis on alternative outcome measures (other than crashes, but safety performance indicators such as risk behaviour, attitudes etc.) did not indicate a significant improvement of observed and self-reported drink-driving behaviour (Phillips et al., 2009). As regards designated driver programmes, Ditter et al. (2005) indicated insufficient evidence to determine their effectiveness.

With reference to drugged driving only one study was eligible for coding, which reports a significant positive change in the attitude that cannabis has a severe impact on driving. No such change could be found for all other surveyed drug types (Angle et al., 2009).

Nathanail and Adamos (2009) and Linkenbach (2005) analysed driver's self-reported drink-driving behaviour after DUI campaigns. None of the reported effects indicate a significant positive change. Concerning perceived impairment due to drink-driving, three studies indicate a (partly significant) improvement of young males' attitudes towards DUI. Another study, however, did not find a change in that respect (Nathanail & Adamos, 2009).

Evaluation studies of designated driver programmes show a (partly significant) increase in using a designated driver (Watson & Nielson, 2008; Linkenbach, 2005). However, acting as designated driver (committing to not drink and drive and to bring others home safely) did not significantly change (Watson & Nielson, 2008).

In applying a regression model considering compulsory breath tests (before and after campaign) and a measure of retained awareness of a television advertising campaign Tay (1999) pointed out that the evaluated campaign is associated with a significant drop in drink-driving behaviour.

However, all analysed studies had at least minor limitations. Some of the evaluated campaigns were accompanied by enforcement activities, lacked details of reported significance testing or measured only short-term campaign effects.

2 Scientific details

2.1 THEORETICAL BACKGROUND

Aim and methods of awareness raising measures and campaigns

The main purpose of awareness raising measures and communication campaigns is to encourage road users to engage in safe behaviour in traffic. With respect to DUI campaigns, the primary aim is favourable attitudes against drink-driving and to restrain from impaired driving. The underlying concept of campaigns in road safety is social marketing which aims at influencing and changing social behaviours.

When developing a campaign, it is crucial to conduct a detailed analysis of the **road safety problem** and the **target group**. Furthermore, psychological theoretical models are very helpful in the development of the campaign message to increase the effectiveness (Robertson & Pashley, 2015). A description of these models – such as the Theory of Planned Behaviour (TPB) – can be found in Theofilatos et al. (2017).

Besides developing the message, the **campaign strategy** has to be defined. Campaigns may use an information approach or emotive, especially using fear to draw the attention of the target audience to the message. However, there are still controversial discussions regarding the effectiveness of fear-based messages (see e.g. Castillo-Manzano et al., 2012). Whether or not a message has reached the target group, is also a question of group characteristics and local culture.

To evaluate whether or not the message of the campaign can influence the behaviour of the target group as intended, a **pre-test of message** and slogan should be conducted (Delhomme et al., 2009; Hoekstra & Wegman, 2011).

For road safety campaigns the following **type of media** is generally used: television, radio, newspaper/magazines, cinema, web/online, social media, billboards, flyers/leaflets/posters, message signs and events involving face to face communication. An overview of advantages and disadvantages of different types of media for road safety campaigns can be found in Delhomme et al. (2009).

Campaign effects and influencing factors

Awareness raising activities and campaigns can positively influence a number of road safety relevant constructs, such as favourable attitudes, knowledge and perceptions as well as safe behaviour and therefore also accident rates. However, there are various factors to be considered to maximise impact. According to Phillips et al. (2011) the following factors of campaigns are associated with accident reduction:

- Personal communication
- Road side delivery (billboards, message signs)
- Drink-driving theme
- Combination with enforcement
- Short campaign duration (0-29 days)

Limitations of campaigns and challenges of evaluation

In the past, evaluations of campaigns were rarely carried out for various reasons. For one, there is sometimes a lack of awareness of the benefit of evaluating, or there may be budget and time constraints. Uncertainties in terms of methodological application are also a barrier.

As previously described, the effectiveness of road safety campaigns can be measured by various means. The most important **outcome measure** is a reduction in crashes. It is difficult though, to link an accident reduction to a campaign while controlling for all other possible contributing factors. The defined outcome measures to account for campaign effects are therefore often 'indirect', like intended behaviour or attitudes etc. Even though there is evidence concerning the influence of these

constructs on actual behaviour, there are always other additional determining factors (e.g. situational factors) that cannot be accounted for.

A before-after-design ideally includes a **meaningful reference group** to control for confounding factors (e.g. a similar geographical region without exposure to the contents of the campaign), which is however rarely the case.

Next to a lack of (systematical and valid) evaluation of effects, campaigns are often **combined or conducted simultaneously** with enforcement measures and implementation of new legislation. If an effect (improvement) is measured then, it remains unclear to which of the single components it is attributable, and to what extent.

2.2 CODED STUDIES

The literature search was carried out in three databases (Scopus, TRID and a KfV-internal literature database) with separate search strategies (for a detailed description see "Supporting documents"). Additionally, a free web-based search was conducted via Google.

Below first information on the characteristics of coded studies is given and subsequently the main research methods used for campaigns and awareness raising measures against driving under the influence is provided.

Description of coded studies

A more detailed description of the campaigns and the corresponding design of evaluation can be found in the supporting documents (3.2).

Description of the main research methods

In order to evaluate the effectiveness of DUI campaigns mainly before-after designs are used. Evaluations of DUI campaigns are rarely linked to accidents and focus mainly on outcomes of questionnaires and interviews using self-reported behaviour, attitudes, beliefs and opinions as measures of effectiveness. For the majority of the evaluation studies, it is not clear from the publication whether or not a theoretical psychological model was the basis for designing the respective campaigns.

The studies vary in whether significance tests are applied/reported or not. A control group is missing in most of the studies. Four meta-analyses calculated (weighted) average effects.

2.3 OVERVIEW OF RESULTS

The following table provides information on the main outcomes of coded studies on DUI campaigns and awareness raising.

Table 1: Summary of coded study results regarding DUI awareness raising and campaigns (sorted by author(s), meta-analyses first)

Author(s), year, country	Exposure variable	Dependant / outcome type	Effects on road safety	Main outcome - description
Ditter et al., 2005, Australia/ USA	Designated driver programmes	Self-reported behaviour (acting as designated driver)	/ Mean change = 0.9 (interquartile range: 0.3 - 3.2)	The programmes showed a mean increase of 0.9 designated drivers per night.
Phillips et al., 2009, international	Road safety campaigns on DUI	Observed and self-reported drink-driving	- Percent change = -0.17 CL: 95%, CI: -0.46 - 0.28	Road safety campaigns on DUI are linked to a non-significant 17% decrease of drink-driving behaviour.
Phillips et al., 2011, international	Road safety campaigns on DUI	Crashes	↗ Percent accident reduction = 0.18 CL: 95%, CI: 0.23 - 0.12	Road safety campaigns on DUI are linked to an 18% accident reduction.

Author(s), year, country	Exposure variable	Dependant / outcome type	Effects on road safety		Main outcome - description
Yadav & Kobayashi, 2015, USA/Australia	Mass media campaigns for reducing DUI	Crashes	–	OR = 1	Summary effects show no evidence of media campaigns reducing the risk of alcohol-related injuries or fatalities.
Angle et al., 2009, UK	Drug-driving campaign "Eyes"	Attitude, impact of heroin on driving	–	Percent change = 0	No significant change in attitude that heroin has a severe impact on driving task
		Attitude, impact of LSD on driving	–	Percent change = -0.02	No significant change in attitude that LSD has a severe impact on driving task
		Attitude, impact of ketamine on driving	–	Percent change = 0	No significant change in attitude that ketamine has a severe impact on driving task
		Attitude, impact of cocaine on driving	–	Percent change = 0.01	No significant change in attitude that cocaine has a severe impact on driving task.
		Attitude, impact of ecstasy on driving	↘	Percent change = -0.05	Significant negative change in attitude (-5%) that ecstasy has a severe impact on driving task
		Attitude, impact of cannabis on driving	↗	Percent change = 0.06	Significant positive change in attitude (6%) that cannabis has a severe impact on driving task
Angle et al., 2012, UK	Drink-driving campaign "Personal Consequences"	Attitude, safe to drive after 1 drink	/	Percent change = 0.02	Increase in attitude (not safe to drive after one drink) by 2% for young males
		Attitude, safe to drive after 2 drinks	–	Percent change = 0	No change in attitude (not safe to drive after two drinks) for young males
		Unacceptability, driving after 2 pints	/	Percent change = 0.11	Increase in unacceptability (driving after two pints) by 11% for young males
Krol, 2009, Poland	"Drunk? Don't drive" media campaign combined with enforcement activities	Opinion, alcohol impairs ability to drive safely (definitely agree)	↗	Percent change = 0.08	Significant increase in opinion that alcohol impairs ability to drive safely by 8% among young drivers
		Opinion, one can drive safely only with no alcohol at all (definitely agree)	↗	Percent change = 0.11	Significant increase in opinion that one can only drive safely with no alcohol at all by 11% among young drivers
Linderholm, 2000, Sweden	TV-programme	Attitude towards drink-driving	/	Percent change = 0.06	The TV programme showed a 6% increase of young drivers thinking negatively about drink-driving (not tested for significance).
Linkenbach, 2005, USA	Road safety campaign on DUI	Perceived norm of peers drink-driving	/	Percent change = -0.05	5.1% decrease in believing that the average peer drove after drinking during the previous month (no test for significance reported; but significant difference compared to control group: 7.5%)
		Self-reported drink-driving behaviour (after	/	Percent change = -0.02	2% decrease in self-reported drink-driving behaviour (no test for significance reported;

Author(s), year, country	Exposure variable	Dependant / outcome type	Effects on road safety	Main outcome - description	
		two or more drinks within the hour)		but significant difference compared to control group: 13.7%)	
		Self-reported behaviour (driving with a designated driver)	/	Percent change = 0.047 4.7% increase in self-reported behaviour to drive with a designated driver (no test for significance reported; but significant difference compared to control group: 15%)	
Nathanail & Adamos, 2009, Greece	Road safety campaign on DUI	Behavioural beliefs	–	Absolute difference (t-test, CL: 95%)	Campaign showed a not significant change in belief regarding the ability to drive safely when drunk
		Behavioural beliefs	–	Absolute difference (t-test, CL: 95%)	Campaign showed a non-significant change in belief regarding being involved in accident when drink driving
		Normative beliefs	–	Absolute difference (t-test, CL: 95%)	Campaign showed a non-significant change in belief that passengers can persuade oneself not to drive when drunk
		Behavioural intention	–	Absolute difference (t-test, CL: 95%)	Campaign showed a non-significant change in likelihood to drive having drunk at least one glass of wine
		Self-reported behaviour	–	Absolute difference (t-test, CL: 95%)	Campaign showed a non-significant change in preference to not drive when drunk
		Behavioural intention	–	Absolute difference (t-test, CL: 95%)	Campaign showed a non-significant change in the likelihood of preventing the driver from drink-driving
		Behavioural intention	↗	Absolute difference (t-test, CL: 95%)	Campaign showed a significant change in likelihood to prevent the driver from drinking even a glass of alcohol
Tay, 1999, New Zealand	Road safety campaign on DUI	Retained campaign awareness (Adstock)	↗	Slope: R ² =0.63 All estimated coefficients of Adstock are statistically significant, indicating that the campaign has changed the structural relationship between advertising and drink-driving behaviour.	
Watson & Nielson, 2008, Australia	Designated driver programme	Self-reported behaviour (acting as a designated driver)	–	Percent change = 0.04	The programme showed a non-significant increase by 4% in the proportion of participants who acted as a designated driver in the past 3 months.
		Self-reported behaviour (driving with a designated driver)	↗	Percent change = 0.15	The programme showed a significant increase by 15% in the proportion of participants who drove with a designated driver in the past 3 months.

