



Driver Distraction 2015

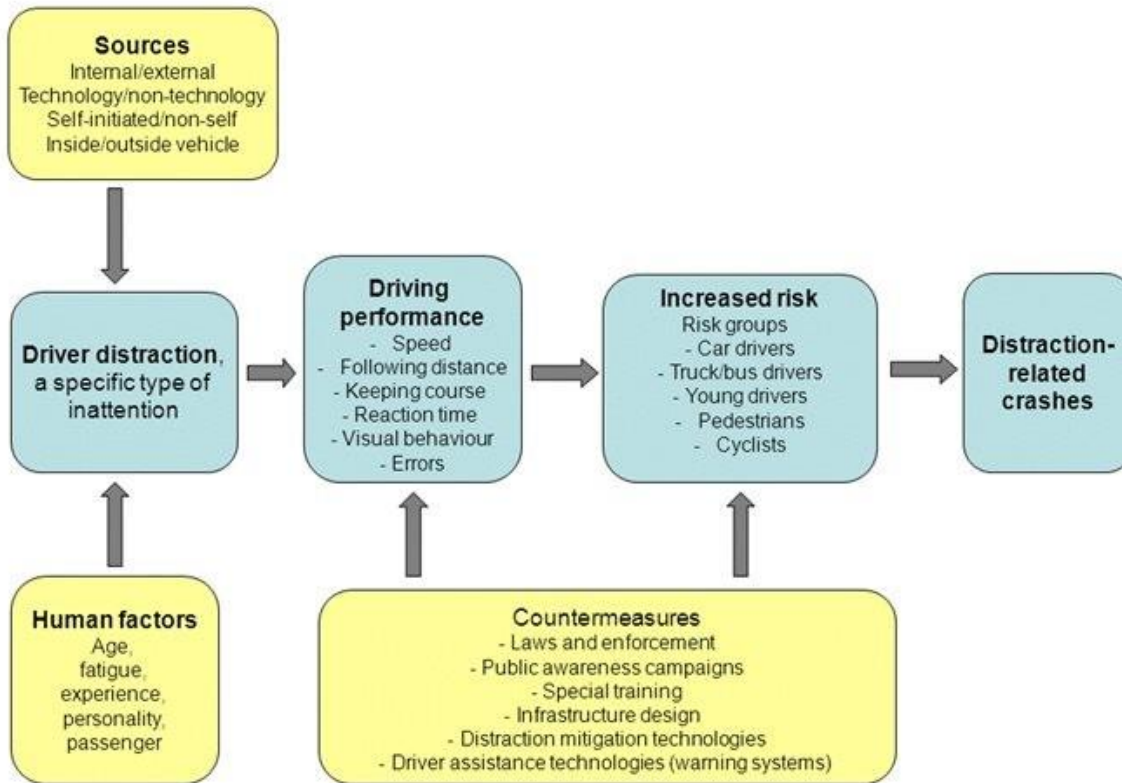


CONTENTS

1	<i>Overview</i>	3
2	<i>Introduction</i>	6
2.1	What is driver distraction?	6
2.2	Sources of driver distraction	7
3	<i>Effects of distraction on driving performance</i>	9
3.1	Research methods	9
3.2	General effects of visual versus cognitive distraction	10
3.3	Effects of talking and listening	11
3.4	Effects of handling equipment	13
3.5	Effects of roadside advertising	17
3.6	Effects of other activities	19
3.7	Processes that explain effects	20
3.8	Self-regulation of attention	21
3.9	Summary of main points on the performance effects of distraction	23
4	<i>Prevalence of driver distraction</i>	24
4.1	Research methods	24
4.2	Prevalence among car drivers	25
4.3	Prevalence among pedestrians and cyclists	27
4.4	Prevalence and age	29
4.5	Summary of main points on the prevalence of distraction	30
5	<i>Driver distraction and crashes</i>	30
5.1	Research methods	31
5.2	Distraction and crash causation	32
5.3	Risk of talking and listening	33
5.4	Risk of handling equipment	35
5.5	Risk of looking at advertising billboards	36
5.6	Risk car drivers versus truck and bus drivers	36
5.7	Differences in crash risk due to driver age and experience	39
5.8	Risk of electronic device use among pedestrians and cyclists	39
5.9	Overview results distraction and risk	40
5.10	Summary of main points on driver distraction and crashes	42
6	<i>Driver distraction in future automated driving</i>	43
7	<i>Countermeasures</i>	44
7.1	Importance of knowledge-based countermeasures	45
7.2	Legislation and enforcement	45
7.3	Training	46
7.4	Publicity campaigns	47
7.5	Technological countermeasures	47
7.6	Road infrastructure measures	49
7.7	Summary of main points on countermeasures	50
	<i>References</i>	52

1 Overview

Figure 1: Outline of road safety aspects related to driver distraction



What is driver distraction?

In recent years, the growing use of mobile phones and other technologies in cars has led to increased interest in the problem of driver distraction among policymakers and researchers. Driver distraction is understood as a form of inattention and has been defined as “The diversion of attention away from activities critical for safe driving toward a competing activity, which may result in insufficient or no attention to activities critical for safe driving” (Regan, Hallett, & Gordon, 2011, p. 1776). The sources of driver distraction can reside inside or outside the vehicle, be technology-related or otherwise traffic-related or not, and be self-initiated or imposed upon by the situation or circumstances. While the sources of distraction may take many forms, there are four basic types of distraction: visual distraction (e.g. looking away from the roadway), auditory distraction (e.g. responding to a ringing cell phone), biomechanical distraction (e.g. manually adjusting the radio volume), and cognitive distraction (e.g. being lost in thought).

Effects on driving

Although the sources of driver distraction may be different, adverse effects include a decrease in performance of the driving task, slower speed, closer following distance, more problems with keeping course, more errors, and narrower visual focus.

As more devices are being installed inside vehicles and as cell phone use continues to increase, the potential for driver distraction – and therefore the risk of severe injury from a distraction-related crash – is rising, especially for teenage drivers and their passengers.

Research indicates that different visual-physical tasks related to device use – texting, entering a number, entering a destination, operation of a music device – have similar effects on driving performance. Car drivers engaged in these activities appear to drive more slowly, to have more deviations in lateral position, and to look away from the road longer and more frequently. Simulator studies also show slower reaction times and a greater number of conflicts. In one study among cyclists similar effects were found as among car drivers, i.e. slower speed, deviation in lateral position and an increase in objects in the visual field that were overlooked.

Prevalence

For different reasons knowledge about duration and frequency of sources of distraction is important. First of all, prevalence data are important for determining the possible change in crash risk that is associated with a particular source of distraction. Second, prevalence data provide information about the activities which may distract road users and about patterns in these activities, which can be used for developing countermeasures. Third, prevalence data are also an important means of verifying whether countermeasures have actually worked.

Research on prevalence of distracting activities has indicated that car drivers spend about 25-30% of total driving time on distracting activities, of which about half concerns conversation with a passenger. Age is an important factor for prevalence; the prevalence figures for young road users are higher than those of middle-aged or older road users.

About one-third of all distracting activities concern distraction outside of the vehicle (such as looking at a vehicle with engine trouble) and about one fifth is a technology related type of distraction (such as mobile phone use). Both crash studies and naturalistic driving studies have shown that distraction contributes to a substantial number of crashes and consequently poses a serious safety problem. Activities that cause visual distraction (e.g. looking away from the road during texting) appear to be the most dangerous, as has been estimated by odds-ratios.

Crash risk

In epidemiological research about 5 to 25% of car crashes have been attributed to driver distraction. In one study concerning truck drivers a much higher estimate of 70% has been found. Differences in estimates between studies are related to differences in operational definitions, in research methods and driver populations.

Several studies suggest that various distracting activities are associated with increased crash risk. Distracting activities of a visual/physical nature, such as typing in a number or applying make-up, are associated with higher crash risk among both car drivers and truck/bus drivers. These tasks require that the driver glances away from the road for a longer time, thus hindering the correct anticipation of unexpected events. For some types of distracting activities, such as mobile phone use, results differ between epidemiological/case-crossover studies on the one hand and naturalistic driving studies on the other.

Various sources of distraction appear to enhance crash risk, but studies differ in the estimates of effects. For example, naturalistic driving studies show a much lower crash risk due to mobile phone use than earlier crash studies. However, the method of naturalistic driving research is still relatively new and the divergence between results for mobile phone use has not yet been resolved. More scientific evidence is needed concerning the exact quantitative relationship

Driver Distraction

between some types of distraction and risk. Most of the research concerns car drivers and truck drivers. More recently, research has appeared that shows that distraction by mobile phones or other portable devices is also a risk factor for pedestrians and cyclists.

There can be various reasons why the negative effect of mobile phone use on driver performance as has been demonstrated in laboratory, simulator and field studies does not fully transfer to real traffic conditions. Firstly, when using the phone either the driver or other road users may adjust their behaviour. Secondly, road users/drivers learn to use the device in a way that needs less attention.

It should be pointed out that risk estimates by odds-ratios only present part of the picture, namely the tasks which are associated with increased risk of crash or near-crash. The remaining part concerns the duration and frequency of sub-tasks. Certain sub-tasks that are performed rarely or that are of short duration are unlikely to lead to a great number of crashes even if they are associated with increased risk. On the other hand, sub-tasks with lower odds-ratios could be more important for crash numbers when they are frequently performed or take a long time to carry out. Consequently, prevalence data are very important in estimating the risks associated with the distracting activity.

Countermeasures

There are five broad categories of countermeasures to address distraction: legislation and enforcement, driver training, publicity campaigns, technology-based countermeasures, and road infrastructure. Driver distraction countermeasures may be directed at drivers, transport companies, roads or vehicles.

Since sources of distraction can be various and since not everything is known yet about which distracting activities are associated with risk, a combination of countermeasures seems appropriate, consisting of legal measures, publicity and training, new technology and last but not least, a change in the way of thinking about what behaviour is acceptable. It is possible to inform road users about dangers of specific activities. A promising intervention is training based on error learning that motivates (young) drivers to use devices more safely while driving. A road infrastructure safety measure that reduces inattentive driving is the installation of rumble strips. Both distraction-specific technologies and general driver assistance technologies have the potential to reduce the negative impact of driver distraction.