* Effects on road safety are coded as: significant positive (↗), significant negative (↘), non-significant (–) or no test for significance reported (∅)

Meta-analyses results

Yadav & Kobayashi (2015) carried out a meta-analysis with focus on drink-driving media campaigns, while Phillips et al. (2009, 2011) analysed the overall effect of road safety campaigns – with additional effect calculations of various campaign themes, including drink-driving. Results are mixed regarding the effects on road safety. The most recent meta-analysis of Yadav & Kobayashi reported no significant effects on accident reduction. However, the authors indicate very heterogeneous approaches of the single studies, so results have to be considered carefully. Also Phillips et al. (2009) conclude that the analysed campaigns on DUI do not lead to a significant improvement of observed and self-reported drink-driving behaviour (impact on accident level not considered).

Phillips et al. (2011) on the other hand found a significant accident reduction due to drink-driving campaigns. All meta-analyses calculated effects of campaigns with and without enforcement components. Only Phillips et al. (2011) reported results adjusted for accompanied enforcement measures, however, not on the DUI-level. Considering different campaign themes it turned out that especially drink-driving campaigns can be associated with accident reduction (see also synopsis "Effectiveness of Road Safety Campaigns").

With regard to designated driver programmes Ditter et al. (2005) indicated an increase of the mean number of designated drivers per night. However, due to the small effect sizes observed there is insufficient evidence to determine the effectiveness of incentive programmes to promote designated driver use.

Additional studies on DUI campaigns

Additionally considered studies were quite different regarding the exposure variable(s) (different aims and resources of campaigns) and outcome variables. Furthermore, all studies had at least minor limitations and some lacked reported significance testing, so it was not feasible to give a summarised analysis in terms of meta-analysis or vote-count analysis.

Table 1 shows an overview of the main results of these studies.

Only one study could be found with respect to the effectiveness of **drugged-driving** campaigns. Angle et al. (2009) report a significant positive change in the attitude that cannabis has a severe impact on driving after the "Eyes" campaign. In contrast, a significant negative change was found regarding the attitude that ecstasy has a severe impact on driving. No change was found for heroin, LSD, ketamine and cocaine. Despite the fact that the study only assessed changes in attitudes, the reported facts do not show a clear trend and therefore, no conclusion can be drawn.

Nathanail & Adamos (2009) and Linkenbach (2005) analysed drivers' **self-reported drink-driving** behaviour after a DUI campaign. The latter found a small decrease of 2% (driving after two or more drinks within the hour), however, did not indicate whether this change is significant or not. The other study reported a non-significant change in the "preference to not drive when drunk" as well as a non-significant change regarding the likelihood to drive having drunk at least one glass of wine. Still, due to a small sample size, results have to be interpreted with caution.

Concerning the **perceived impairment** due to drink-driving Krol (2009) indicated a significant increase of 8% among young drivers and an 11% increase in thinking that one can only drive safely with no alcohol at all ("Drunk? Don't drive" media campaign). Also Angle et al. (2012) and Linderholm (2000) report an increase of young males (11% and 6%, respectively), who think negatively about drink-driving. However, no information concerning significance is provided. Nathanail & Adamos (2009) on the other hand found no difference in **beliefs** regarding either the ability to drive safely or being involved in an accident when drunk after a Greek DUI campaign.

Some of the coded studies evaluated **designated driver programmes**. Only Watson & Nielson (2008) found a significant increase in participants who drove with a designated driver after the Australian "Skipper" campaign. However, acting as designated driver did not significantly change. Linkenbach (2005) also reports an increase in passengers driving with a designated driver (no significance test reported).

In order to examine the relationship on advertising exposure (DUI campaign, New Zealand) and drink-driving behaviour Tay (1999) used regression models including the following two variables: compulsory breath tests (before and after campaign), advertising stock (measures the retained awareness of advertising). Different models show that the estimated coefficients for the Adstock variables are statistically significant and negative. Results of the **log-linear model** indicate that the television advertising campaign is associated with a significant drop in drink-driving behaviour

during the period analysed, after adjusting for changes in compulsory breath tests and seasonal trends.

Modifying conditions

Most of the coded individual studies focus on young drivers and to some extent on passengers aged up to 34 years. Thus, conclusions can only be drawn regarding this age group.

Phillips et al. (2011) carried out a meta-regression (model of predictor variables) based on 119 individual campaign effects to identify the relative importance of factors influencing the effectiveness of road safety campaigns. They identified the following factors of campaigns to be associated with accident reduction:

- Personal communication
- Road side delivery (billboards, message signs)
- Combination with enforcement
- Short campaign duration (0-29 days)

Phillips et al. (2009) outlined conclusions on a meta-regression by Vaa et al. (2004). They considered various outcome variables, not only accident reduction (e.g. self-reported behaviour or attitudes) and found the same factors to be beneficially influencing campaign outcomes.

2.4 CONCLUSION

General

The focus of this synopsis is on drink-driving campaigns, as only one study on a drug-driving campaign was identified and thus no general conclusions can be drawn.

Main results

Results provide some indications that drink-driving campaigns can have positive effects on road safety. One out of two meta-analyses showed an association with crash reduction. A further meta-analysis and other individual studies with indirect outcome measure (observed and self-reported behaviour) showed mixed results, as well. While self-reported drink-driving behaviour did not considerably change, attitudes towards drink-driving were favourably influenced to some extent. The evaluation studies of designated driver programmes show a (partly significant) increase in using a designated driver. However, acting as designated driver did not significantly change. Furthermore, one study indicated a significant drop in drink-driving behaviour after a television advertising campaign (number of positive compulsory breath tests).

Biases and transferability

All studies had at least minor limitations. It is difficult to link changes in accidents solely to a campaign. The defined outcome measures to account for campaign effects are therefore often 'indirect' like intended behaviour or attitudes. Even though there is evidence concerning the influence of these constructs on actual behaviour, there are also always other determining factors that cannot be accounted for. Furthermore, often self-reported data is used to assess effectiveness, which may introduce biases such as social desirability.

Another limitation is that some evaluated campaigns were accompanied by enforcement activities or other road safety measure. In that case, it is not clear to what extent the effects are attributable to the single measures. Also, all individual campaigns (exposure) were heterogeneous regarding design (exact target group, period, media etc.).

Moreover, many studies did not indicate whether significance was tested. Long term effects are available for only a few studies. Therefore, sustainable changes in behaviour due to campaigns remain unclear. Finally, to control for confounding factors ideally a meaningful reference group is included, which is rarely done.

3 Supporting documents

3.1 LITERATURE SEARCH STRATEGY

The literature search was conducted in December 2016. It was carried out in three databases and a complementary free internet search. The queried databases were

- Scopus: a large abstract and citation database of peer-reviewed literature
- TRID: a large online bibliographic database of transportation research
- DOK-DAT: a KfV-internal literature database.

Database: Scopus

Date: 16th of December 2016

limitations: published: 2006 to present

Search No.	Search terms, logical operators, combined queries	Hits
#1	"Campaign" OR "awareness" OR "public information"	248,963
#2	"DUI" OR "driving under influence" OR "alcohol" OR "drunk driving" OR "drink driving" OR "drugged driving" OR "drugs" OR "medic*" OR "alcohol-impaired driving" OR "drug-impaired driving"	4,684,113
#3	"road safety" OR "traffic safety"	12,033
#4	#1 AND #2 AND #3	131
#5	Limit to Europe, Russia, USA, Canada, Australia and New Zealand	80

Table 2: Used search terms, logical operators, and combined queries of literature search (Scopus).

Detailed search terms as well as their linkage with logical operators and combined queries are shown in Table 2. Using search fields title, abstract and keywords (TITLE-ABS-KEY), and a general limitation to studies which were published from 2006 to current, led to 131 studies.

In a further reduction step, results were limited to European countries, as well as Russia, USA, Canada, Australia and New Zealand. This led to a final sample of 80 studies of literature search in the database Scopus (Table 2).

Database: DOK-DAT

Date: 7th of December 2016

Search no.	Search terms, operators, combined queries	Hits
#1	"Werbung" (advertisement) AND "Sicherheit" (safety)	467
#2 (within #1)	"Wirksamkeit*" (effectiveness) OR "Evalu*" (evaluation) OR "Bewertung*" (assessment)	278

Table 3: Used search terms, logical operators, and combined queries of literature search (DOK-DAT).

German search fields 'Titel', 'ITRD Schlagworte' and 'freie Schlagworte' were used. Hits were only limited to the years 1990 to 2016 and got 278 more potential studies (Table 3).

Database: TRID database

Date: 20th of December 2016

Search no.	Search terms / operators / combined queries	Hits
#1	"safety" AND "campaign" AND "evaluation"	240

Table 4: Used search terms, logical operators, and combined queries of literature search (TRID).

Search terms were “safety”, “campaigns” and “evaluation”. Hits were limited to the years 2000 to 2016 and got 240 potential studies (Table 4).

The literature search strategy, querying three databases, did not result in a sufficient number of evaluated awareness raising measures. Based on the expertise of the consortium, it became evident that some evaluation studies are not published in scientific journals (grey literature, conference papers etc.). Therefore, it was decided to complement the results with a non-standardised, free search with the internet search engine Google. In a first step, relevant road safety campaigns were identified. In a second step, the aim was to find according evaluation papers of these campaigns. The following search terms were used in different combinations: campaign, evaluation, effectiveness, awareness raising, driving under the influence, drunk driving, drink-driving, drug-driving and medication and led to 38 further studies for screening.

Results literature search

Database	Hits
Scopus (remaining papers after several limitations/exclusions)	80
DOK-DAT	278
TRID database	240
Free literature search (Google)	38
Total number of studies to screen title/ abstract	636

Table 5: Results of databases and free search after limitations

In all, literature search led to 636 potential titles/abstracts for screening.

Screening

Total number of studies to screen title/ abstract	636
Exclusion criteria: no campaign/evaluation or topic not or not sufficiently covered or duplicates	597
Studies to obtain full-texts	39

Table 6: Screening of abstracts

After screening the titles and abstracts 39 studies remained for screening the full-text.

Total number of studies to screen full-text	39
Full-text could be obtained	26
Reference list examined Y/N	Partly
Eligible papers	26

Table 7: Papers obtained for full-text screening

Screening of the full texts

Total number of studies to screen full paper	26
Studies covered by another topic	3
Reported effect already covered in other considered study	3
Studies excluded because no evaluation or quantitative effects reported	3
Studies covered by meta-analysis	3
Not relevant	5
Remaining studies	9
DUI effects coded within "campaigns general" (meta-analysis)	2

Table 8: Screening of full-texts

Studies are presented in the following table sorted by authors' name, meta-analyses are mentioned first.