In view of the interest in driver distraction among both policymakers and the general public, and in view of the higher quality of recent data-collection techniques, it can be expected that the knowledge concerning driver distraction will grow considerably in the future. What we know now has changed over recent years and will undergo more changes in coming years. Both the knowledge about risk in relationship to various sources of distraction and about effective countermeasures is important.

2 Introduction

This text provides an introduction to the subject of driver distraction, its various sources, consequences, and possible countermeasures. Distraction in road traffic is increasingly recognized as a risk factor. Scientists, policymakers, media and road users are increasingly aware of the problem. The problem of distraction appears to be growing because of the increasing presence of electronic equipment/devices – such as mobile phones, navigation systems – in road traffic.

This first section examines the characteristics of driver distraction and describes several sources of distraction. It describes the relationships between the concepts of inattention, driver distraction and concentration loss. Section 3 outlines how driver distraction affects aspects of driving behaviour, such as speed choice, following behaviour, keeping course, reaction time, and visual behaviour. To study the magnitude of the problem of driver distraction, information is required about the prevalence of distracting activities while driving and the risks associated with these activities. Section 4 presents results on the prevalence of driver distraction among car drivers, truck drivers, cyclists and pedestrians. The relationship between driver distraction and crash risk is described in Section 5. Attention is given to change in risks due to talking and listening, to handling equipment, and looking at advertising billboards, and to differences in change in risk between car drivers and truck drivers. The final section outlines possible countermeasures against driver distraction, such as legislation and enforcement, driver training, publicity campaigns, road infrastructure, and technological countermeasures (Section 6).

2.1 What is driver distraction?

The task of driving requires continuous attention to road and traffic circumstances and vehicle control. Drivers may pay insufficient attention to driving because: they are occupied with other activities such as making a phone call, tuning the radio, listening to the radio, talking with a passenger, or eating while driving. In addition, driver attention can be drawn by noticeable things or events inside or outside the car, like a crash on the other lane, a striking person on the pavement, a conspicuous billboard alongside the road, or a wasp in the car. Finally, drivers may become tired or think about other things than driving (e.g. daydream) without being fatigued, which may distract the driver away from activities critical for safe driving.

Based on a conceptual analysis of common elements in various definitions of distraction, Lee et al. (2008) provide the following general definition: 'Driver distraction is a diversion of attention away from activities critical for safe driving toward a competing activity' (Lee et al., 2008, p. 34).

Related concepts to driver distraction are inattention, and concentration loss. When the competing task for driving is thinking about other things or daydreaming without being fatigued, then this is called concentration loss. Thus, concentration loss can be seen as a type of driver distraction where the source of distraction is internal.

Regan et al. (2011) have defined driver inattention as "insufficient or no attention to activities critical for safe driving" and assert that driver distraction is one of several mechanisms by which inattention occurs. Regan et al. (2011) differentiate taxonomically between the following mechanisms of inattention:

Driver Distraction

- Driver restricted inattention – “insufficient or no attention to activities critical for safe driving brought about something that physically prevents (due to biological factors) the driver from detecting (and hence from attending to) information critical for safe driving”.
- Driver misprioritised inattention – “insufficient or no attention to activities critical for safe driving brought about by the driver focusing attention on one aspect of driving to the exclusion of another, which is more critical for safe driving”.
- Driver neglected inattention – “insufficient or no attention to activities critical for safe driving brought about the driver neglecting to attend to activities critical for safe driving”.
- Driver cursory inattention – “insufficient or no attention to activities critical for safe driving brought about by the driver giving cursory or hurried attention to activities critical for safe driving”.
- Driver-diverted inattention – The diversion of attention away from activities critical for safe driving toward a competing activity, which may result in insufficient or no attention to activities critical for safe driving”. The competing activity can be driving or non-driving related.

Within this taxonomy, driver distraction can be considered as one specific mechanism of inattention, and concentration loss can be considered as a special type of driver distraction triggered by an internal source.

2.2 Sources of driver distraction

There are various sources of distraction. The sources can reside inside or outside the vehicle, be technology-related or otherwise, traffic-related or not, and be self-initiated or imposed by the situation/circumstances. While the sources of distraction may take many forms, it is helpful to examine distraction in terms of four distinct categories: (1) visual distraction (e.g., looking away from the roadway); (2) auditory distraction (e.g., listening to a ringing cell phone); (3) manual distraction/interference (e.g., manually adjusting the radio volume), and (4) cognitive distraction (e.g., being lost in thought).

Many distracting activities that drivers engage in can involve more than one of these components (e.g., visually searching for a control to manipulate). For example, the use of media devices while participating in traffic can distract the road user in each of the described four ways (Meesmann et al., 2009; Lee, 2007):

- Manual distraction/interference because the use of the device interferes with physical control of the vehicle.
- Visual distraction when the user watches the device instead of the traffic situation.
- Cognitive distraction because the music, the conversation, or other information that directs attention away from the driving task.
- Auditory distraction because a ringtone or music can divert attention away from the driving task.

Besides leading to one or more of these distractions, listening to music or having a conversation may also change mood or mind set and thus have an effect on driving behaviour. An overview of possible sources and types of distraction is presented in Table 1.

Young, Regan and Lee (2008) argue that the extent to which a distraction impacts on driving performance and safety depends on four moderating factors. Firstly, the extent to which a distraction adversely affects driving performance may be influenced by a number of particular driver characteristics. Some examples include:

- Age and driving experience: Research has shown that less experienced drivers are less able to perform competing activities without compromising activities critical for safe driving as they have only partially automated some driving skills (Regan & Hallett, 2011)
- Alcohol intoxication: Research has shown that 'easy' secondary behaviours (e.g., changing the radio channel) can be made substantially more distracting when under the influence of alcohol (e.g., Harrison and Fillmore, 2011)
- Drowsiness: Research has shown that drivers that are sleep deprived (i.e., drowsy) are more likely to be distracted than drivers that aren't, which is linked to an increased risk of poor driving performance (Anderson & Horne, 2013).

Secondly, the driving task itself can moderate the potential to engage in distracting activities. Generally speaking, the performance of a secondary task will be more distracting when the driving environment itself is attentionally demanding (Young et al., 2008). For example, driving conditions such as winding roads, poor weather and heavy traffic require more attention to the roadway and thus engagement in secondary activities in these situations is more likely to interfere with activities critical for safe driving.

The demand of the secondary task can moderate how deleterious it may be to driving performance. In general, the more attention required by a secondary activity, the less likely it can be timeshared without degrading activities critical for safe driving (Regan & Hallett, 2011). For example, recent research has shown that the engagement with infotainment devices with more demanding visual-manual interfaces is more likely to undermine driving performance than engagement with simpler devices (Lee, Roberts, Hoffman, & Angell, 2012)

The ability of the driver to self-regulate, or change driver behaviour to maintain adequate driving performance in the face of competing tasks (Young et al., 2008), can also impact on distracted driving. For example, self-regulation can involve drivers preparing for potential distractions and acting accordingly (e.g., turning off phone before it rings during driving). In addition self-regulation can also involve drivers responding to distractors to mitigate distraction after it occurs (e.g. asking passenger to stop talk when navigating a turn at a busy intersection).

Table 1. Different sources and types of distraction

	Traffic related?	Self-initiated?	Technology-related	Inside Vehicle	Type of distraction
Phone	No	Yes	Yes	Yes	Auditory-cognitive
Passenger	No	Yes/No	No	Yes	Visual-auditory-cognitive
Music	No	Yes	Yes	Yes	Auditory-perhaps cognitive
Texting	No	Yes	Yes	Yes	Visual-cognitive-physical
Equipment handling	No	Yes	Yes	Yes	Visual-cognitive-physical
Enter destination in Navigation system	Yes	Yes	Yes	Yes	Visual-cognitive-physical
Follow instructions Navigation	Yes	Yes	Yes	Yes	Visual-auditory-cognitive
Reacting to warnings	Yes	No	Yes	Yes	Visual-auditory-cognitive
Looking at advertisements	No	No	No	No	Visual-cognitive
Eat, drink, reaching for object, facial care	No	Yes	No	Yes	Visual-physical
Daydreaming	No	Yes/No	No	Yes/no	Cognitive

Source: Stelling and Hagenzieker, 2012

3 Effects of distraction on driving performance

This section provides an overview of the effects of distraction on driving task performance. Section 3.1 briefly provides some explanation of the advantages and disadvantages of research methods that are used to study behavioural effects of driver distraction. The next section will look at the general effects of visual and cognitive distraction (Section 3.2). The following four sections describe specific effects of talking and listening (Section 3.3), handling equipment (Section 3.4), looking at roadside advertising (Section 3.5) and other activities (Section 3.6). The theoretical mechanisms that may explain the effects of distraction are described in Section 3.7. The question as to whether or not road users are able to self-regulate distraction is answered in Section 3.8. Finally, Section 3.9 presents a summary of main points.

3.1 Research methods

The effects of distraction on driving performance have been mostly studied experimentally, frequently in a driving simulator or sometimes in a laboratory or the field. These effects are not necessarily the same as those in real traffic. The relationship between aspects of driving performance and actual crash risk is also not always well-known. There is almost no research that has studied behavioural effects and the crash risk of a particular source of distraction at the same time. The performance indicators that have been studied are both vehicle control

variables (lateral position, speed, following distance) as well as the ability to perceive and react to environmental stimuli/cues (reaction time, visual behaviour, errors).

Studies of the effects of distraction on driving task have often used a laboratory method that used a driving simulator, a virtual environment, or animations on a computer screen. The advantages of a laboratory or simulator study are that the environment can be controlled, such that the situations desired by the experimenters can be presented, and that all participants are subject to the same situations. A large number of different situations like varying road conditions, illuminations and weather conditions can be studied without waiting for them to occur in the natural environment.

A drawback of laboratory research is that participants are obviously aware of the fact that they are being observed which may lead to non-natural behaviour. The available time for research in a simulator is usually restricted; therefore it is not clear whether only the novelty effect of a certain measure or device is investigated, or whether the same behaviour would be observed in a longer-term study. Thus, laboratory studies are characterized by a high level of control but they are in some respects artificial and may be too different from real-life driving. In other words, they may lack external validity.