No.	Publication	Coded Y/N	Reason
1.	Yadav, R.-P. & Kobayashi, M. (2015). A systematic review: effectiveness of mass media campaigns for reducing alcohol-impaired driving and alcohol-related crashes. <i>BMC Public Health</i> , 15:857. DOI 10.1186/s12889-015-2088-4.	Y	
2.	Adam, D. (1994). AADAC bowls over teens with new ad campaign. <i>Injury Prevention News</i> , 7(3), 10-11.	N	No quantitative effects reported
3.	Angle, H., Bone, S., Goddard, E. & Johns, E. (2009). THINK! Road Safety Campaign Evaluation Post evaluation of the 'Eyes' THINK! Drug Drive campaign Report. BMRB/HA/SB/45108903	Y	
4.	Angle, H., Pinkney, S., Johns, E. & Cass, G. (2009). THINK! Road Safety Campaign Evaluation. Post evaluation of the 'Personal Consequences' Drink Drive campaign. TNS-BMRB Report.	Y	
5.	Bartl, G., Urbaneck, K., Chaloupka-Risser, C., Gfrerer, W., Ortner, W., Schrader, C., Schützhofer, B., Strauss, B. & Stobl, C. (2010). Österreichische Alkoholenker-Studie 2010. Wien: Institut alles-führerschein.at, November 2010, 48.	N	Not relevant
6.	Beck, K.H. (2009). Lessons learned from evaluating Maryland's anti-drunk driving campaign: assessing the evidence for cognitive, behavioral, and public health impact. <i>Health Promot Pract.</i> , 10, 370-377.	N	Study covered by meta-analysis Yadav (2015)
7.	Boots, K., Midford, R. (1999). "Pick-a-Skipper": an evaluation of a designated driver program to prevent alcohol-related injury in a regional Australian city. <i>Health Promotion International</i> , 14(4), 337-345.	N	Study in other measures category

8.	Delaney, A., Lough, B., Whelan, M. & Cameron, M. (2004). A Review of Mass Media Campaigns in Road Safety. Report No. 220, Monash University Accident Research Centre, ISBN: 0 7326 1730 8.	N	Studies to be considered in campaigns general
9.	Elder R.W., Shults, R.A., Sleet, D.A., Nichols, J.L., Thompson, R.S. & Rajab, W. (2004). Effectiveness of Mass Media Campaigns for Reducing Drinking and Driving and Alcohol-Involved Crashes: A Systematic Review. American Journal of Preventive Medicine, 27(1), 57-65.	N	Study covered by meta-analysis Yadav (2015)
10.	Elliot, B. (1993) Road safety mass media campaigns: a meta-analysis. Canberra: Federal Office of Road Safety (report CR 118)	N	Study covered by meta-analysis Yadav (2015)
11.	Guria, J. (1999). An economic evaluation of incremental resources to road safety programmes in New Zealand., Accident Analysis & Prevention, 31(1) 91-99.	N	Study in other measures category
12.	Krol, B. (2009). Evaluation of the Polish "Drunk? Don't drive" campaign 2008. In S. Forward & A. Kazemi (Ed.), A theoretical approach to assess road safety campaigns. Evidence from seven European countries. Belgian Road Safety Institute, 2009.	Y	
13.	Van Lamoen, N. (2014). Evaluation of the "Safer Summer" road safety campaign. Final Report. Road Policing Support, Police National Headquarters, New Zealand.	N	Study in other measures category
14.	Linderholm, I. B. (2000). Drink and drive. Can media campaigns solve the problem? Paper presented at the proceedings of 2000 15 th Conference On Alcohol, Drugs and Traffic Safety, Stockholm, Sweden.	Y	
15.	Linkenbach, J. & Perkins, H. W. (2005). Montana's MOST of Us Don't Drink and Drive Campaign. Social Norms Strategy to Reduce Impaired Driving Among 21-to-34-Years-Olds. Final Report. DOT HS 809 869, Montana State University.	Y	
16.	Macpherson, T. & Lewis, T. (1998). New Zealand Drink-driving Statistics: The Effectiveness of Road Safety Television Advertising. Marketing Bulletin, 9, 40-51.	N	Reported effect already covered in Tay (1999)
17.	Nathanail, T. & Adamos, G. (2009). Evaluation of the Greek drink driving campaign. In S. Forward & A. Kazemi (Ed.), A theoretical approach to assess road safety campaigns. Evidence from seven European countries. Belgian Road Safety Institute, 2009.	Y	
18.	Nathanail, E. & Adamos, G. (2013). Road safety communication campaigns: Research designs and behavioral modeling. Transportation Research F, 18, 107-122.	N	Not relevant
19.	Royeck, C. (2000). Die Präventionsarbeit des Deutschen Verkehrssicherheitsrates e.V. und seiner Mitglieder zum Thema Alkohol, Drogen und Medikamente im Straßenverkehr. In H.-P. Krüger (Ed.), Drogen im Straßenverkehr - ein Problem unter europäischer Perspektive (310-316). Freiburg im Breisgau: Lambertus-Verlag.	N	Not relevant

20.	Tay, R. (1999). Effectiveness of the anti drink driving advertising campaign in New Zealand. <i>Road & Transport Research</i> , 8(4), 3-15.	Y	
21.	Tay, R. (2001). Methodological issues in evaluation models: The New Zealand road safety advertising campaign revisited. <i>Road & Transport Research</i> 10(2), 29ff.	N	Reported effect already covered in Tay (1999)
22.	Tay, R. (2002). Exploring the Effects of a Road Safety Advertising Campaign on the Perceptions and Intentions of the Target and Nontarget Audiences to Drink and Drive. <i>Traffic Injury Prevention</i> , 3, 195-200.	N	Reported effect already covered in Tay (1999)
23.	Watson, B. & Nielson, A. (2008). An evaluation of the 'Skipper' designated driver program: Preliminary results. In <i>High Risk Road Users Motivating Behaviour Change: what works and what doesn't work?</i> Australasian College of Road Safety Annual Conference. Brisbane, 18-19 September 2008, 14 S.	Y	
24.	Whittam, K., Dwyer, W. & Simpson, P. (2006). Effectiveness of a media campaign to reduce traffic crashes involving young drivers. <i>Journal of Applied Social Psychology</i> , 36, 614-628.	N	Studies to be considered in campaigns aggressive behaviour
25.	U.S. Department of Transportation (2007). Evaluation of the National Impaired Driving High-Visibility Enforcement. Report No. DOT HS 810 789.	N	No quantitative effects reported
26.	Ramirez, R, Nguyen, D., Cannon, C., Carmona, M. & Freisthler, B. (2008). A Campaign to Reduce Impaired Driving Through Retail-Oriented Enforcement in Washington State. Demonstration Project Report.	N	Not relevant

3.2 DESCRIPTION OF CODED STUDIES

Table 9 provides a description of the background characteristics of the coded studies that deal with campaigns and awareness raising on Driving Under the Influence (DUI).

Table 9: Information on sample and design of coded studies (sorted by author(s), meta-analyses first)

Author(s), year, country	Measure description	Evaluation design	Research conditions
Ditter et al., 2005, Australia/USA	Designated driver programmes with incentives in 2 countries (before 2003)	Meta-analysis of 7 studies	Change in average number of designated drivers
Phillips et.al, 2009, international	Road safety campaigns on DUI partly combined with enforcement activities in 14 countries	Meta-analysis of 19 studies	A weighted average was calculated from 105 effects.
Phillips et.al, 2011, international	Road safety campaigns on DUI partly combined with enforcement activities in 12 countries (1975-2007)	Meta-analysis of 27 studies	A weighted average was calculated.
Yadav & Kobayashi, 2015, USA/Australia	Mass media campaigns on reducing alcohol impaired driving and alcohol-related crashes, with or without enforcement efforts in the USA and Australia (2002-2013)	Meta-analysis of 7 studies	A pooled summary effect was calculated from studies containing alcohol-related injuries and fatalities.
Angle et al., 2009, UK	THINK "Eyes" publicity campaign (TV, online, radio DJs and posters) focused on 17-34 year old drivers to reduce drug-driving (2009)	Before-after interviews: Before=July 2009 After=September 2009	In-home interviews, used Computer Assisted Personal Interviews (n=1,991)
Angle et al., 2012, UK	THINK "Personal Consequences" publicity campaign with a special focus on young drivers (17/18-29 years) to reduce drink-driving (2012)	Before-after interviews: Before=July 2007 After=January 2012	In-home interviews, used Computer Assisted Personal Interviews n=2,031
Krol, 2009, Poland	Mass media "Drunk? Don't drive" campaign (TV spot local/national, poster advertising) combined with enforcement activities on drink-driving with a focus on young drivers – 20-30 years (2008)	Before-after questionnaire: Before=March 2008 After=2 weeks after campaign	Random sample of n=800 regular drivers
Linderholm, 2000, Sweden	TV programme in 3 parts (aired in December 1998) that focused on young people aged 16-25 to raise awareness of drink-driving	Before-after questionnaire: Before=November 1998 After=February 1999	Random sample of n=2,000 drivers
Linkenbach, 2005, USA	"MOST of us Don't drink and drive" campaign (TV, radio, newspaper, billboard, movie slide-advertisements) with focus on young drivers and passengers	Before-after interviews (CATI) with non-exposed reference area: Before=November 2001 After=June 2003	Random sample of n before=1,000 n after=517

Author(s), year, country	Measure description	Evaluation design	Research conditions
	aged 21-34 to reduce drink-driving (2002-2003)		
Nathanail & Adamos, 2009, Greece	Drink-driving campaign (brochures, posters, workshop) with focus on young drivers and passengers aged 18-30 (2008)	Before-after face to face interview: Before=2 weeks before campaign After=3 months after campaign	n before (test group)=66 n after (test group)=52
Tay, 1999, New Zealand	Drink-driving campaign (advertising) targeting drivers – combined with enforcement activities (October 1995)	Log-linear model (considering number of positive evidential breath tests, number of compulsory breath tests and advertising stock)	
Watson & Nielson, 2008, Australia	"Skipper", designated driver programme (supported by media and incentives) targeting drivers and passengers (July 2007)	Before-after questionnaire Before=3 weeks before programme After=4 months after implementation	n before=405 n after=410

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Awareness raising and campaigns – Speeding



Pilgerstorfer, M., Eichhorn, A., June 2017

1 Summary

1.1 COLOUR CODE

Light green (probably effective): Results show that anti-speeding campaigns can have significant positive effects on road safety (behaviour). However, some campaigns are combined with enforcement activities, while others do not indicate long-term effects or do not take other indirect effects, like changes in traffic, into account.

1.2 KEYWORDS

Speeding, inappropriate speed, campaign, evaluation, awareness raising, attitude, advertisement, speed choice

1.3 ABSTRACT

The main purpose of speeding campaigns is to raise awareness regarding speeding and inappropriate speed, that is speed not adapted to the prevailing traffic, road or weather conditions. Results provide some indication that speeding campaigns have a positive effect on road safety. A meta-analysis showed a significant 16% reduction in speeding. While one individual study reported a 30-45% decrease of fatalities and significant changes in attitudes and behaviour, some other studies did not find any significant changes either in actual behaviour, or in attitudes. Further, it should be noted that some analysed speeding campaigns were accompanied by enforcement activities. Therefore, it is not clear to what extent the effects are attributable to the campaign itself.

1.4 BACKGROUND

This synopsis focuses on the effectiveness of campaigns addressing speeding and inappropriate speed, specifically. For more detailed information on campaigns and awareness raising in general, please also see the synopsis "Effectiveness of road safety campaigns".

How is 'campaign' as a road safety measure defined?

The EU project CAST¹ provides the following definition of campaigns in the field of road safety: "Road safety communication campaigns can be defined as purposeful attempts to inform, persuade, or motivate people in view of changing their beliefs and/or behaviour in order to improve road safety as a whole or in a specific, well-defined large audience, typically within a given time period by means of organised communication activities involving specific media channels often combined with interpersonal support and/or supportive actions such as enforcement, education, legislation, enhancing personal commitment, rewards, etc." (Elliott, 1993; Rice & Atkin, 1994; Vaa et al., 2008, as cited in Delhomme et al., 2009).

How do awareness raising and campaigns against speeding affect road safety?

The effect of a campaign can be increased information, knowledge, raised awareness, changes of attitude and changed behaviour to the extent that eventually the frequency of accidents is reduced. However, since accident occurrence is multicausal and highly influenced by chance, there is rarely a direct link from a campaign to accident reduction. Many anti-speeding campaigns are combined with other activities like enforcement. Then it is difficult to attribute the effect to a single element of

¹ From 2006 to 2009, the EU Project CAST "Campaigns and Awareness-Raising Strategies in Traffic Safety" was carried out by 19 partners from 15 European countries. This project identified essential parameters of campaigns and effectiveness.

this combination. Campaigns can also be used to establish favourable preconditions in the public for new legislation.