A step further towards real conditions is the use of test track studies which are performed on a closed course but while driving a real car. The conditions are more controlled than in a field study. The situations under investigation can be more dangerous than in field studies, because surrounding traffic is either absent or controlled. However, as with simulator studies, the participants are usually aware of the experimental setting and of being observed, it is not easy to perform long-term studies, and the number of participants is limited as for a laboratory study.

Field experiments on a closed driving circuit or on a special test route on a public road may be more successful in approaching real-life driving conditions. A field study is the method closest to real driving, and therefore has high external validity. The possibility of controlling the environment is relatively limited, and participants cannot deliberately be exposed to dangerous situations. In field experiments there is often little or no control over other variables that may affect driving performance.

A special observation method is Naturalistic Driving (ND) where the behaviour of drivers is registered for a longer period of time via the use of inconspicuous cameras and/or sensors which also register vehicle movements and external driving circumstances. In this type of research, participating drivers undertake normal journeys. Since the level of control over variables is smaller than in experimental studies, it is more difficult to demonstrate causal connections with these types of data collection methods.

3.2 General effects of visual versus cognitive distraction

Because driving is primarily a visual task, visual distraction is sometimes referred to as being especially dangerous for safe driving performance (Klauer et al., 2006). Visual distraction can cause drivers to look away from the roadway and has been found to lead to large and frequent lane deviations, abrupt steering movements, and slow responses to lead vehicle braking events (Kauer et al., 2006). Moreover, the diversion of visual attention away from the roadway may

lead to failures in detecting hazardous events and increase the reaction time to safety-critical events (Regan & Hallett, 2011). Perhaps not surprisingly, such indices of impaired driving performance are strongly related to off-road glance patterns (Klauer et al., 2006).

Compared to visual distraction, the effects of cognitive distraction on driving performance may be more covert. Like visual distraction, cognitive distractions can undermine a driver's sensitivity to critical cues and traffic signals in the roadway environment (e.g. "looked at but not see"; Strayer et al., 2003). A meta-analysis of 23 studies found that cognitive distraction caused by using auditory e-mail systems, performing math calculations, or holding hand-free cell phone conversations delayed driver response to hazards by an average of 130 ms (Horrey & Wickens, 2006). In addition, drivers that are cognitively distracted tend to have longer fixations and a denser gaze concentration in the centre of the road context, which may result in failures to perceive important information in peripheral vision (Regan & Hallett, 2011).

3.3 Effects of talking and listening

Based on a review by Stelling and Hagenzieker (2012), Table 2 summarises information from research on the effects of talking and listening on driving task performance.

Stelling and Hagenzieker (2012) mention the following effects of talking on the phone or with a passenger on the driving behaviour of *car drivers*:

- reduction of driving speed
- increase in following distance
- longer reaction times
- more problems with keeping vehicle on course
- narrower visual focus resulting in missing objects and making errors

Table 2. Summary of effects of talking and listening on driving task performance

Performance indicators	Talking by phone	Talking with a passenger	Music listening
Speed	↓ ↓ ↓	↓	— / ↑ —
Deviations from lateral position	↑ — ↑	— 4	— / ↑ —
Following distance	↑		—
Visual behaviour			
• glancing at relevant traffic information	↓		— / ↑ 5
• missed objects	↑ ↑ ↑		—
• looking away from road	↑	—	
• looking inside/device/advertisements			
• looking in mirrors			
Conflicts	↑ ↑ / —		
Errors	↑ ↑ ↑	— —	↑ ↑ ↑ / —
Reaction times	↑ ↑ ↑	↑	↑ / ↓ / — — —
Various	Attentiveness ↑	Driver support ↑ Noticing events ↑	Attentiveness & aggression ↑ Stress ↓ Effort with hard/ high paced music ↑
<p>↑an increase; ↓ a decrease; — no effect, (↑) Between brackets expected effect (not yet researched) In black effects among car drivers; in blue effects among pedestrians; in brown effects among bicyclists 4 combined with abruptly braking; 5 only for males (not for females)</p>			

Source: based on Stelling and Hagenzieker (2012)

Other road users

Little research has been carried out on the effects of talking and listening among other road users. Two field studies among cyclists demonstrate that a conversation by phone leads to a reduction of speed, an increase in both reaction time and the number of objects that are missed, and to a narrower visual focus (Waard, de, et al., 2010, 2011). Pedestrians that use the phone walk slower than pedestrians not using a phone or listening to music (Neider et al., 2010; Hyman et al., 2010). Pedestrians who use the phone also miss more objects (Nasar et al., 2008).

Handheld versus hands-free phone use

Different types of studies – meta-analysis of simulator studies, laboratory and field experiments – show that the negative effects on driving task performance such as increased reaction time and narrower visual focus are the same for handheld and hands-free use of the phone (Caird et al., 2008; Strayer et al., 2011).

Talking by phone or with a passenger

A number of studies indicate that having a conversation by phone or with a passenger does not differ in its effect on change in reaction time (Consiglio et al., 2003; Horrey&Wickens, 2006) or on the number of missed objects in the peripheral field of vision (Horrey&Wickens, 2006). However, in some simulator studies it is found that reaction time is slower when talking on the phone than talking with a passenger (Burns et al., 2003; Hunton & Rose, 2005). Regan (2007) suggests that passengers often provide support for task performance of drivers and that they interrupt the conversation when the task demands of driving increase for the driver. In a simulator study, it has been shown that a passenger is conscious of the driving situation leading to adjustment of complexity and pace of conversation (Drews et al., 2008).

A recent simulator driver study showed that the presence of a passenger was associated with a reduction in the visual scanning range of male adolescent drivers (Pradhan et al., 2014). The authors contend that the presence of a passenger may inflict a level of cognitive distraction on the driver which results in more concentrated central gaze, which may pose a threat as peripheral events could be missed. Reiterating this point, White and Caird (2010) found that the presence of passengers were detrimental to the drivers' ability to detect hazardous events in a simulated driving study (i.e., resulted in a greater number of 'looked-but-failed-to-see' instances).

Listening to music

Jancke et al. (1994) found that merely listening to a radio was associated with degraded driving performance such as poorer lane keeping.

The effects of listening to music on driving performance depend on the type of music. Simulator and laboratory studies show that especially loud, high paced or emotional music affect driving task performance. Car drivers who listen to loud music react more slowly and commit more traffic violations than other drivers (Callens, 1997). High-paced music also leads to more traffic violations and to higher speed (Brodsky, 2002). Emotionally-toned music, either cheerful or sad, slows down the speed of driving (Pêcher et al., 2009). On the positive side, listening to music can help drivers to stay alert as has been shown in a simulator study by Oron-Gilad, Ronen and Shinar (2008). Van der Zwaag (2012) investigated the influence of music on mood and physiology while driving. Her research reveals that music influences mood and physiological state in low and high demand driving situations without necessarily impairing driving performance. Additionally, this research shows that, in accordance with mood regulation theory, music can be effectively used to calm drivers during high demand driving situations. Evidence was also found that positive music can prevent anger building-up during anger-inducing driving conditions.

3.4 Effects of handling equipment

Based on the review by Stelling and Hagenzieker (2012), Table 3 presents an overview of effects of using devices inside the vehicle on driving task performance indicators.

A number of studies have looked at effects of tasks that require visual-physical operation of equipment and thus can lead to visual-physical distraction, such as texting, entering a number in a mobile phone, entering a destination in a navigation system or operating a music device. Most of these studies are simulator studies some of them have been field experiments on a trial

route. Research on the use of mobile phones has often neglected to make a distinction between various sub-tasks of phone use (entering a number, talking, texting etc.) and is therefore not systematic in approach.

Handling devices

Results show that different visual-physical tasks related to device use – texting, entering a number, entering a destination, operation of a music device – have similar effects on driving performance (Törnros & Bolling, 2005; Drews et al., 2009; Hoskins et al., 2009; Owens et al., 2011). Car drivers engaged in these activities appear to drive slower, to have more deviations in lateral position and to look away from the road longer and more frequently.

Simulator studies also show slower reaction times and a greater number of conflicts. In one study among cyclists similar effects were found as among car drivers, i.e. slower speed, deviation in lateral position and an increase in objects in the visual field that were overlooked. It is likely that pedestrians and cyclists use navigation on their smart phones but nothing is known about possible effects of entering a destination or following route instructions whilst walking or cycling.

A meta-analysis by Caird et al. (2014) examined the detriments in driving associated with receiving and sending text messages while driving. The authors concluded that texting adversely affects reaction time, performance on crashes, lateral control, longitudinal control, glance behaviour, and subjective workload.

Reed and Robinns (2008) examined the difference in driving performance decrements associated with writing a text message compared to reading a text message. The study found that writing a text message was linked to increased lateral and longitudinal variability compared to only reading a message. Writing a text message, due to its visual-input required to touch the keypad, may be especially distracting for the driver compared to reading a message.

Speech recognition technology may be associated with less driver distraction compared to manual texting. Various studies have shown that both voice-based texting through an integrated vehicle system (Owens et al., 2011) and speech-to-text software on the cell phone (He et al., 2013) are associated with less glances from the forward roadway and reduced variability in lateral control respectively. However, engaging in voice-activated text messaging still degrades driving performance compared to not texting at all (Owens et al., 2011; He et al., 2013).

Music

A few studies have looked into the effects of operating a music device (most often an MP3 player). It appears that difficult tasks such as searching for a song and switching a device on, interfere with driving performance (Young et al., 2011). In the case of easier tasks such as turning off a device or pausing or fast forwarding, no behavioural effects have been detected (Chisholm et al., 2008). Recent research has shown that the interaction with MP3 players with longer playlists (i.e., more 'demanding' as there were more songs to search through) was associated with greater variability in vehicular speed and lateral position compared to interactions with simpler MP3 players (Lee, Roberts, Hoffman & Angell, 2012).

Interacting with an in-vehicle (built in) music system can produce driver distraction and be detrimental to driving performance. One study has shown that actions associated with manually choosing music to play on a touch screen system (e.g., looking, touching, scrolling etc.) is associated with increased variability of lateral control (Kujala, 2013). In addition, tuning a radio

Driver Distraction

has been shown to degrade speed control and delay driver responses to unexpected hazards (Horberry et al., 2006). Garay-Vega et al. (2010) suggest that voice-activated music systems may be less detrimental to driving performance compared to those requiring manual input.