When looking at campaigns as a single measure it has to be pointed out that multi-theme campaigns (addressing several risk factors) do not have any effect at all (Delhomme et al., 2009).

Campaigns addressing only speeding do have positive effects on:

- Attitudes to speeding and speed limits
- Speed choice/speed reduction/speeding
- Reduction of accidents and fatalities

Which factors influence the effect of anti-speeding campaigns on road safety and which are the modifying conditions?

Important factors for an effective campaign are clearly defined road safety problems and target groups, as well as a corresponding tailored message. Furthermore, it is necessary to use theoretical psychological models that explain the risk behaviour or safety problem (Delhomme et al., 2009). It is important to note that communication has to be based on the cultural codes used in the target community (national, regional, sub-groups etc.). Other influencing factors are the duration and intensity of a campaign. Other situational factors such as simultaneous competing events (e.g. tragic accident reported in media) or increased enforcement can also have an impact on the campaign effects.

How is the effect of campaigns against speeding and inappropriate speed measured?

The vast majority of studies in this field apply a before-after design to measure the campaign effect. Only a few studies give a comparison with a control group, as it is very difficult to find a suitable control group for nation-wide interventions. Accident statistics are seldom the means for evaluation in the studies of the present analysis.

The following measures are used in the studies to assess the effectiveness of anti-speeding campaigns:

- Observed behaviour such as mean speed on a defined street section or speed limit violations
- Behaviour and intended behaviour reported in questionnaires and interviews
- Attitudes, opinions, norms, knowledge, behavioural beliefs, risk perception reported in questionnaires and interviews
- Accident occurrence

1.5 OVERVIEW OF RESULTS ON SPEEDING CAMPAIGNS

The effectiveness of road safety campaigns can be measured by various means. The ultimate outcome measure is a reduction in crashes, which was used in one considered study. Watsford (2007) reported a 30-45% decrease of (especially speeding related and young driver speeding related) fatalities and significant changes in attitudes and behaviour.

A meta-analysis of 11 studies on campaigns against speeding (Phillips et al., 2009) indicated a significant reduction in speeding. According to weighted average effects, calculated after accounting for publication bias, speeding campaigns resulted in a significant 16% reduction in speeding (confidence level: 95%; Confidence Intervals (CI): -0.25 to -0.06).

A Canadian campaign evaluation (Islam & El-Basyouny, 2013) indicated that the implementation of several awareness raising activities combined with enforcement significantly reduced mean speed both in the short (5.8%) and long (4.5%) terms. Another evaluation study (van Schagen et al., 2016) reported a short-term change in speed on 30 km/h roads and a non-significant change in speeding behaviour on 50 km/h roads. Angle et al. (2009) found weak positive trends on some single items targeting attitudes towards speeding. However, most speeding related attitudes have not changed significantly.

Carey & Sarma (2016) found that a high threat message, when combined with high perceived efficacy, can lead to a decrease in speed choice, as well.

2 Scientific details

2.1 THEORETICAL BACKGROUND

Aim and methods of awareness raising measures and campaigns

The main purpose of awareness raising measures and communication campaigns are to encourage road users to engage in safe behaviour in traffic. The underlying concept of campaigns in road safety is social marketing which aims at influencing and changing social behaviours.

When developing a campaign, it is crucial to conduct a detailed analysis of the **road safety problem** and the **target group**. Furthermore, psychological theoretical models are very helpful in the development of the campaign message to increase the effectiveness (Robertson & Pashley, 2015). A description of these models – such as the Theory of planned behaviour – can be found in Theofilatos et al. (2017).

Besides developing the message, the **campaign strategy** has to be defined. Campaigns may use an information approach or emotions, especially fear, to draw the target audience's attention to the message. There are still controversial discussions regarding the effectiveness of fear-based messages (see e.g. Castillo-Manzano et al., 2012).

To evaluate whether or not the message of the campaign can influence the behaviour of the target group as intended, a **pretest of message** and slogan should be conducted (Delhomme et al., 2009; Hoekstra & Wegman, 2011).

For road safety campaigns the following **type of media** is generally used: television, radio, newspaper/magazines, cinema, web/online, social media, billboards, flyers/leaflets/posters, message signs and events involving face to face communication. An overview of advantages and disadvantages of different types of media for road safety campaigns can be found in Delhomme et al. (2009).

Campaign effects and influencing factors

Awareness raising activities and campaigns can positively influence a number of road safety relevant constructs, such as favourable attitudes, knowledge and perceptions as well as safe behaviour and therefore also accident rates. However, there are various factors to be considered to maximise impact. According to Phillips et al. (2011) the following factors of campaigns are associated with accident reduction:

- Personal communication
- Road side delivery (billboards, message signs)
- Drink-driving theme
- Combination with enforcement
- Short campaign duration (0-29 days)

Limitations of campaigns and challenges of evaluation

In the past, evaluations of campaigns were rarely carried out for various reasons. For one, there is sometimes a lack of awareness of the benefit of evaluating, or there may be budget and time constraints. Uncertainties in terms of methodological application are also a barrier.

As previously described, the effectiveness of road safety campaigns can be measured by various means. The most important **outcome measure** is a reduction in crashes. It is difficult though, to link an accident reduction to a campaign while controlling for all other possible contributing factors. The defined outcome measures to account for campaign effects are therefore often 'indirect', like intended behaviour or attitudes etc. Even though there is evidence concerning the influence of these constructs on actual behaviour, there are always other additional determining factors (e.g. situational factors) that cannot be accounted for.

A before-after-design ideally includes a **meaningful reference group** to control for confounding factors (e.g. a similar geographical region without exposure to the contents of the campaign), which is however rarely the case.

Next to a lack of (systematical and valid) evaluation of effects, campaigns are often **combined or conducted simultaneously** with enforcement measures and implementation of new legislation. If an effect (improvement) is measured then, it remains unclear to which of the single components it is attributable, and to what extent. Furthermore, even though research indicates in general a positive effect of an additional enforcement strategy on road safety, this might not be the case for specific topics such as speeding (Hoekstra & Wegmann, 2012).

2.2 CODED STUDIES

The literature search was carried out in three databases (Scopus, TRID and a KfV-internal literature database) with separate search strategies (for a detailed description see "Supporting documents"). Additionally, a free web-based search was conducted via Google.

Below first information on the characteristics of coded studies is given, and subsequently the main research methods used for evaluating campaigns and awareness raising measures against speeding are provided.

Description of studies

Table 1 provides further description of the background characteristics of the coded studies that deal with campaigns and awareness raising against speeding (sorted by author(s), meta-analysis first).

Table 1. Information on sample and design of coded studies (sorted by author(s), meta-analyses first)

Author(s), year, country	Measure description	Evaluation design	Research conditions
Phillips, , et al., 2009, international	Meta-analysis. 11 studies were evaluated concerning the impact of speeding campaigns (69 effects on speeding)		
Angle, et al., 2009, UK	Before/after questionnaire on attitudes and behaviour	Car drivers 15+	1,994 interviews; 1,308 with drivers; data were weighted to be representative
Carey, & Sarma., 2016, Ireland	4-group (threat+efficacy, threat only, neutral, control) experimental design (before/after) using video based speed tasks; questionnaire	Mostly University students aged 18-24 years	62 male participants
Islam, & El-Basyouny, 2013, Canada	Before/after experimental design; speed and traffic data were collected on a 24/7 basis for a period of 55 days at 12 locations (7 test and 5 comparison sites)	Drivers	> 9,000 vehicles measured
Van Schagen, et al., 2016, Netherlands	Before/during design; speed data were collected on a 24/7 basis for a period of 55 days for 16 weeks at 20 locations (10 with/without posters)	Drivers	> 10 million vehicles measured
Watsford, 2008, Australia	Before/after comparison of road fatalities statistics; questionnaire survey on attitudes and behaviour	Novice drivers aged 17-25 years	

Description of the main research methods

In order to evaluate the effectiveness of speeding campaigns before-after designs are used. There are two main approaches: mostly, questionnaires are used for assessing changes in attitudes, opinions and self-reported behaviour. With analysing speed data, changes in the actual speeding behaviour can be observed. Only few studies consider accident/fatality statistics.

For the majority, it is not clear from the evaluation studies whether or not a theoretical psychological model was the basis for designing the respective campaigns. Experimental designs are rarely used, as they assess only short-term effects of specific campaign elements (video, poster, radio spot etc.).

Young (male) drivers are considered as the main risk group for speeding. Therefore, many campaigns (and evaluations) focus on young and novice car drivers.

2.3 OVERVIEW OF RESULTS

The following table presents information on the main outcomes of coded studies on anti-speeding campaigns.

Table 2: Summary of coded study results regarding speeding awareness raising and campaigns (sorted by author(s), meta-analysis first)

Author, Year, Country	Exposure variable	Outcome variable	Effects on Road Safety		Main outcome description
Phillips, et al., 2009, international	Road safety campaigns	Speeding	↗	Weighted average effect= -0.16, CL:95%, CI: -0.25- -0.06	There is a significant percent change in speeding.
Angle, H., et al., 2009, UK	"THINK!" campaign	Acceptance of speed limits	–	Percent change=0.04	Most attitudes regarding speed limits have not changed significantly. There is only a weak positive trend on one item: "There is always a good reason for a 30mph limit".
		Personal responsibility	–	Percent change=0.05	Most attitudes regarding personal responsibility have not changed significantly. There is only a weak positive trend on one item: "The driver is always at least partly to blame if they knock over a pedestrian".
		Personal responsibility	–	Percent change=0.02	Most attitudes regarding personal responsibility have not changed significantly. There is only a weak positive trend on one item: "If I were to speed I could do something I'd regret for the rest of my life".
		Behavioural control	–	Percent change=0.04	Most attitudes regarding perceived behaviour control have not changed significantly. There is only a weak positive trend on one item: "Someone who drives at 35mph in a 30mph area is driving dangerously".
Carey, R.N. & Sarma, K.M., 2016, Ireland	Advertisement – experimental setting	Speed choice	↗	Absolute difference=-3,286.92 ms	The threat+efficacy group showed a significant change in speed (responding appr. 3 sec. earlier than at baseline)
	Advertisement – experimental setting	Speed choice	↗	Relative difference	The threat+efficacy group changed their speed significantly more than the neutral group.
	Advertisement – experimental setting	Speed choice	↗	Relative difference	The threat+efficacy group changed their speed significantly more than the control group.

Author, Year, Country	Exposure variable	Outcome variable	Effects on Road Safety		Main outcome description
	Advertisement – experimental setting	Speed choice	–	Relative difference	There is no significant difference of change in speed choice between the threat and efficacy group and the threat only group.
Islam, M.T. & El-Basyouny, K., 2013, Canada	Speed management plan - local	Speed choice (overall)	↗	Absolute difference=-2.26 km/h CL:95%	There is a significant overall reduction of mean speed of 2.26 km/h (4.5%).
	Speed management plan - local	Speed choice (day/weekday)	↗	Absolute difference=-2.06 km/h CL:95%	There is a significant reduction of mean speed day/weekday of 2.06 km/h.
	Speed management plan - local	Speed choice (day/weekend)	↗	Absolute difference=-2.25 km/h CL:95%	There is a significant reduction of mean speed day/weekend of 2.25 km/h.
	Speed management plan - local	Speed choice (night/weekday)	↗	Absolute difference=-2.86 km/h CL:95%	There is a significant reduction of mean speed night/weekday of 2.86 km/h.
	Speed management plan - local	Speed choice (night/weekend)	↗	Absolute difference=-3.49 km/h CL:95%	There is a significant reduction of mean speed night/weekend of 3.49 km/h.
Van Schagen, et al., 2016, Netherlands	Anti-speeding campaign - nationwide	Speed choice (30 km/h locations)	↗	Absolute difference	Significant decrease in average speed and speed limit violations between Phase 0 and Phase 1 on 30 km/h locations.
		Speed choice (50 km/h locations)	–	Absolute difference	No significant change in average speed and speed limit violations between P0 and P1 on 50 km/h locations.
	Poster to remind speed limit	Speed choice	–		There were no significant differences in average speed and speed limit violations between areas with and without posters.
	Anti-speeding campaign	Speed choice	–	Absolute difference	There were no significant long term (P5) effects of the campaign.
Watsford, R., 2008, Australia	Speeding campaign "No one thinks big of you" - regional	Speeding fatalities	↗	Percent accident reduction=0.32	In the campaign region speed related fatalities have decreased significantly after the campaign.
		Speeding young drivers fatalities	↗	Percent accident reduction=0.45	In the campaign region young driver speed related fatalities have decreased significantly after the campaign.
		Attitude	↗	Percent change=0.14	Young males who said "drivers are less likely to speed if they have their friends in the car" increased (from 2% to 16%).
		Behaviour	↗	Percent change=-0.15	Fewer young males reported that they have recently been in a car that has driven over the speed limit (from 84% to 69%).