Navigation

The behavioural effects of operating a navigation system have been researched in a few studies that compare manual and voice activated input of a destination. These studies show that manual operation has greater detriment effects on driving performance than voice-activated control (Tijerina et al., 1998; Chiang et al., 2004). Research also shows that following voice-guided directions from navigation systems is less detrimental to driving performance than following directions that are only displayed visually (Dingus et al., 1995).

Social media

To the best of our knowledge, only one study has looked at the effects of engaging with social media apps via the cellphone on driver distraction and driving performance. Basacik et al. (2011) found that both writing and reading messages on the Facebook app were associated with driving decrements compared to just driving, especially writing the message. Both activities were associated with increased variability in headway distance and longer glances off the forward roadway. Writing the message was associated with a 30% increase in reaction time to hazardous events.

Table 3. Summary of effects of operation of devices on driving task performance

Performance Indicators	Device related sources of distraction					
	Texting (TT), entering number (EN); operation music device (OM)			Entering destination in navigation system	Following instructions from navigation systems	Reacting to warnings ³
	TT	EN	OM			
Speed	↓	↓	↓	↓1	↑2	↓
Deviations from lateral position	↑ ↑	↑	↑	↑1	↓2	
Following distance	↑					
Visual behaviour glancing at relevant traffic information						↑
missed objects						
looking away from the road			↑	↑1		↓
Looking inside/device/ advertisement			↑	↑1		
looking at mirrors						
Conflicts	↑		↑			↓
Errors	↑↑					
Reaction time	↑		↑			↓
Various	Risk perception with texting ↑				Mental workload ↓2	Mental workload with multiple systems (↑)

↑an increase; ↓ decrease; — no effect, (↑) Between brackets expected effect (not yet researched) In black effects among car drivers; in blue effects among pedestrians; in brown effects among bicyclists;
 1 manual entering compared with voice activated;
 2 use of a navigation system compared with a map;
 3 effects on those aspects of driving behaviour at which the system is directed

Source: Based on Stelling and Hagenzieker (2012)

Head-mounted displays

Recent research has examined driver use of Google Glass, a type of head-mounted display, to write and read a text message via voice activation software. Preliminary results are promising, with one study suggesting that text messaging via this medium is associated with a reduced number of lane excursions and reduced variability in steering control compared to texting via the cell phone (both manually or speech based) (He et al., 2015). He et al. (2015) are careful to point out that, although Google Glass may have some driving-safety benefits over conventional text messaging, it is not safer than just not texting at all.

Warning systems

Little is known about behavioural effects of interaction with various systems (ADAS), such as Collision Avoidance Systems (CAS) or a navigation system that inform or warn a driver about current traffic situations. Simulator studies have shown that following route instructions from a navigation system is less distracting than use of a map, and that auditory instructions have the least effects on driving performance. Problems with keeping course, slower speed, and mental load/effort are greatest when using a map and smallest when following auditory instructions (Srinivasan & Jovaris, 1997).

The potentially distracting effects of different warning systems have only been studied briefly because these systems are intended to draw attention away from other (traffic) tasks. Simulator studies have focused on the design and effectiveness of these systems for specific aspects of driving, perhaps overlooking unwanted side-effects of these systems. For example, warning systems have been shown to lead to shorter reaction times in case of rear-end collisions (Scott & Gray, 2008), but this beneficial effect will not lead to extra safety if car drivers start to drive faster or use shorter following distances because of the new system. Such an adjustment of behaviour based on a feeling of subjective safety is called behavioural adaptation (OECD, 1990).

It is imperative that warning systems employ alarms and signals that are informative to the driver without being too overwhelming and without producing cognitive distraction. For example, alerts that are signaled concurrently (or temporally close) have the potential to startle and distract the driver, which may exacerbate reaction times to critical driving events (Fitch, Bowman, & Llaneras, 2014). Alarms must also be of appropriate salience, as those that are too discrete will likely be missed, while those that are too salient will be perceived as annoying and could distract the driver (Lees & Lee, 2007).

Effects of handling mobile phones on task performance of cyclists

Waard, de, et al. (2010) investigated the direct effects of the use of mobile phones on cycling behaviour. Twenty-four cyclists circled a secluded cycle track under six different conditions: with or without the use of devices and with or without simultaneously carrying out a simple or more complex arithmetic task while handling a mobile phone. The study indicated that, on average, cyclists using a mobile phone cycled at a lower speed, reported more mental effort, and experienced greater risks. While texting messages, cyclists kept further away from the road edge. When using the phone or texting a message, cyclists more often overlooked things compared to not using the phone or texting. Text messaging had the greatest effect on cycling behaviour and was also perceived as the most hazardous, even though speed was reduced. In the study, no or only limited effects of listening to music on cycling behaviour were found. However, cyclists themselves indicated that they experienced a higher risk while listening to music compared to not listening to music. In a later study with a similar setup (Waard, de, et al., 2011) it was found that listening to music while cycling reduces auditory perception - cyclists miss more auditory information. These negative effects were greater when earphones were used and when the rider was listening to something at high-volume or fast tempo. It was also found that hands-free use of a mobile phone while cycling had similar negative effects on cycling behaviour to hand-held phone use, with the exception of effects on response time.

A recent observational study found that cyclists using a mobile phone maintained a cycling position further away from the kerb, which is unsafe due to the close proximity of passing vehicles (de Waard, Westerhuis, & Lewis-Evans, 2015).

3.5 Effects of roadside advertising

Roadside advertising and information billboards are intended to draw the driver's attention, which may cause diminished attention to the current traffic situation. Information signs at the roadside serve a different purpose: these signs are intended to increase road safety. However, in both cases the driver's diminished attention could result in more crashes in their vicinity.

Trick and Enns (2009) proposed that a stimulus such as a billboard may capture driver attention in two different ways. Firstly, a billboard may capture visual attention *automatically/reflexively* via bottom-up processes, typically triggered by certain characteristics such as bright colours, flashing lights or the display of motion. This type of attentional capture usually occurs when a

Driver Distraction

stimulus is 'surprising' or unexpected (e.g. by a new flashing electronic billboard not seen before). On the other hand, a billboard may also capture visual attention via top-down processes, in which the driver is *motivated* to deliberately devote attention to it (e.g. a driver wanting to look at his or her favourite billboard). Even though billboards have the ability to capture visual attention via both mechanisms, Trick and Enns (2009) posit that bottom-up processes may be of special concern due to the difficulty in disengaging (i.e. from ignoring reflexive responses).

A number of studies, simulator studies or field experiments, have shown that roadside advertising can influence driving behaviour (Beijer et al., 2004; Crundall et al., 2006; Chattington et al., 2009; Young et al., 2007). The effects that have been found are a decrease in speed and a greater variation in lateral position. Advertising billboards also draw the visual attention from drivers, increase reaction time, and lead to more errors. Moving billboards and billboards positioned in the central field of vision or at street level (rather than at a raised level) are particularly distracting (Beijer et al., 2004; Crundall et al., 2006). A simulator study among motorcyclists with a probationary licence showed that emotion-inciting billboards were, again, particularly distracting (Megias et al., 2011).

A recent study has also shown that where conventional billboards (i.e., conveying static information) are visually distracting, dynamic billboards (i.e., conveying dynamic or electronic information) appear to be even more so (Dukic et al., 2013; Decker et al., 2014). More specifically, research shows that dynamic billboards generally attract a greater number of visual fixations which are generally longer in duration compared to conventional billboards and other road safety signs (Dukic et al., 2013). The potential for dynamic billboards to capture visual attention for longer durations, especially longer than 2.0 s, has been associated with high crash risk (Klauer et al., 2006). The authors converge to suggest the transient features of dynamic billboards are particularly good at capturing attention.

The information that billboards convey also can influence the extent of driver distraction they impose. For example, messages that are emotion-eliciting (Megias et al., 2011) and taboo-related (Chan, Madan, & Singhal, 2014) have been found to be particularly distracting.

Decker et al. (2014) conducted a systematic literature review of studies examining the effect of roadside advertising on the visual behaviour of drivers (see Table 4). Decker et al. conclude that where passive billboards may be visually distracting, electronic billboards are even more so.

Table 4. Studies reviewed by Decker et al. (2014).

Study	Findings
Beijer et al. (2004)	Driving simulator study. Mean glance duration towards billboards varied considerably ($M = 0,57$ s ($S.D. = 0,41$). Number of glances longer for electronic signs (vs. static signs).
Chan et al. (2010)	Driving simulator study. Novice and experienced drivers have similar glance patterns to roadside advertising.
Chattington et al. (2009)	Driving simulator study. Results showed longer and more frequent glances towards video adverts (vs. static adverts). Video adverts impair driving performance (i.e. braking behaviour, speed variability).
Divekar et al. (2012)	Driving simulator study. The long glances of drivers to external stimulus (i.e. a search task, similar to billboard) degraded driving safety (missed moving threats and potentially hidden hazards).
Dukic et al. (2013)	Instrumented vehicle study. Drivers glanced for longer and more often at electronic billboards than at other signs.
Edquist et al. (2008)	Driving simulator study. Billboards had significant effect on driver speed (slower), ability to follow directions on road signs (slower with more errors), and eye movements (increased amount of time fixating on roadsides at the expense of scanning the road ahead).
Edquist et al. (2011)	Driving simulator study. Presence of billboards changed the pattern of visual attention of drivers, increased time needed for drivers to respond to road signs, and increased number of driving errors.
Kettwich et al. (2008)	Instrumented vehicle study. Electronic billboards attracted longer and a greater number of glances (vs. passive billboards).
Lee et al. (2004)	Instrumented vehicle study. The presence of both static and electronic billboards did not affect visual behaviour, speed variability and lane deviations of drivers (vs. control sites).
Lee et al. (2007)	Instrumented vehicle study. Digital billboards attracted longer glances compared to conventional billboards and control sites (i.e. with no billboard).
Perez et al. (2012)	Instrumented vehicle study. Glance patterns did not differ between electronic and static billboards, both with glance durations well below 2,0 s threshold.
Smiley et al. (2004)	Instrumented vehicle study. Billboards less likely to be looked at than traffic signs. However, when billboards were looked at, the glances were made at short headways and occasionally unsafe circumstances.
Young et al. (2007)	Driving simulator study. Presence of electronic billboards adversely effects lateral control, increases mental workload and eye fixations, and can draw attention away from relevant road signs. A monotonous driving context may increase the risk of billboard distraction.

3.6 Effects of other activities

Daily activities such as eating and drinking influence the driving task as is evident from a naturalistic driving study among car drivers (Stutts et al., 2003). Eating and drinking lead to greater deviations from lateral position, lower speed and more crashes and near crashes. Car drivers also look away from the road more frequently while eating and drinking. They also look away more frequently when they reach for objects or when they are preoccupied with external thoughts.

A recent simulator study demonstrated that drivers engaged in eating/drinking behaviour were more likely to have more collisions, pedestrian strikes, and centre line crossings than controls (Alosco et al., 2012).

Effects of advertising billboards, eating and drinking, reaching for objects and external thoughts on behaviour of pedestrians and cyclists are unknown.

One driving simulator study has looked into the effects of daydreaming on the driving task (Brouwer & Martens, 2007). The participants in the study who were induced to engage in a thinking task while driving task showed greater variation in speeds, and looked less frequently at rear view and wing mirrors. Moreover, the participants reported paying less attention to the driving task.

3.7 Processes that explain effects

There are three basic information-gathering processes that may explain the effects of driver distraction on driving performance: selective attention, divided attention, and visual behaviour.

Selective attention

Selective attention refers to the process whereby one of several competing messages from the environment is chosen for further information processing whereas other messages are filtered out (Wickens et al., 2004). In essence, performing several tasks simultaneously means switching very rapidly between these tasks (Dzubak, 2008). However, during this switch some time the attention is lost (Rogers & Monsell, 1995). This can explain why car drivers need longer reaction times and make more errors if they perform an extra task, such as speaking on the phone or handling a navigation system.

Divided attention and dual-task interference

Driver distraction may be conceptualised as a type of dual-task interference, in which some competing secondary activity interferes with and impairs the concurrent performance of the primary driving task. A number of psychological theories are aimed at accounting for why humans are limited in their performance of two tasks concurrently or temporally close. For example, Pashler (1994) argues that this dual-task interference is due to a bottleneck processing within the human attentional system, only allowing enough attentional resources for the performance of one task, otherwise delaying and impairing the performance of both tasks in question. Conversely, Kahneman (1973) posits that the attentional system is limited by a finite amount of mental resources as opposed to this funnel system, and that dual-task interference occurs when the resources required by the multiple tasks exceed the limit of the “pool”.

Multiple Resource Theory (Horrey & Wickens, 2003) expands upon this single pool theory, stating that multiple ‘pools’ exist for different properties of the task. The model claims that each resource channel is capacity-limited, and that dual-task interference occurs if the tasks demand and exceed the resources of a single channel. These channels are defined by four dimensions: processing stage (i.e., perception, also called central processing, or response), processing code (i.e., the process of analogue/spatial or categorical/verbal information), perceptual modalities (i.e., visual or auditory), and visual channel (i.e., focal or ambient vision). In relation to a driving-relevant example, MRT suggests that since driving primarily demands resources associated with visual perception and makes only minor demands on auditory perception, a secondary task that is visual (e.g., looking at phone) will cause greater dual-task interference than one that is auditory (e.g., listening to radio).

Visual behaviour

According to Theeuwes (2008) the time that a driver glances away from traffic and glances at equipment or an object should not last longer than 1,6 seconds. Horrey and Wickens (2007) found that 80% of simulator-crashes could be attributed to glances at objects inside the vehicle that took longer than 1,6 seconds. A naturalistic driving study of Klauer et al. (2006) showed that long duration glances away from the road were related to increased crash risk. The risk of a crash or near crash doubled when drivers did not look at the road for 2 seconds or longer. Research has demonstrated that the average time of the longest glances at a mobile phone while texting is longer than 2 seconds (Hosking et al., 2009). Typing a message and other intensive visual tasks associated with handling a device inevitably draw attention away thus interfering with the driving task. Visual tasks are, therefore, high risk activities while driving (Hanowski et al., 2009).

Young and Salmon (2012) argue that more precise knowledge is needed about the mechanisms underlying the relationship between distraction and error. The literature provides some insights into the broad mechanisms, including breakdowns in information processing and, impaired visual scanning, but often the specific mechanisms and at what point they occur in a chain of events still remains unclear. For example, it is clear that drivers' inability to recognize information and events occurring earlier on in road scenes are often due to information processing deficits rather than failure to fixate the events. However, it is uncertain if these observed impairments results from disruptions to the encoding of information at the point of fixation or in the retrieval of the information at a later point. Furthermore, these authors point out that research has focused on how distraction contributes to performance impairments and errors, thereby ignoring the question on how distraction might disrupt drivers from recovering successfully from errors. Research is needed to explore the relationship between driver distraction and error recovery, including the mechanisms by which distraction may interrupt successful recovery strategies.

3.8 Self-regulation of attention

Are drivers able to self-regulate their attention when they notice their driving performance is not up to standard? Field experiments by Chrisler (2010) suggest that drivers lack the ability to self-regulate attention deficits while driving. In two simulator experiments, participants evaluated their driving performance before and after driving a simulated curving road under different distraction conditions. In Experiment 1 drivers failed to appreciate their distraction-induced performance decreases and did not recognize the dissociation between staying in lane performance and pedestrian identification performance. In a second experiment Chrisler (2010) found that drivers did not adjust their speed to offset being distracted. He concluded that continuous feedback that steering skills are robust to distraction may prevent drivers from being aware that they are distracted.

Taken together, the results of these two experiments have shown that drivers fail to perceive decreases in the area of identification performance, and instead rely on the positive feedback of staying in lane performance to guide driving strategy (in this instance limited mainly to speed choice). Based on these data, Chrisler argues that we should not expect drivers to be capable of successfully adjusting their driving behaviours to compensate for distraction. The lack of understanding of the dissociation in driving performance decreases caused by distraction is likely to cause inappropriate driving decisions due to unrecognized reductions in awareness (Endsley, 2000).

Driver Distraction

If drivers are not able to self-regulate attention in normal circumstances, the situation worsens when they get tired or fatigued. A study by Barr et al. (2011) provides a better understanding of the relationship between driver drowsiness and driver distraction and inattention. Quantitative evidence was obtained to verify the hypothesis that drivers suffering from fatigue and drowsiness experience “tunnel vision”. When drivers become drowsy, the rate of eye transitions and the proportion of time their eyes are off the road ahead were both found to decrease. Therefore, drowsy drivers are less aware of the driving environment around them, and their ability to recognize potential hazards from other vehicles or objects outside the vehicle is compromised.

Recent evidence also suggests that drowsy and fatigued drivers are more likely to become distracted during driving. A driving simulator study by Anderson and Horne (2013) showed that curtailed sleep the night before led to a fourfold increase in long eye glances (i.e., looking away from the main roadway for >3s). Moreover, driving incidents that occurred as a direct result of inattention or distraction more than doubled.

Older drivers have been shown to self-regulate their driving behaviour to minimise their risk of crashing. Once aware of their difficulties in sharing attention between various tasks they will probably be less inclined to combine driving with other non-driving related activities such as operating a radio or a CD player or having a telephone conversation. Lerner (2008) investigated drivers’ willingness and perceived risk of engaging in various secondary tasks (e.g. eating, drinking, performing different functions with a mobile phone or a navigation system). In general, younger drivers expressed more willingness than middle-aged or older drivers to use in-vehicle technologies. Younger drivers also perceived this usage as less risky than middle-aged and older drivers. Lerner concluded that older drivers’ reluctance to engage in distracting tasks while driving may be a process of self-regulation. In addition, older drivers have been found to be almost four times less likely than younger drivers to report eating/drinking on regular occasions (Young & Lenne, 2010), suggestive of a strategic decision or form of self-regulation practice by older drivers.

In a research survey, Goldenbeld et al. (2012) showed that, among cyclists, willingness to engage in distracting tasks also depends very much on age. While middle-aged and older adult cyclists tended to avoid the use of equipment while cycling in more demanding traffic situations, this was far less visible for teen cyclists and young adult cyclists. Between 30-40% of the teen or young adult cyclists who listened to music while cycling always or nearly always did so in more demanding traffic conditions (darkness, intersections, or heavy traffic). Middle-aged and older cyclists who listened to music 16-23% did this always or nearly always in more demanding conditions. Similarly, between 7-13% of the teen and young adult cyclists always or nearly always used a mobile phone in more demanding situations, whereas almost none of the older cyclists did this always or nearly always.

3.9 Summary of main points on the performance effects of distraction

- The effects of distraction on driving performance have mostly been studied in experiments, frequently in a driving simulator or sometimes in a laboratory or in the field. These effects are not necessarily the same as those in real traffic.
- The relationship between aspects of driving performance and actual crash risk is not always well-known. There is almost no research that has studied both behavioural effects and crash risk at the same time.
- The performance indicators that have been studied are both control variables (speed, lateral position, following distance) as well as the ability to perceive and react to environmental stimuli/cues (visual behaviour, reaction time, errors, conflicts with other road users).
- Different visual-physical tasks related to device use (texting, entering a number, entering a destination, operating a music device) lead to reduced driving performance, i.e. more frequent and longer periods looking away from the road, more objects are missed, greater variation in lateral position, slower reaction time, and a greater number of conflicts with other road users.
- Handheld and hands-free use of phones appear to have similar negative effects on driving task performance.
- Talking with a passenger appears to have less effect on driving task performance since passengers may support the driver with the driving task and adjust the pace and complexity of conversation in reaction to changing task demands.
- Eating and drinking while driving leads to greater deviations from lateral position, lower speed and more (near) crashes. Car drivers also look away from the road more frequently while eating and drinking and when they reach for objects or when they are preoccupied with external matters.
- Roadside advertising can influence driving behaviour. The effects that have been found are a decrease in speed and a greater variation in lateral position. Advertising billboards also draw the visual attention of drivers, increase reaction time, and lead to more errors. Moving billboards and billboards positioned in the central field of vision or on street level (instead of raised level) are a particular distraction for drivers.
- The effects of driver distraction on driving task performance can be explained by three basic processes: selective attention, divided attention and visual behaviour. Distraction diminishes driving performance because attention is drawn to irrelevant tasks (non-driving tasks or less important driving tasks), attention is divided between tasks and is insufficiently focused on important driving information, or visual scanning causes important information to be overlooked.
- Drivers are not able to self-regulate attention to a sufficient degree. Fatigued driving is one of the factors that increases inattention and narrow visual focus.