* Effects on road safety are coded as: positive (↗), negative (↘), non-significant (–) or no test for significance reported (∅)

Meta-analysis results

A meta-analysis of 11 studies on campaigns against speeding (Phillips et al, 2009) indicated a significant reduction in speeding. According to weighted average effects, calculated after accounting for publication bias, speeding campaigns resulted in a significant 16% reduction in speeding (Confidence level: 95%; CI:-0.25 to -0.06). However, no differentiation was made between studies reporting on campaigns with and without combined enforcement strategy. Thus, it remains unclear what the effects of single vs. combined measures are.

Additional studies on speeding campaigns

The evaluation of the British "THINK!"² speeding campaign ("Live with it"; Angle et al., 2009) focused on **attitudes**. Most speeding related attitudes have not changed significantly. Nonetheless, weak positive trends on some items targeting attitudes towards speeding have been identified (acceptance of 30 mph speed limit; driver's responsibility and behavioural control). The evaluation of another campaign (No one thinks big of you; Watsford, 2007) showed significant changes in attitudes and behaviour (compliance with speed limits).

Regarding **speed choice** findings from a Canadian campaign evaluation indicated that the implementation of several awareness raising activities combined with enforcement significantly reduced speed both in the short and long terms. Overall, the short term mean speed reduction was 2.94 km/h, which is equivalent to a 5.8% reduction. In the long term, the overall reduction of mean speed was 2.26 km/h, which is equivalent to a 4.5% reduction (Islam & El-Basyouny, 2013).

However, van Schagen et al. (2016) indicated that a Dutch campaign did not influence speed and speeding behaviour on 50 km/h roads. They found an effect of a local speed limit reminder on speed choice on 30 km/h roads, but this effect was temporary and had disappeared within a week.

Carey & Sarma (2016) found, that a high threat message, when combined with high perceived efficacy, can lead to a decrease in speed choice, as well.

With respect to **fatalities** Watsford (2007) reported a 30-45% decrease (especially speeding related and young driver speeding related) attributed to the 'No one thinks big of you' campaign.

Modifying conditions

Phillips et al. (2009) outlined conclusions on a meta-regression by Vaa et al. (2004). They found the following factors to be beneficially influencing campaign outcomes:

- Personal communication
- Road side delivery
- Combination with enforcement
- Short campaign duration

2.4 CONCLUSION

General

The considered evaluated campaigns put emphasis on speeding and rarely on inappropriate speed. However, the evaluation studies often discuss speed choice in general.

Main results

Results provide some indications that anti-speeding campaigns can have significant positive effects on road safety.

A meta-analysis of 11 studies (Phillips et al., 2009) reported a significant 16% reduction in speeding and Islam & El-Basyouny (2013) as well found an overall long-term reduction of mean speed (4.5%). Furthermore, Watsford (2007) reported a 30-45% decrease of (especially speeding related and young driver speeding related) fatalities and significant changes in attitudes and behaviour.

² "Think!" is the name for a bundle of road safety campaigns in the UK which address various risk behaviours and road user groups.

However, some studies did not find any significant changes either in actual behaviour, or in attitudes (Angle et al., 2009; van Schagen et al., 2016).

Biases and transferability

It is difficult to link changes in accidents solely to a campaign. The defined outcome measures to account for campaign effects are therefore often 'indirect' like self-reported data on behaviour or attitudes. Even though there is evidence concerning the influence of these constructs on actual behaviour, there are also always other determining factors that cannot be accounted for. Indirect effects, such as changes in traffic composition, traffic density or seasonal conditions, may affect speeding behaviour. Furthermore, enforcement activities may influence speeding as well. When campaigns are combined with law enforcement, as evaluated by Islam & El-Basyouny (2013), it is not clear to what extent the effects are attributable to the single measures.

To control for confounding factors ideally a meaningful reference group is included, which is however rarely possible for national campaigns.

All individual campaigns (exposure) were heterogeneous regarding design (exact target group, period, media etc.). Regarding transferability from a speeding campaign and campaign design to another country, cultural codes should be considered. A detailed analysis of the speeding behaviour on the country level helps to identify the target group(s) for intervention.

3 Supporting documents

3.1 LITERATURE SEARCH STRATEGY

The literature search was conducted in November and December 2016. It was carried out in three databases with separate search strategies. The first one was performed in 'Scopus' which is a large abstract and citation database of peer-reviewed literature. The second literature search was conducted in a KfV-internal literature database ('DOK-DAT'), and the third in the integrated TRID database. Additionally, a complementary free internet search was conducted via Google.

Database: Scopus **Date:** 2nd of December 2016

Search No.	Search terms, logical operators, combined queries	Hits
#1	"Campaign" OR "awareness" OR "public information"	248,963
#2	"Speed*" OR "inappropriate speed" OR "appropriate speed" OR "adapted speed" OR "inadapted speed" OR "fast driving" OR "velocity"	1,027,124
#3	"road safety" OR "traffic safety"	12.033
#4	#1 AND #2 AND #3	135
#5	Limit to Europe, Russia, USA, Canada, Australia and New Zealand	81

Table 3: Used search terms, logical operators, and combined queries of literature search (Scopus).

Detailed search terms, as well as their linkage with logical operators and combined queries are shown in Table 3. Using search field titles, abstract and keywords (TITLE-ABS-KEY) and a general limitation to studies which were published from 2006 to current led to 135 studies. Results were further limited to studies from Europe, Russia, USA, Canada, Australia and New Zealand. This led to a final sample of 81 studies of literature search in database Scopus (Table 3).

Database: DOK-DAT **Date:** 7th of December 2016

Search no.	Search terms, operators, combined queries	Hits
#1	"Werbung" (advertisement) AND "Sicherheit" (safety)	467
#2 (within #1)	"Wirksamkeit*" (effectiveness) OR "Evalu*" (evaluation) OR "Bewertung*" (assessment)	278

Table 4: Used search terms, logical operators, and combined queries of literature search (DOK-DAT).

German search fields 'Titel', 'ITRD Schlagworte' and 'freie Schlagworte' were used. Hits were only limited to the years 1990 to 2016 and got 278 more potential studies (Table 4).

Database: TRID database **Date:** 20th of December 2016

Search no.	Search terms, operators, combined queries	Hits
#1	"safety" AND "campaign" AND "evaluation"	240

Table 5: Used search terms, logical operators, and combined queries of literature search (TRID).

Search terms were "safety", "campaigns" and "evaluation". Hits were limited to the years 2000 to 2016 and got 240 potential studies. After limitation to "speeding", 7 studies remained (Table 5).

The literature search strategy, querying three databases, did not result in a sufficient number of evaluated awareness raising measures. Based on the expertise of the consortium, it became evident that some evaluation studies are not published in scientific journals (grey literature, conference papers etc.). Therefore, it was decided to complement the results with a non-standardised, free search with the internet search engine Google. In a first step, relevant road safety campaigns were

identified. In a second step, the aim was to find according evaluation papers of these campaigns. The following search terms were used in different combinations: campaign, evaluation, effectiveness, awareness raising, speed, speeding, speed limit. The unstandardised search resulted in further 15 studies.

Results Literature Search

Database	Hits
Scopus (remaining papers after several limitations/exclusions)	81
DOK-DAT	278
TRID database	240
Unstandardised Search via Google & recommended literature	15
Total number of studies to screen title/ abstract	614

Table 6: Results of databases and free search after limitations

All in all, this literature search led to 614 potential studies for screening.

Screening

Total number of studies to screen title/ abstract	614
De-duplication	1
Exclusion criteria: not or other topic, no evaluation	587
Studies to obtain full-texts	26

Table 7: Screening of abstracts

After screening the titles and abstracts 26 studies remained for screening the full-text.

Total number of studies to screen full-text	26
Full-text could be obtained	25
Reference list examined Yes/No	Y
Eligible papers	25

Table 8: Papers obtained for full-text screening

Screening of the full texts

Total number of studies to screen full paper	25
Other topic (e.g. enforcement, unsafe behaviour) - excluded	7
Data used in more recent study - excluded	1
Studies with no codable data - excluded	4
Studies without before-after measurement - excluded	4
Studies with other focus - excluded	2
Studies not available in English - excluded	2
Remaining studies	5
Speeding effects coded within "campaigns general" (meta-analysis)	1

Table 9: Screening of full texts

Prioritising Coding

- Prioritising Step A (meta-analysis first)
- Prioritising Step B (best fitting in coding scheme, in particular quantitative data)

- Prioritising Step C (published more recently)
- Prioritising Step D (Central-European countries before others)

Studies are presented in the following table sorted by authors' name; meta-analysis is mentioned first.

No.	Publication	Coded Yes/No	Reason
1.	Phillips, R., Ulleberg, P. & Vaa, T. (2009). Do road safety campaigns work? A meta-analysis of road safety campaign effects. In: Forward, S. & Kazemi, A. 2009. A theoretical approach to assess road safety campaigns. Evidence from seven European countries. 25-45.	Y	Meta-Analysis
2.	Angle, H., Greggs, J. & Goddard, E. (2009). THINK! Road Safety Campaign Evaluation Post Stage: 'Live With It' speed campaign and Motorcycle campaign. BMRB Report 2009.	Y	
3.	Australian Office of Road Safety (2013). Speeding Enforcement (Post-It Notes) Campaign Evaluation – Summary Report. https://rsc.wa.gov.au/RSC/media/Documents/Road%20Data/Research%20and%20Reviews/Campaign%20Evaluations/speeding-post-it-campaign-research-2013.pdf	N	No before-after measurement
4.	Carey, R.N. & Sarma, K.M. (2016). Threat appeals in health communication: messages that elicit fear and enhance perceived efficacy positively impact on young male drivers. BMC Public Health (2016) 16:645.	Y	
5.	Delaney, A., Lough, B, Whelan, M. & Cameron, M. (2004). A Review Of Mass Media Campaigns in Road Safety. Monas University Accident Research Centre. Report No. 220.	N	Other topic (general)
6.	D'Elia, A., Newstead, S. & Cameron, M. (2007). Overall Impact During 2001-2004 of Victorian Speed-Related Package. Monash University Accident Research Centre. Report No. 267.	N	Other topic (enforcement)
7.	Elvik, R. (2014). Evaluating the Effectiveness of Norway's "Speak Out!" Road Safety Campaign: The Logic of Causal Inference in Road Safety Evaluation Studies. Journal of the Transportation Research Board, 1717.	N	Other topic (unsafe behaviour)
8.	Friswell, R., Williamson, A., Allsopp, G., Gavin, A. & Bryant, P. (2008). Impact of a direct mail safety campaign for motorcyclists. 2008 Australasian Road Safety Research, Policing and Education Conference, Adelaide, South Australia.	N	Other topic (safe ride lines)
9.	Guria, J. (1999). An economic evaluation of incremental resources to road safety programmes in New Zealand., Accident Analysis and Prevention Vol.31 No.1/2, 91-99.	N	Main focus is not on campaigns & speeding
10.	Islam, M.T. & El-Basyouny, K. (2013). An integrated speed management plan to reduce vehicle speeds in residential areas: Implementation and evaluation of the Silverberry Action Plan. <i>Journal of Safety Research</i> , 45, 85-93.	Y	
11.	Kaye, S., Lewis, I., Algie, J. & White, M. J. (2016). Young drivers' responses to antispeeding advertisements: Comparison of self-report and objective measures of persuasive processing and outcomes. <i>Traffic Injury Prevention</i> , 17 (4), 352-358.	N	No before-after measurement
12.	Klimmt, C., Maurer, M. & Baumann, E. (2014). Prozessevaluation der Kampagnenfortsetzung 2011-2012 "Runter vom Gas". <i>Berichte der</i>	N	No before-after measurement