4 Prevalence of driver distraction

This section describes the research on the prevalence of driver distraction. Section 4.1 describes advantages and disadvantages of research methods. Sections 4.2 and 4.3 describe research on the prevalence of driver distraction among car drivers, pedestrians and cyclists. Section 4.4 pays special attention to the importance of age in the prevalence of driver distraction. Section 4.5 offers a summary of the main points.

For different reasons, knowledge about duration and frequency of sources of distraction is important. Firstly, prevalence data are important for determining the possible change in crash risk associated with a particular source of distraction. Secondly, prevalence data provide information about which activities may distract road users and about patterns in these activities which can be used for developing countermeasures. Thirdly, prevalence data are also an important means of verifying whether countermeasures have actually worked. In short, future research should provide us with knowledge about a broad spectrum of distracting activities in order to determine risk, and develop and evaluate countermeasures for specific categories of distraction.

4.1 Research methods

Studies that aim at determining the prevalence of distracting activities have used survey-type research and observational research and, especially, naturalistic driving-observations. Each method has its limitations and no single method fully registers all distracting activities. Surveys can be performed relatively quickly and cheaply, they can cover large geographical areas and provide insight into behaviour that is difficult to observe. On the other hand, surveys are very much dependent on the accurate memories and honest answers of respondents. Respondents may tend to give socially desirable answers. Internet-surveys do not include respondents with no internet-connection.

Observation studies also have their limitations. Observations at the roadside depend upon the accuracy of the observer. Often the time available for making observations is limited. Roadside observations are often limited to relatively brief periods and a limited number of locations which raises questions about representativeness.

Naturalistic driving studies allow us to observe the behaviour of road users in real traffic conditions over a longer period of time. One disadvantage of this method is that driving behaviour may be influenced by the knowledge of being under observation. Completely reliable and valid registration of eye movements is also not yet possible in naturalistic driving (Regan et al., 2008).

4.2 Prevalence among car drivers

An overview of prevalence measures of distracting activities among car drivers is presented in Table 5.

Table 5. An overview of prevalence measures of distracting activities among car drivers.

Sources of distraction	Distractive activity	% Car drivers engaged in activity		% of total driving time spent on activity	
		Survey	ND-study	Survey	ND-study
Talking and listening	Talking over mobile phone	48 [l]*	30 [a]		1,3 [a]*
	• Handheld	30 [l]* 35 [g]*			
	• Hands-free	35 [l]* 32 [i]			
	Conversation with passenger	40 [b]** 38 [c]** 81 [d]**	77,1 [a]	39 [c]*	15,3 [a] 16,2 [h]***
	Listening to music	92 – 95 [k] 93,7 (radio) [g] 76,7 (cd) [g] 16,7 (iPod) [g]	94 [a]		
Handling devices	Texting	12 [b] 14,1 [f] 17 [e], 26 [j]			
	• Reading	25 [i], 35 [g]			
	• Sending	14 [i], 30 [g]			
	Entering number		27,1 [a]		1,3 [a]*
	Handling music device	95 [b] 47,5 – 65 [k]	1,4 [a]		1,3 [a]
	Entering a destination in a navigation system	12 [i]			
	Following instructions of a navigation system	25 [i]			
	Using a navigation system (generally)	2 [d] 8 [g]			
Other	Eating, drinking (spilling food)	9 [c] 49 [d] 81 [g]	71,4 [a]	30 [c]	1,4 [a] 4,6 [h]
	Reaching after objects	2 [b]	7,1 [a]		
	External cares	8 [d]	45,7 [a]	3 [c]	0,3 [a]

Studies: [a] Stutts et al. (2003); [b] McEvoy (2006); [c] Huemer & Vollrath (2011); [d] Royal (2003); [e] Telstra (2003); [f] AAA Foundation for Traffic Safety (2008); [g] Young & Lenné (2010); [h] Klauer et al. (2006); [i] Lansdown (2009); [j] Madden & Lenhart (2009); [k] Laberge-Nadeau et al. (2003); [l] Intomart GfK, (2008)

Notes: * Combined category use of mobile phone: conversation, handling phone, entering number
 ** Combined category: interaction with a passenger, predominantly having a conversation
 *** Combined category: use of navigation system and Collision Avoidance System

Source: Based on the review by Stelling and Hagenzieker (2012)

Although the figures vary, Table 5 shows that a relatively high number of car drivers engage in distracting activities. In particular, listening to music (radio), talking with a passenger, and eating and drinking frequently occur while driving. More than 90% of car drivers listens to music (radio) and a high percentage (47,5-95%) handle a music device while driving. Between 40 and 80% of drivers talk with a passenger and about 50 to 80% eat or drink inside the car. The ND-study of Stutts et al. (2003) shows that 30% of car drivers use a mobile phone while driving. A Dutch survey found that 48% of car drivers use a phone while driving (Intomart, 2008). About a third use phones hands-free and equally a third handheld. About 15-35% of car drivers sends or reads text messages while driving.

Although many studies have focused on patterns of mobile phone use while driving, little is known about the prevalence of specific sub-tasks of phone use, such as entering the number or only speaking. In recent years there has been an increasing interest in texting while driving: about 13-35% of car drivers (dependent upon question format) sends or reads messages while driving.

Table 5 also shows that whereas many car drivers spend time on distracting activities, the relative amount of time spent on these activities is low. ND-studies show that car drivers spend 23-31% of total driving time on distracting activities (Klauer et al., 2006; Stutts et al., 2005). About half of this time the driver spends talking with a passenger (about 15-16%) and about the same amount of time is spent on other distracting activities such as eating and drinking, mobile phone use and other activities not mentioned in Table 4 (smoking, reading, or even preparing sandwiches).

For specific types of distracting activities there is almost no knowledge at all about prevalence. For example, there is hardly any knowledge about prevalence of looking at advertising billboards, the use of advanced driver assistance systems (ADAS) such as a Collision Avoidance Systems (CAS), Lane Departure Warning Systems (LDWS) or navigation systems. It can be expected that the application and use of these types of systems will increase in the coming years.

Children passengers as a distraction

Another naturalistic driving study (not mentioned in Table 5) found that children (1-8 yrs.) were a large source of distraction to the driver, accounting for 12% of all potential sources of driver distraction (Koppel et al., 2011). For example, drivers were observed checking on their children either by turning back to look at rear seat occupants or by viewing children in the rear-view mirror. On around 46% of these occasions, the driver was engaged in this secondary task for 3 or more seconds and in some cases (8%) for more than 11 seconds.

More than half of these potentially distracting activities were engaged in by drivers while the study vehicle was in motion (56%). To put these results in perspective, it should be noted that drivers spent significantly longer periods engaged in non-child occupant-related activities compared with child occupant-related activities. In addition, a significantly higher proportion of non-child occupant-related activities involved drivers having their eyes off the road for more than 2 seconds while the vehicle was in motion (14%) compared to child occupant-related activities (10%).

It is interesting to note that a recent naturalistic study showed that distracting driving behaviours, such as cell phone use, are less frequent when child passengers are in the vehicle compared to driving alone (Roney et al., 2013). This may be due to parents wanting to practice safer driving

behaviours when travelling with children, or may represent a self-regulatory strategy in the presence of a child that is already burdening the driving with a level of distraction.

Texting while driving

Research examining the prevalence of text messaging behaviour while driving is mainly based on surveys. Surveys can examine the more subjective aspects of driver perceptions, attitudes and behaviour and can gather data from a large number of participants. Surveys also have the advantages of being relatively cheap and quick and easy to administer. Additionally, answers to surveys can be anonymous which increases the chances of participants responding honestly.

Hallett et al. (2012) performed an online survey of texting while driving in New Zealand. A total of 1057 eligible participants completed the survey, of whom 723 were female (68,4%) and 334 (31,6%) were male. Respondents were asked to estimate how many text messages, on average, they read and sent while driving (i.e. in motion) in a 1 week period. The response options for both questions were 'zero', '1-5', '6-10', '11-20', and 'more than 20'. A total of 66,2% of participants (637 of 962) reported reading at least 1-5 text messages and 52,3% (503 of 962) reported sending at least 1-5 text messages while driving, during a typical week. At the upper end of the scale, 7,4% and 5,3% of participants reported reading and sending on average 15,5 text messages per week, respectively. On average, 6,9% of participants reported reading at least 20 text messages while driving per week, while 5,5% reported sending at least 20 text messages while driving per week.

Participants were asked, as a general question, if they felt that text messaging impairs their driving performance. The response options were, "yes", "no" and "not applicable as I never text messages while driving". Including only participants who admitted to text messaging while driving, 89,1% (650 of 730) of participants responded "yes" to this question.

Overall, the results of this study revealed that text messaging while driving was a prevalent behaviour among participants. In accordance with previous research, reading text messages while driving was reported to be more frequent than sending text messages while driving. In total, 66% of participants reported reading at least 1-5 text messages while driving and 52% reported sending at least 1-5 text messages while driving, during a typical week. Additionally, sending text messages was perceived as being more dangerous than reading text messages while driving with drivers being optimistic about the risk of crashing, that is, respondents perceived text messaging while driving themselves as somewhat safer than text messaging by other drivers when they were passengers.

4.3 Prevalence among pedestrians and cyclists

A few studies have appeared that present some data on prevalence of distracting activities among pedestrians or cyclists. Based on the review by Stelling and Hagenzieker (2012), the results of these studies are summarised in Table 6.

Table 6. Prevalence among cyclists and pedestrians

	% cyclists that on almost every trip (left figure) or on some trips (right figure) engaged in an activity Source: a		% cyclists observed engaging in an activity Source: b	% pedestrians engaged in activity during a walk Sources: c (left figure); d (right figure)	
Conversation by phone	3,3	55	1,2	16	24
Conversation with passenger			4,9	14	26,6
Listening to music	15	39	4,9	18,5	27,5
Texting and entering phone number	3		0,3		
Sending message	35				
Reading message	49				
Sources: a: Goldenbeld et al. (2012): survey b: Waard, de et al. (2010): observation on three locations c: calculation by Stelling & Hagenzieker (2012) d: Hyman et al. (2010): observation at one location					

The prevalence figures of cyclists concerning device use are roughly comparable with those of car drivers. A direct comparison is difficult since figures for cyclists are limited to two Dutch studies whereas the figures for car drivers have been taken from a wide array of international studies.

Pedestrians

For pedestrians, prevalence data are insufficient to draw conclusions. In the right column of Table 6, Stelling and Hagenzieker (2012) present prevalence data based on a calculation of data of two observation studies by Hyman et al. (2010), performed at one location. In the first study more than 300 pedestrians were observed (first number per activity in right column) and in the second study about 150 (the second number in right column). About equal proportions of pedestrians listen to music or have a conversation by phone or with a fellow pedestrian. Clearly, one study is not sufficient to draw far reaching conclusions about prevalence of distraction under pedestrians.

Cyclists

In the Netherlands, a survey was set up to monitor the extent of the use of portable, electronic devices while cycling amongst different age groups and to estimate the possible consequences for safety (Goldenbeld et al., 2012). The main research questions concerned age differences in the self-reported use of electronic devices while cycling, self-reported crash involvement and risk. Almost 70% of the Dutch cyclists used a mobile phone or another portable electronic device at least sometimes while cycling. One in every six cyclists did so on every cycling trip. Thirty-one per cent of the respondents never used a mobile phone or another electronic portable device while cycling. On the other hand, 17% of the respondents did so during nearly all cycling trips. Listening to music was the most frequent mode of equipment use, with 15% of cyclists listening to music on every trip or nearly every trip. Furthermore, 3% used the phone on every trip or nearly every trip; 3% sent or read a text message on every trip or nearly every trip; and 1,7%

looked for information on every trip or nearly every trip. Overall, 55% of cyclists used the phone at least occasionally while cycling. Seventeen per cent of cyclists reported using a hand-held phone while cycling during some trips; 2,4% of cyclists reported doing this during all or nearly all cycle trips. Answering a call on a handheld phone while cycling was reported by 23% during some trips and 2,4% reported doing this on every trip or on nearly every trip. In contrast, the use of a hands-free phone to either make or answer a call on some trips was reported by only 5% of cyclists.

Power-Two Wheelers

A recent observational study of motorcyclists showed that the prevalence of mobile phone use was over 0,6%, with an inflated rate of 1,45% among motorcyclists not wearing a helmet (Pérez-Núñez et al., 2013).

4.4 Prevalence and age

Young road users more frequently engage in distracting activities than older road users and are the most frequent users of (new) technologies while driving (Lee, 2007). For many younger drivers, using an electronic device has become part of the traffic task. Compared to older road users, young people more often use a phone, text, and listen to music while driving a car, but also while cycling. Some distractions that are not related to technology also occur more frequently among younger road users. In a survey, McEvoy et al. (2006) found that younger drivers (18-30 yrs.) not only engaged more frequently in mobile phone use than older drivers (50-65 yrs.) but also in the operation of windshield wipers, lights and ventilation systems. They also paid more attention to events, people and objects outside the car. Another study by Young and Lenné (2010) comparing young (18-25 yrs.), adult (26-54yrs.) and older (55+ yrs.) drivers confirmed that younger people (18-25 yrs.) use mobile phones, text, listen to music, and eat and drink while driving more frequently than older drivers (26-54 yrs.; 55+ yrs.).

A recent observational study demonstrated that younger drivers (<30 years of age) engaged in any distracting activity, interacting with other passengers, and texting/dialling more frequently than drivers aged 30-50 and >50 years (Huisinigh, Griffin, & McGwin, 2014). The authors also showed that driver engagement in distracting activities typically occurred when the car was stopped, suggesting that drivers are aware that engagement in these activities may increase attentional competition while concurrently driving.

Age also appears to be an important factor in the prevalence and use of electronic devices among cyclists. A study by Goldenbeld et al. (2012) shows that the use of devices while cycling is very age-specific. Device use for various purposes – (music, phone, information, texting) – was about twice as high among teenaged and young adult cyclists (12-34 years) than among older cyclists (35+ years). Three quarters of 12-17 year olds sometimes used a device to listen to music while cycling, whereas only one eighth of the over 50s did. Younger cyclists (both 12-17 and 18-34 years old) indicated that they continued to use devices for listening or phoning in specifically busy or otherwise complex traffic situations more frequently than older cyclists. More specifically, older cyclists (50+) selectively reported not using devices in these situations – which is a form of compensatory behaviour – two to three times more frequently than younger cyclists (12-34 years).

4.5 Summary of main points on the prevalence of distraction

- Prevalence data are important for determining the possible change in crash risk that is associated with a particular source of distraction. Secondly, prevalence data provide information about which activities may distract road users and about patterns in these activities which can be used for developing countermeasures. Thirdly, prevalence data are also an important means of verifying whether countermeasures have actually worked. In short, future research should provide us with knowledge about a broad spectrum of distracting activities in order to determine risk and develop and evaluate countermeasures for specific categories of distraction.
- Based on available research, it can be concluded that a large number of road users are engaged in activities that can distract from the driving task. Listening to music is very popular among both car drivers and cyclists. Many car drivers are engaged in conversation with a passenger, or using a phone, or eating and drinking. Car drivers spend about 25-30% of total driving time on distracting activities of which about half consists of conversation with a passenger. Age is an important factor for prevalence; the prevalence figures for young road users are substantially higher than those of middle-aged or older road users.
- Prevalence data on distracting activities among cyclists are scarce. The few available studies on cyclists have focused on device use, especially mobile phone use, texting and listening to music. Other types of distracting activities have not been studied yet. Prevalence data on distracting activities among pedestrians are scarce.
- It should be pointed out that the prevalence data for car drivers do not include all possible sources of distraction. Although estimates vary due to differences in research methods and classification of activities, it is presumed that figures underestimate the real size of the problem (Regan et al., 2008).
- A further point for consideration is that prevalence data can become outdated very quickly. The emergence and increasing use of new technologies will lead to new or different patterns of distraction.

5 Driver distraction and crashes

This section presents research on the relationship between distraction and road crashes. Section 5.1 briefly describes the main research methods used to study the relationship between distraction and crashes. Section 5.2 presents findings on the proportion of crashes attributed to distracting activities. In the following three sections, special attention is paid to risk increases due to talking and listening (Section 5.3), to handling equipment (Section 5.4), and looking at advertising billboards (Section 5.5). Section 5.6 specifically compares risk of distracting activities between car drivers and truck/bus drivers and section 5.7 investigates differences in crash risk due to driver age and experience. Section 5.8 looks at risk of device use among cyclists and pedestrians. Section 5.9 provides an overview of findings and section 5.10 presents a summary of the main points.

5.1 Research methods

Identifying the crash risk due to different distracting activities is a difficult research task. Causal relationships are hard to verify. Studies have found relationships between distracting activities and crashes and have attempted to estimate crash risk on the basis of the evidence. It should be borne in mind that, even when a distracting factor was present, the crash itself could have been partly or even totally caused by other factors. Distraction is not the only road safety subject affected by this problem. There are many risk factors for which it is quite difficult to establish crash risk in a very precise and reliable way (see for instance Elvik et al., 2009).

Crash studies are mostly based on police reports of crashes sometimes completed by interviewing persons involved. Two types of crash studies can be distinguished, case-control or case-crossover. In case-control studies, crash statistics of drivers involved in a distractive activity are compared with crash statistics of other drivers who are not involved in a distractive activity. In a case-crossover design, individual drivers involved in crashes are compared with themselves with respect to risk behaviour during periods when they were not involved in a crash. For example, mobile phone use during a crash is compared with mobile phone use of the same driver in a similar period before crash.

Epidemiological research, such as crash studies, often has large sample size and the results can be seen as representative for the population. However, crash studies are likely to provide an under-estimation of the role of distraction in crashes. There are several reasons for this. Firstly, crashes registered by the police represent only part of the total number of crashes. Second, the possible influence of distraction on crash is determined after the event, and information given by the driver or witnesses is not always reliable. Thirdly, the police are not able to detect all types of distraction. Fourthly, in various countries such as the Netherlands, Australia, Belgium, Germany, Greece, Israel, the police do not systematically register whether the driver was in any way distracted during the crash. Finally, even when a distracting activity was present during the crash, there is often insufficient knowledge about whether this was the only or the most important crash cause. Drivers themselves will be reluctant to report a connection between distraction and crash.

A useful addition to general crash research is in-depth investigation of crashes that collects detailed information with the aim of determining which factors and circumstances have led to which type of crashes and the type of injuries which are associated with these crashes. In in-depth investigation a special research team collects additional information on the crash by inspecting crash location and vehicle damage and by interviewing persons involved in crashes.

A disadvantage of crash research is that it cannot provide information on the prevalence of distracting activities. In this respect, naturalistic driving research has an advantage. ND- research can provide us with information about what behaviour and events preceded the crash (or near-crash). This type of research enables the researcher to analyse data concerning crashes or near crashes in comparison with data concerning 'normal' periods of (uneventful) driving (the 'baseline'). This enables the researcher to determine odds-ratios for specific distracting activities. In this context, the odds-ratio is a measure for the change in crash risk associated with a particular distracting activity. An odds-ratio greater than 1 represents an increased crash risk, while that less than 1 represents reduced crash risk.

5.2 Distraction and crash causation

Table 7 presents an overview of study findings concerning the percentage of crashes where distraction has played some role. Taking several study results into consideration, it is estimated that distraction plays a role in the causation of 5% to 25% of car-crashes (Hurts et al., 2011). Higher estimates are given for truck drivers: a naturalistic driving study Olsen et al. (2009) presents an estimate as high as 70%.

Table 7. Overview of studies that provide estimates of percentage of crashes where distraction is involved.