No.	Publication	Coded Yes/No	Reason
	Bundesanstalt für Straßenwesen, Mensch und Sicherheit Heft M 246, Bergisch Gladbach.		
13.	Klimmt, C. & Maurer, M. (2012). Evaluation der bundesweiten Verkehrssicherheitskampagne "Runter vom Gas". Berichte der Bundesanstalt für Straßenwesen, Mensch und Sicherheit Heft M 223, Bergisch Gladbach.	N	No before-after measurement
14.	Phillips, R. O. & Sagberg, F. (2013). Evaluation of the Norwegian Anti-speeding Campaign 'Which Side of the Speed Limit Are You On'. TØI Report.	N	Not available in English
15.	Phillips, R. & Torquato, R. (2009). A review of 45 anti-speeding campaigns. TOI report 1003/2009.	N	Only review, no codable meta-analysis effects. Available studies contained will be coded separately.
16.	Plant, B.R.C., Reza, F. & Irwin, J.D. (2011). A systematic review of how anti-speeding advertisements are evaluated. Journal of the Australasian College of Road Safety Vol. 22 No.4, S. 18-26.	N	No codable data
17.	Rundmo, T. & Iversen, H. (2004). Risk perception and driving behaviour among adolescents in two Norwegian counties before and after a traffic safety campaign, Safety Science 42, 1–21	N	Other topic (unsafe behaviour)
18.	Stead, M. & Eadie, D. (2007). Evaluation of Foolsspeed Campaign. Final Phase Report. Scottish Executive Social Research.	N	No codable data
19.	Stead, M., MacKintosh, A. M., Tagg, S. & Eadie, D. (2002). Changing speeding behaviour in Scotland, an evaluation of the "Foolsspeed" Campaign. Scottish Executive Central Research.	N	Same data as in Stead, 2005 (already coded in Phillips, meta-analysis)
20.	Tay, R. (2005). The effectiveness of enforcement and publicity campaigns on serious crashes involving young male drivers: Are drink driving and speeding similar? Accident Analysis & Prevention 37 (2005) 922-929.	N	Main focus is not on campaigns & speeding
21.	Van Lamoen, N. (2014). Evaluation of the "Safer Summer" Road Safety Campaign. Final report. Road Policing Support, Police National Headquarters, New Zealand Police.	N	Other topic (enforcement)
22.	Van Schagen, I., Commandeur, J.J.F., Goldenbeld, C. & Stipdonk, H. (2016). Monitoring speed before and during a speed publicity campaign. Accident Analysis and Prevention (article in preparation).	Y	
23.	Wandtner, B. (2016). Die Wirkung von Verkehrssicherheitsbotschaften im Fahrsimulator - eine Machbarkeitsstudie., Berichte der Bundesanstalt für Straßenwesen, Mensch und Sicherheit Heft M 266, Bergisch Gladbach, 37 S.	N	No campaign evaluation (no codable data)
24.	Watsford, R. (2008). The success of the 'Pinkie' campaign - Speeding. No one thinks big of you: A new approach to road safety marketing. 2008 Joint ACRS-Trafelsafe National Conference.	Y	
25.	Whittam, K.P., William O. Dwyer, Patricia W. Simpson, Frank C. Leeming (2006). Effectiveness of a Media Campaign to Reduce Traffic Crashes Involving Young Drivers. Journal of Applied Social Psychology, 36(3), 614-628. DOI: 10.1111/j.0021-9029.2006.00021.x	N	Other topic (unsafe behaviour)

No.	Publication	Coded Yes/No	Reason
26.	Wittink, R.D., Levelt, P.B.M. (1994). Influencing Speeding through Information Campaigns. SWOV, Leidschendam.	N	Not available in English

3.2 REFERENCES

Meta-analysis

Phillips, R., Ulleberg, P. & Vaa, T. (2009). Do road safety campaigns work? A meta-analysis of road safety campaign effects. In: Forward, S. & Kazemi, A. 2009. *A theoretical approach to assess road safety campaigns. Evidence from seven European countries*, 25-45.

List of studies included in Phillips et al., 2009

Anund, A. (1996). Zon-96. Accessed via CAST partner Per Henriksson using structured questionnaire.

Marosi, K. & Nielsen, H.S. (1997). 10 = 44. Evaluering af en hastighedskampagne fra forsommeren 1997. Rådet for Større Færdselssikkerhed & De lokale Færdselssikkerhedsudvalg.

Olsson Lokalt hastighetsprojekt på Nynäsvägen (2003). Utvärdering av kampanjaktiviteter, attityd och beteenden, Våren. Accessed via CAST partner Per Henriksson using structured questionnaire.

Rooijers, T. (1988). Effects of different public information techniques in reducing driving speed. In Anonymous, Road User Behaviour: Theory and Practice, Second International Conference of Road Safety, Groningen, The Netherlands, August 1987.

Samdahl, D.R. & Daff, M.R. (1986). Effectiveness of a neighbourhood road safety campaign, 13th Proceedings of the Australian Road Research Board, 25-45.

Statens trafiksäkerhetsverk Vilt och trafik (1978). Undersökning av kampanjeffekter. Accessed via CAST partner Per Henriksson using structured questionnaire.

Stead, M., Tagg, S., MacKintosh, A.M. & Eadie, D. (2005). Development and evaluation of a mass media Theory of Planned Behaviour intervention to reduce speeding, *Health Education Research* 20, 36-50.

Stuster, J.W. (1995). Experimental evaluation of municipal speed enforcement program.

Thompson, C. (1998). Results from the development and evaluation of the 1998 speed mass media community education campaign for Western Australia, Office of Road Safety, Transport Western Australia, 84-87.

Van Houten, R. & Nau, P.A. (1983). Feedback interventions and driving speed: a parametric and comparative analysis, *Journal of Applied Behavior Analysis*, 16, 253-281.

Webster, K., & Schnerring, F. (1987). An evaluation of 40 Km/h speed limits. Forum Papers, Australian Transport Research Forum, 807-827. Queensland Department of Transport.

List of additional coded studies

- Angle, H., Greggs, J. & Goddard, E. (2009). THINK! Road Safety Campaign Evaluation Post Stage: 'Live With It' speed campaign and Motorcycle campaign. BMRB Report 2009.
- Carey, R.N. & Sarma, K.M. (2016). Threat appeals in health communication: messages that elicit fear and enhance perceived efficacy positively impact on young male drivers. *BMC Public Health*, 16, 645.
- Islam, M.T. & El-Basyouny, K. (2013). An integrated speed management plan to reduce vehicle speeds in residential areas: Implementation and evaluation of the Silverberry Action Plan. *Journal of Safety Research*, 45, 85-93.
- Van Schagen, I., Commandeur, J.J.F., Goldenbeld, C. & Stipdonk, H. (2016). Monitoring speed before and during a speed publicity campaign. *Accident Analysis and Prevention* (article in preparation).
- Watsford, R. (2008). The success of the 'Pinkie' campaign - Speeding. No one thinks big of you: A new approach to road safety marketing. 2008 Joint ACRS-Trafelsafe National Conference.

References on further background information (sorted by authors)

- Castillo-Manzano, J., Castro-Nuno, M. & Pedregal, D. (2012): How many lives can bloody and shocking road safety advertising save? *Transportation Research Part F* 15 (2012), 174-187.
- Delhomme, P., De Dobbeleer, W., Forward, S. & Simoes, A. (2009). Manual for Designing, Implementing, and Evaluating Road Safety Communication Campaigns. EU-Project CAST. Belgium 2009.
- Hoekstra, T. & Wegmann, F. (2012). Improving the effectiveness of road safety campaigns: Current and new practices. *IATSS Research* 34, 80-86.
- Phillips, R.; Ulleberg, P. and Vaa, T. (2011): Meta-analysis of the effect of road safety campaigns on accidents. *Accident Analysis and Prevention* 43 (2011) 1204-1218.
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- Vaa T., Assum, T., Ulleberg, P. & Veisten, K. (2004). Effekter av informasjonskampanjer på atferd og trafikkulykker - forutsetninger, evaluering og kostnadseffektivitet. TØI Rapport. 727/2004 Institute of Transport Economics. Oslo.

Awareness raising and campaigns – Aggressive and Inconsiderate Behaviour



Eichhorn, A., Kaiser, S., June 2017

1 Summary

1.1 COLOUR CODE

Light green (probably effective)

There is some indication that campaigns addressing aggressive, unsafe or inconsiderate behaviour in road traffic have a positive impact on accident occurrence and self-reported (un)safe and (in)considerate behaviour.

1.2 KEY WORDS

Road safety campaign; traffic safety campaign; evaluation study; adolescents; young; car passengers; unsafe driving; reckless driving, inconsiderate behaviour; aggressive driving; truck safety; better driver campaign

1.3 ABSTRACT

The main purpose of campaigns addressing aggressive, unsafe or inconsiderate behaviour in road traffic is to raise awareness as well as to promote considerate behaviour towards all other road users.

Results provide some indications that campaigns targeting aggressive or inconsiderate behaviour can have positive effects on road safety. Some studies indicate an association with the number of killed and injured car passengers, non-fatal and severe injuries or at fault accidents. However, campaign evaluations with indirect outcome measures showed rather mixed results (significant reduction in speeding, non-significant change in unsafe behaviour and rule violations).

Furthermore, it should be noted that the studies considered are quite different regarding the exposure variable(s) (different aims and resources of campaigns) and outcome measures and have at least minor limitations: combining a campaign with other road safety measures is often seen and a detailed documentation of evaluation methods is missing in some cases.

1.4 BACKGROUND

This synopsis focuses on the effectiveness of campaigns addressing aggressive, unsafe or inconsiderate behaviour of different types of road users. For more details on campaigns and raising awareness raising, please also see the synopsis "Effectiveness of road safety campaigns".

How is 'campaign' as a road safety measure defined?

The EU project CAST¹ provides the following definition of campaigns in the field of road safety: "Road safety communication campaigns can be defined as purposeful attempts to inform, persuade, or motivate people in view of changing their beliefs and/or behaviour in order to improve road safety as a whole or in a specific, well-defined large audience, typically within a given time period by means of organised communication activities involving specific media channels often combined with interpersonal support and/or supportive actions such as enforcement, education, legislation, enhancing personal commitment, rewards, etc." (Elliott, 1993; Rice & Atkin, 1994; Vaa et al., 2008, as cited in Delhomme et al., 2009, p. 16).

¹ From 2006 to 2009, the EU Project CAST "Campaigns and Awareness-Raising Strategies in Traffic Safety" was carried through by 19 partners from 15 European countries. This project identified essential parameters of campaigns and effectiveness.

How do awareness raising and campaigns affect road safety?

The effect of a campaign can be increased information, knowledge, raised awareness, changed attitude, and changed behaviour to the extent that eventually the frequency of accidents is reduced. However, since accident occurrence is multicausal and highly influenced by chance, there is rarely a direct link from a campaign to accident reduction. Many campaigns are combined with enforcement and new legislation. It is difficult to attribute the effect to a single element of this combination. Campaigns can also be used to establish favourable preconditions in the public for new legislation.

Which factors influence the effect of a campaign on road safety and which are the modifying conditions?

Important factors for an effective campaign are clearly defined road safety problems and target groups, as well as a corresponding tailored message. Furthermore, it is necessary to use theoretical psychological models that explain the risk behaviour or safety problem (Delhomme et al., 2009). It is important to note that communication has to be based on the cultural codes used in the target community (national, regional, sub-groups etc.). Other influencing factors are the duration and intensity of a campaign. Also, other situational factors such as simultaneous competing events (e.g. tragic accident reported in media) can have an impact on the campaign effects.

How is the effect of campaigns tackling aggressive and inconsiderate behaviour measured?

The following measures are used to assess the effectiveness of campaigns tackling aggression in traffic:

- Accident occurrence (all, fatal, non-fatal, severe injuries)
- Self-reported behaviours and observations

The vast majority of studies in this field apply a before-after design to measure the campaign effect.

1.5 OVERVIEW OF RESULTS

Concerning campaigns on aggressive or unsafe driving behaviour, three evaluation studies report significant reductions on different levels: number of killed and injured car passengers aged 16 to 19 years (Elvik, 2000); non-fatal and severe injuries (Zampetti et al., 2012); at fault accidents (Whittam et al., 2006). However, a fourth study did not find a significant decrease in overall or speeding accidents (Rundmo et al., 2004).

Self-reported unsafe or inconsiderate behaviour was evaluated in two further studies with inconsistent results. A significant decrease for speeding was reported, while self-reported unsafe behaviour and rule violations were not significantly reduced (Rundmo et al., 2004). After an aggressive driving campaign in the US, truck and car drivers felt less exposed to other aggressive drivers. On a more objective level however, measured headway time was not significantly reduced (Lin et al., 2009).

Evaluation results after a campaign to increase visibility and awareness of powered two-wheelers show increases in motorists paying attention to this road user group (no information on significances).

As aggressive or unsafe driving behaviour comprises different concrete behaviours like speeding, tailgating, non-yielding to other road users, the campaigns, and consequently the considered studies, were quite different regarding exposure (different aims and means of campaigns) and outcome measures. All included studies had at least minor limitations: some of the evaluated campaigns were accompanied by enforcement activities or the studies' lack of reported methodological details. While some studies measured long term effects, they did not account for confounding factors such as law changes, traffic indicators or seasonal differences.

2 Scientific details

2.1 THEORETICAL BACKGROUND

Aim and methods of awareness raising measures and campaigns

The main purpose of awareness raising measures and communication campaigns is to encourage road users to engage in safe and considerate behaviour in traffic. The underlying concept of campaigns in road safety is social marketing which aims at influencing and changing social behaviours.

When developing a campaign, it is crucial to conduct a detailed analysis of the **road safety problem** and the **target group**. Furthermore, psychological theoretical models are very helpful in the development of the campaign message to increase the effectiveness (Robertson & Pashly, 2015). A description of these models – such as the Theory of Planned Behaviour (TPB) – can be found in Theofilatos et al. (2017).

Besides developing the message, the **campaign strategy** has to be defined. Campaigns may use an information approach or be emotive, especially using fear to draw the attention of the target audience to the message. There are still controversial discussions regarding the effectiveness of fear-based messages (see e.g. Castillo-Manzano et al., 2012).

To evaluate whether or not the message of the campaign can influence the behaviour of the target group as intended, a **pre-test of message** and slogan should be conducted (Delhomme et al., 2009; Hoekstra & Wegman, 2011).

For road safety campaigns the following **type of media** is generally used: television, radio, newspaper/magazines, cinema, web/online, social media, billboards, flyers/leaflets/posters, message signs and events involving face to face communication. An overview of advantages and disadvantages of different types of media for road safety campaigns can be found in Delhomme et al. (2009).

Campaign effects and influencing factors

Awareness raising activities and campaigns can positively influence a number of road safety relevant constructs, such as favourable attitudes, knowledge and perceptions as well as safe behaviour and therefore also accident rates. However, there are various factors to be considered to maximise impact. According to Phillips et al. (2011) the following factors of campaigns are associated with accident reduction:

- Personal communication
- Road side delivery (billboards, message signs)
- Drink-driving theme
- Combination with enforcement
- Short campaign duration (0-29 days)

Limitations of campaigns and challenges of evaluation

In the past, evaluations of campaigns were rarely carried out for various reasons. For one, there is sometimes a lack of awareness of the benefit of evaluating, or there may be budget and time constraints. Uncertainties in terms of methodological application are also a barrier.

As previously described, the effectiveness of road safety campaigns can be measured by various means. The most important **outcome measure** is a reduction in crashes. It is difficult though, to link an accident reduction to a campaign while controlling for all other possible contributing factors. The defined outcome measures to account for campaign effects are therefore often 'indirect', like intended behaviour or attitudes etc. Even though there is evidence concerning the influence of these constructs on actual behaviour, there are always other additional determining factors (e.g. situational factors) that cannot be accounted for.

A before-after-design ideally includes a **meaningful reference group** to control for confounding factors (e.g. a similar geographical region without exposure to the contents of the campaign), which is however rarely the case.

Next to a lack of (systematical and valid) evaluation of effects, campaigns are often **combined or conducted simultaneously** with enforcement measures and implementation of new legislation. If an effect (improvement) is measured then, it remains unclear to which of the single components it is attributable, and to what extent.

2.2 CODED STUDIES

The literature search was carried out in three databases (Scopus, TRID and a KfV-internal literature database) with separate search strategies (for a detailed description see "Supporting documents"). Additionally, a free web-based search was done via Google.

Below, first information on the characteristics of coded studies is given, and subsequently the main research methods used for campaigns and awareness raising measures promoting safe and considerate behaviour in road traffic is provided.

Description of studies

Table 1 provides further description of the background characteristics of the coded studies that deal with campaigns and raising awareness.

Table 1: Information on sample and design of coded studies (sorted by year of publication, meta-analysis first)

Author(s), year, country	Measure description	Evaluation design	Research conditions
Department of Transport, 2015, UK	THINK Motorcycle campaign (TV, online, cinema, radio and posters) focused on motorists to look out for PTW (2010-2014)	Before-after face to face interviews Before=February 2010 After=August 2010	n=610
Elvik, R., 2000, Norway	"Speak out" road safety campaign focused on young and novice drivers and passengers (16-19 years) to address unsafe driving (1993-1995) – combined enforcement activities	Multivariate analysis of fatal and injury accidents (before-after): Before=1987-1992 After 1=1993-1998 After 2=1994-1998 After 3=1995-1998	Two comparison groups: one matched group (neighbouring county), one general group (all other counties)
Lin et al., 2009, USA	"Better driver" road safety campaign (media coverage, billboards, website and community based communication) focused on LGV, HGV and car drivers to tackle aggressive driving (2009) – combined enforcement activities	Before-after observations and interviews: 3 waves before: May 2009 2 waves after: July 2009	Interviews: n before=35 n after=127
Rundmo et al., 2004, Norway	Road safety & education campaign (multimedia production, school visits, training programme, poster, commercials & police surveillance focused on 18-24 year old road users (1998-1999)	Before-after questionnaire: Before=October 1998 After=June 1999 Accident data	Questionnaire: n before=725 n after=3,323 Accident data: two Norwegian counties (test and control group)

Author(s), year, country	Measure description	Evaluation design	Research conditions
Zampetti et al., 2012, Italy	Road safety education campaign (bill-posting, brochures, mass media communication with press conferences, articles in local papers, radio and TV interviews and a website) for the general population. Additionally, an intensified school campaign for 13-16 year olds was carried out (2003-2008)	Before-after injury data from hospital admission records: Before=2003 After=2008	n before=907 n after=755
Whittam et al., 2006, USA	"What's the hurry" road safety campaign (TV, radio, billboard) focused on young car drivers aged 16-19 years (1996)	Before-after accident data (time-series)	Control group was a comparison area.

Description of the main research methods

In order to evaluate the effectiveness of campaigns aiming at mitigating aggressive, unsafe and inconsiderate behaviour, mainly before-after designs are used. Some studies describe long term trends in accident or injury data. Furthermore, interviews and questionnaires are common to assess changes in self-reported behaviours.

The studies vary in whether significance tests are applied/reported or not. A control group is missing in several studies.

It is not clear from the evaluation studies whether or not a theoretical psychological model was the basis for designing the respective campaigns.

2.3 OVERVIEW OF RESULTS

The following table provides information on the main outcomes of coded studies on aggressive, unsafe and inconsiderate behaviour campaigns and awareness raising.

Table 2: Summary of coded study results regarding DUI awareness raising and campaigns (sorted by author(s))

Author(s), year, country	Exposure variable	Dependant / outcome type	Effects on road safety	Main outcome - description	
Department of Transport, 2015, UK	Road safety campaign on considerate behaviour towards PTW	Self-reported behaviour	/	Percent change = 0.06	Road safety campaign is linked to an increase of motorists looking out for PTW (no test for significance reported)
		Self-reported behaviour	/	Percent change = 0.1	Road safety campaign is linked to an increase of motorists checking blind spots for PTW (no test for significance reported)
		Self-reported behaviour	/	Percent change = 0.04	Road safety campaign is linked to an increase of motorists checking for PTW when changing lanes (no test for significance reported)
		Self-reported behaviour	/	Percent change = 0.06	Road safety campaign is linked to an increase of motorists checking twice for

Author(s), year, country	Exposure variable	Dependant / outcome type	Effects on road safety		Main outcome - description
					PTW when pulling out (no test for significance reported)
Elvik, R., 2000, Norway	Road safety campaign on safe driving of young and novice drivers	Fatal and injury crashes	↗	Percent change = -0.27 CL: 90%, CI: -0.44 - -0.07	The campaign resulted in a significant reduction of 27% in fatal or injury accidents for car passengers aged 16-19 (after period 1993-1998).
		Fatal and injury crashes	—	Percent change = 0.01 CL: 90%, CI: -0.29-0.41	The campaign resulted in a non-significant reduction of 1% in fatal or injury accidents for car drivers aged 16-19 (after period 1993-1998).
Lin et al., 2009, USA	Road safety campaign on aggressive driving for truck and car drivers	Headway to vehicle in front (time difference)	—	Wilcoxon rank sum test	The campaign resulted in a non-significant difference in headway time for car drivers before and after the campaign.
		Headway to vehicle in front (time difference)	—	Wilcoxon rank sum test	The campaign resulted in a non-significant difference in headway time for truck drivers before and after.
		Encountering aggressive drivers (self-reported)	/	Percent change = 0.03	A 3% increase in car drivers encountering aggressive driving every day was found after the campaign (no test for significance reported).
		Encountering aggressive drivers (self-reported)	/	Percent change = -0.32	A 32% reduction in truck drivers encountering aggressive driving every day was found after the campaign (no test for significance reported).
Rundmo et al., 2004, Norway	Road safety campaign on safe driving of adolescents	Self-reported speeding	↗	t=-8.26 with effect size d=0.81	Self-reported speeding was significantly reduced after the campaign.
		Self-reported unsafe behaviour	—	t-test with effect size d=0.26	Not significant small reduction in self-reported unsafe driving caused by social pressure after the campaign.
		Self-reported rule violation	—	t-test with effect size d=0.13	Not significant small reduction in self-reported rule violations after the campaign.
		Speeding accidents	—	Percent accident reduction = 0.13	The reduction in accidents caused by speeding after the campaign was not significant.
		Accidents overall	—	Percent accident reduction = 0.07	The reduction in accidents overall after the campaign was not significant.
Zampetti et al., 2012, Italy	Road safety education campaign	Non-fatal injuries	↗	Relative proportion (per 1,000 inhabitants) = -0.5 CL: 95%	The number of non-fatal injuries in 2003 after the basic and intensive programme decreased significantly till 2008 by 0.5 per 1,000 inhabitants (non-significant difference for the basic programme only).
		Severe injuries	↗	Relative proportion (per	The number of severe injuries in 2003 after the basic and intensive programme

Author(s), year, country	Exposure variable	Dependant / outcome type	Effects on road safety	Main outcome - description
			1,000 inhabitants) = -0.2 CL: 95%	decreased significantly till 2008 by 0.2 per 1,000 inhabitants (non-significant difference for the basic programme only).
Whittam et al., 2006, USA	Road safety campaign on safe behaviour	At fault crashes overall	↗ Percent accident reduction = 0.216 CL: 95%	A significant decrease of all at fault accidents during the intervention by 21.6% was found, while there was a non-significant increase by 3.2% in the comparison area.
		At fault crashes, serious injuries	– Percent accident reduction = 0.164 CL: 95%	A non-significant decrease of severe at fault accidents during the intervention by 16.4% was found, while there was a non-significant increase by 1.9% in the comparison area.

* Effects on road safety are coded as: significant positive (↗), significant negative (↘), non-significant (–) or no test for significance reported (↯)

Studies on safe and considerate driving campaigns

Four out of six studies reported accident and crash data before and after the respective campaigns (Elvik, 2000; Rundmo et al., 2004; Zampetti et al., 2012 & Whittam et al., 2006).

Elvik (2000) evaluated the "Speak out" campaign that aimed at encouraging passengers to speak up to unsafe drivers. He indicated a statistically significant reduction of 27% in the number of killed and injured car passengers aged 16 to 19 years. However, the reduction was not significant for car drivers in the respective age group. Zampetti et al. (2012) analysed hospital admission reports and found a significant decrease in non-fatal and severe injuries (-0.5 and -0.2 per 1,000 inhabitants) after an intense road safety education campaign. With regard to the reference group which received only a basic campaign (no school visits) no significant difference resulted. Finally, a significant decrease of all at fault accidents during an intervention by 21.6% was reported by Whittam et al. (2006). However, the evaluated road safety campaign did not lead to a significant reduction of severe injuries due to at fault crashes. Rundmo et al. (2004) also indicated non-significant reductions in overall and speeding accidents.

Concerning self-reported unsafe or inconsiderate, behaviour Rundmo et al. (2004) only found a significant decrease for speeding, while self-reported unsafe behaviour and rule violations were not significantly reduced. A campaign in the US that aimed at reducing aggressive driving among truck and car drivers led to 32% reduction of observing other aggressive drivers. The headway measure time did not change significantly, however (Lin et al., 2009).

To raise awareness among car drivers regarding PTW on the road a "THINK!" campaign was conducted in the UK. Results show increases in motorists looking out and checking blind spots for PTW as well as checking for PTW when changing lane and pulling out. However, no information is given on significances.

Modifying conditions

Phillips et al. (2011) carried out a meta-regression (model of predictor variables) based on 119 individual campaign effects to identify the relative importance of factors influencing the effectiveness of road safety campaigns with various themes. The following factors of campaigns were identified to be associated with accident reduction:

- Personal communication
- Road side delivery (billboards, message signs)
- Combination with enforcement
- Short campaign duration (0-29 days)

Phillips et al. (2009) outlined conclusions on a meta-regression by Vaa et al. (2004). They considered various additional outcome variables besides accident reduction (e.g. self-reported behaviour or attitudes) and found the same factors to be beneficially influencing campaign outcomes.

2.4 CONCLUSION

General

The considered studies were quite different regarding the exposure variable(s) (different aims and resources of campaigns) and outcome measures and had at least minor limitations, so it was not feasible to give a summarised analysis in terms of meta-analysis or vote-count analysis.

Main results

Concerning campaigns on aggressive, inconsiderate or unsafe driving behaviour, three evaluation studies reported significant reductions on different levels: number of killed and injured car passengers aged 16 to 19 years (Elvik, 2000); non-fatal and severe injuries (Zampetti et al., 2012); at fault accidents (Whittam et al., 2006). However, a fourth study did not find a significant decrease in overall and speeding accidents (Rundmo et al., 2004).

Self-reported unsafe or inconsiderate behaviour was evaluated in two further studies with inconsistent results. A significant decrease for speeding was reported, while self-reported unsafe behaviour and rule violations were not significantly reduced (Rundmo et al., 2004). After an aggressive driving campaign in the US, truck and car drivers felt less exposed to other aggressive drivers. On a more objective level however, measured headway time was not significantly reduced (Lin et al., 2009).

Evaluation results after a campaign to increase visibility and awareness of powered two-wheelers show increases in motorists paying attention to this road user group (no information on significances).

Biases and transferability

All studies had at least minor limitations. The defined outcome measures to account for campaign effects are partly 'indirect' like self-reported behaviour. Even though there is a link between self-reported and actual behaviour, there are always other determining factors that cannot be accounted for. Furthermore, questionnaires and interviews may introduce biases such as social desirability. Another limitation is that some evaluated campaigns were accompanied by or conducted simultaneously to enforcement activities or other road safety measure. In that case, it is not clear to which extent the effects are attributable to the single measures. Also, all individual campaigns (exposure) were heterogeneous regarding design (exact target group, period, media etc.).

Some studies did not indicate whether or not significance was tested, or lacked reporting of methodological details. Long term effects are available for only a few studies. Therefore, sustainable changes in behaviour due to campaigns remain unclear. Finally, to control for confounding factors ideally a meaningful reference group is included, which is barely done.

3 Supporting documents

3.1 LITERATURE SEARCH STRATEGY

The literature search was conducted in December 2016. It was carried out in three databases and a complementary free internet search. The queried database were

- Scopus: a large abstract and citation database of peer-reviewed literature
- TRID: a large online bibliographic database of transportation research
- DOK-DAT: a KfV-internal literature database.

Database: Scopus

Date: 16th of December 2016

limitations: published: 2006 to present

No.	Search terms, logical operators, combined queries	Hits
#1	"Campaign" OR "awareness" OR "public information"	248,963
#2	"Aggressive driving" OR "aggressi*" OR "safe driving" OR "unsafe driving" OR "reckless driving" OR "safe distance" OR "tailgait*" OR "headway distance" OR "overtak*" OR "passing" OR "lane keep*" OR "car follow*" OR "time pressure" OR "hurried driving" OR "road violation" OR "courtesy on the road"	213,545
#3	"road safety" OR "traffic safety"	12,033
#4	#1 AND #2 AND #3	51

Table 3: Used search terms, logical operators, and combined queries of literature search (Scopus).

Detailed search terms, as well as their linkage with logical operators and combined queries are shown in Table 3. Using search fields title, abstract and keywords (TITLE-ABS-KEY) and a general limitation to studies which were published from 2006 to current led to 51 studies (Table 3).

Database: DOK-DAT

Date: 7th of December 2016

Search no.	Search terms, operators, combined queries	Hits
#1	"Werbung" (advertisement) AND "Sicherheit" (safety)	467
#2 (within #1)	"Wirksamkeit*" (effectiveness) OR "Evalu*" (evaluation) OR "Bewertung*" (assessment)	278

Table 4: Used search terms, logical operators, and combined queries of literature search (DOK-DAT).

German search fields 'Titel', 'ITRD Schlagworte' and 'freie Schlagworte' were used. Hits were only limited to the years 1990 to 2016 and got 278 more potential studies (Table 4).

Database: TRID database

Date: 20th of December 2016

Search no.	Search terms, operators, combined queries	Hits
#1	"safety" AND "campaign" AND "evaluation"	240

Table 5: Used search terms, logical operators, and combined queries of literature search (TRID).

Search terms were "safety", "campaigns" and "evaluation". Hits were limited to the years 2000 to 2016 and got 240 potential studies (Table 5).

The literature search strategy, querying three databases, didn't result in a sufficient number of evaluated awareness raising measures. Based on the expertise of the consortium, it became evident

that some evaluation studies are not published in scientific journals (grey literature, conference papers etc.). Therefore, it was decided to complement the results with a non-standardised, free search with the internet search engine Google. In a first step, relevant road safety campaigns were identified. In a second step, the aim was to find the related evaluation papers of these campaigns. The following search terms were used in different combinations: Aggressive driving, safe driving, unsafe driving, reckless driving, safe distance, tailgating, headway distance, overtaking, passing, lane keep*, car following, time pressure, hurried driving, road violation, courtesy on the road.

Results Literature Search

Database	Hits
Scopus (remaining papers after several limitations/exclusions)	51
DOK-DAT	278
TRID database	240
Free literature search (Google)	38
Total number of studies to screen title/ abstract	607

Table 6: Results of databases and free search after limitations

In all, literature search lead to 607 potential studies for screening.

Screening

Total number of studies to screen title/ abstract	607
Exclusion criteria: no campaign/evaluation or topic not or not sufficiently covered or duplicates	600
Studies to obtain full-texts	7

Table 7: Screening of abstracts

After screening the titles and abstracts 39 studies remained for screening the full-text.

Total number of studies to screen full-text	7
Full-text could be obtained	7
Reference list examined Yes/No	Partly
Eligible papers	7

Table 8: Papers obtained for full-text screening

Screening of the full texts

Total number of studies to screen full paper	7
No evaluation or quantitative effects reported	1
Not relevant	2
Remaining studies	4
Coded within other measures topic	2

Table 9: Screening of full-texts

List of references resulting from search strategy (sorted by authors)

No.	Publication	Coded Yes/No	Reason
1.	Currie, G. (2009). Using a public education campaign to improve driver compliance with streetcar transit lanes. <i>Transportation Research Record</i> , 2112, 62-69.	N	Thematically not relevant
2.	Department of transportation UK (2015). THINK! Motorcycle safety campaign 2014 evaluation presentation. Retrieved from https://www.gov.uk/government/publications/think-motorcycle-safety-campaign-2014-evaluation	Y	
3.	Elvik, R. (2000). Evaluating the effectiveness of Norway's "Speak out!" road safety campaign: The logic of causal inference in road safety evaluation studies. <i>Transportation Research Record: Journal of the Transportation Research Board</i> , 1717, 66-75.	Y	
4.	Ewert, U. (1998). Informationskampagne führt zu Verhaltensänderungen. <i>Zeitschrift für Verkehrssicherheit</i> , 44(2), 74.	N	Thematically not relevant
5.	Hernik, J. & Dziadas, A. (2013). The effectiveness of social campaigns in the eye of their receivers, on campaigns promoting safe driving example. <i>Zarządzanie Publiczne</i> , 4(24), 379-391.	N	No measures of effectiveness reported
6.	Lin, P.S. Lee, C., Meeta, S. & Gonzalez-Velez, E. (2009). The better Driver Campaign. USF Center for Urban Transportation Research.	Y	
7.	Rundmo, T. & Iverson, H. (2004). Risk perception and driving behaviour among adolescents in two Norwegian counties before and after a traffic safety campaign. <i>Safety Science</i> , 42(1), 1-21.	Y	
8.	Whittam, K.P., Dwyer, W.O., Simpson, P.W. & Leeming, F.C. (2006). Effectiveness of a Media Campaign to Reduce Traffic Crashes Involving Young Drivers. <i>Journal of Applied Social Psychology</i> , 36(3), 614-628.	Y	
9.	Zampetti, R., Messina, G., Quercioli, C., Vencia, F., Genco, L., Bartolomeo, L. & Nante, N. (2012). Nonfatal Road Traffic Injuries: Can Road Safety Campaigns Prevent Hazardous	Y	

Behavior? An Italian Experience. <i>Traffic Injury Prevention</i> , 14, 261-266.		
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