Type of study	Percentage crashes where distraction plays a role
Crash studies	10-12% [a]
Naturalistic driving studies	23% (personal cars) [b] 71% (trucks) [c] 80% (including inattention) [d]
In-depth crash investigation	24-31% (Netherlands) [e] 32% (Europe) [f]
References: [a] Gordon (2008); [b] Klauer et al. (2006); [c] Olsen et al. (2009); [d] Neale et al. (2005); [e] Davidse et al. (2011); [f] Talbot et al. (2013) (including both distraction and inattention)	

Crash studies of driver distraction find that driver distraction is a contributory factor in at least 10-12% of crashes (Gordon, 2008). This method uses police data. These data are sometimes complemented by interviews with the drivers/passengers involved in a crash.

A study by Talbot et al. (awaiting publication) used data about distraction and inattention from the SafetyNet Accident Causation Database. This database was formulated as part of the SafetyNet project to address the lack of representative in-depth accident causation data within the European Union. Data were collected in 6 European countries using ‘on-scene’ and ‘nearly on-scene’ crash investigation methodologies. In this study, inattention was defined as ‘Low vigilance due to loss of focus. Factors that could lead to inattention include coughing; driving on a road where the features and environment remain the same for an extended period (boring road); and over-familiarity with the journey, e.g. not noticing a sign has changed. 32% of crashes recorded in the database involved at least one driver, rider or pedestrian designated as ‘Inattentive’ or ‘Distracted’. 212 of the drivers were assigned ‘Distraction’ and 140 drivers were given the code ‘Inattention’.

Naturalistic driving studies provide us with higher estimates of crashes where distraction plays a role. The ‘100-Car Study’ that followed the driving behaviour of drivers of 100 cars during one year estimates that in almost 80% of crashes and 65% of near-crashes some type of distraction or inattention played a role in the three seconds preceding a crash or near crash (Neale et al., 2005). Looking specifically at distraction by a non-traffic related task (and not at inattention in general), this study found that distraction played a role in 23% of crashes and near-crashes (Klauer et al., 2006). An ND-study by Olsen et al. (2009) studied driving behaviour of 203 truck drivers (in 55 commercial trucks) during 3 months. The researchers found that distraction (by a non-traffic-related task) played a role in 71% of crashes and 46% of near crashes. The higher estimates for the role of distraction in the Olsen et al. study may be caused by lower numbers of crashes in the study, the later date of the study, or the inclusion of more sources of distraction (e.g. texting). Differences in driving behaviour between car drivers and commercial truck drivers may also explain the divergence in results. For example, truck drivers need to scan more of their

environment because the size of their vehicles restricts their view. They also drive more at night and undertake longer journeys.

5.3 Risk of talking and listening

Based on a review by Stelling and Hagenzieker (2012), Table 8 presents changes in crash risk (odds-ratio) when distracted by talking or listening while driving as estimated in epidemiological crash research and naturalistic driving studies. Table 9 presents crash risk data from the interaction with mobile phones and traffic/ road environment. An odds-ratio higher than 1 signifies a distractive activity associated with greater risk than 'normal' driving, whereas, an odds-ratio lower than 1 indicates a lower risk. Odds-ratios that are significantly different from 1 are printed in bold.

Case-crossover crash studies have demonstrated that using a mobile phone while driving increases crash risk by a factor of 4 (Redelmeier&Tibshirani; McEvoy et al., 2005). Case- control crash studies (Violanti & Marshall, 1996; Laberge-Nadeau et al., 2003) also recorded a higher crash risk for mobile phone users (factors 5.6, 1.1/1.2 males/females). However, three naturalistic driving studies show no increased risk of mobile phone use (Klauer et al., 2006; Olsen et al., 2009; Hickman et al., 2010).

A meta-analysis by Elvik (2011) analysed 12 studies on the relationship between phone use and crash risk. The studies contained examples of different study methods (2 case control, 2 case crossover, 4 survey, 1 naturalistic driving and 3 induced exposure). Of the 12 studies six contained relatively reliable information about the use of mobile phones at the time of a crash. The analysis of these six studies showed that risk estimates were quite diverse. The summary estimate of the odds-ratio of crash involvement associated with the use of a mobile phone was 2.86 (i.e., almost a threefold increase in risk). There was evidence of publication bias in the remaining studies with less precise information about mobile phone use which undermines confidence in their risk estimates.

Table 8. Estimates of relative risk (odds-ratios) of talking/listening among drivers of personal cars and trucks/buses). Odds-ratios that are statistically significant different from 1 are in bold.

Distractive activity	Naturalistic Driving-studies		Crash studies
	Person car drivers	Truck-/ bus drivers	
Conversation by mobile phone			4,34 [b] 4,15 [c] 5,66 [b] 1,17 (males) [b] 1,27 (females) [b]
• Handsfree		0,44 [b] 0,65 [c]	5,94 [b] 3,85 [c]
• Handheld	1,3 [a]	1,04 [b] 0,9 [c]	3,94 [b] 4,95 [c]
	0,79 [i]	0,73 (portable hands-free) [i]	
	0,61 (novice drivers) [j]	0,71 (integrated hands-free) [i]	
	0,76 (experienced drivers) [j]		
Conversation with a passenger	0,5 [a]	0,35 [b]	

References: [a] Klauer et al. (2006); [b] Olson et al. (2009); [c] Hickman et al. (2010); [d] Redelmeier & Tibshirani (1997); [e] McEvoy et al. (2005); [f] Violanti & Marshall (1996); [g] Laberge-Nadeau et al. (2003); [h] Backer-Grøndahl & Sagberg (2009); [i] Fitch, Soccolich et al. (2013); [j] Klauer et al. (2014)

The discussion about why different type of studies lead to different result for mobile phone use is ongoing but not yet resolved. The different types of studies, case crossover, case control and naturalistic driving all have their limitations. In studies by Redelmeier and Tibshirani (1997), Laberge-Nadeau et al. (2003) and Violanti & Marshall (1996), a very broad definition of mobile phone use was used which did not distinguishing between specific sub-tasks such as talking, texting, entering number, or reading. In naturalistic driving studies, odds-ratios are calculated for each of the sub-tasks. This particular difference could be one of the possible explanations of why results differ. The methodology of naturalistic driving is also relatively new and discussion of how this methodology can best be applied continues. For example, one of the issues in ND-research is the use of near-crashes as substitute for real crashes. Another issue is the best choice or operationalisation of an appropriate baseline of behaviour.

What possible reasons could there be for the negative effect of mobile phone use on driver performance as demonstrated in laboratory, simulator and field studies not fully transferring to real traffic conditions? Stelling and Hagenzieker (2012) mention three possible explanations:

- behavioural compensation: road users compensate by using a mobile phone in situations where the demands of the driving task are low and by keeping conversations short;
- behavioural compensation by other road users: other road users mobile phone use compensates by anticipation and more alert reactions;
- learning effect: road users/drivers learn to use the device and need less attention to handle it effectively.

Table 9. Risk (odds-ratios) associated with cellphone use by traffic situation. Odds-ratios that are statistically significant different from 1 are in bold

	Commercial drivers		Light vehicle drivers	
Overall use				
	Free flow traffic	1,14	Free flow traffic	1,22
	Some restriction	0,95	Some restriction	0,76
	Restricted/unstable	0,81	Restricted/unstable	0,58
	No junction	1,20	No junction	1,10
	Junction	0,53	Junction	0,49
Talking/listening on hand-held				
	Free flow traffic	1,13	Free flow traffic	1,10
	Some restriction	0,98	Some restriction	0,80
	Restricted/unstable	1,95	Restricted/unstable	0,63
	No junction	1,18	No junction	1,06
	Junction	0,59	Junction	0,49
Talking/listening on portable hands-free				
	Free flow traffic	0,36	Free flow traffic	0,00
	Some restriction	0,48	Some restriction	0,00
	Restricted/unstable	0,50	Restricted/unstable	0,00
	No junction	0,44	No junction	0,00
	Junction	0,51	Junction	0,00

Source: data derived from Fitch et al., 2015

5.4 Risk of handling equipment

Table 10 is based on Stelling and Hagenzieker's review (2012) and presents the change in crash risk (odds-ratio) for different distractive activities, as estimated in epidemiological crash research and naturalistic driving studies. An odds-ratio higher than 1 signifies that a distractive activity is associated with greater risk than 'normal' driving, whereas an odds-ratio lower than 1 indicates a lower risk. Odds-ratios that are significantly different from 1 are printed in bold.

Table 10. Estimates of relative risk (odds-ratios) of handling devices among drivers of personal cars and trucks/buses). Odds-ratios that are statistically significant different from 1 are in bold.

Distractive activity	Naturalistic Driving study		Crash studies
	Car drivers	Truck-/bus drivers	
Texting	1,73 [i]	23,2 [b] 163,6 [c]	
	3,87 (novice drivers) [j]		
Entering number	2,8 [a]	5,93 [b] 3,5 [c]	
	0,99 [i]		
	8.32 (novice drivers) [j]		
	2.49 (experienced drivers) [j]		
Handling a music device	0,6 [a] (radio) 2,3 [a] (cd player)		

References: [a] Klauer et al. (2006); [b] Olson et al. (2009); [c] Hickman et al. (2010); [d] Redelmeier & Tibshirani (1997); [e] McEvoy et al. (2005); [f] Violanti & Marshal (1996); [g] Laberge-Nadeau et al. (2003); [h] Backer-Grøndahl & Sagberg (2009); [i] Fitch, Soccolich et al. (2013); [j] Klauer et al.

5.5 Risk of looking at advertising billboards

One study on roadside advertising indicates that looking at advertising billboards increases crash risk by a factor of 17. This conclusion was derived from a survey study by Backer-Grøndahl & Sagberg (2009) in which car drivers who had crashed in the past year reported on possible sources of distraction during a crash including advertising billboards and about whether or not they or other parties were culpable. Subsequently, numbers of drivers who were reported to be culpable in a crash were compared with numbers of drivers who were reported as not being culpable in order to calculate the relative risk. A calculation of relative risk was made for each separate source of distraction. In this study it was assumed that non-culpable drivers are representative of the total population which is open to question and self-reporting on culpability is unlikely to be totally reliable. Thus, the results and conclusions of this study are not definitive.

Other studies have also attempted to determine the crash risk associated with looking at advertising billboards. Often these studies show a correlation but no causal connection and also have not calculated an odds-ratio. Tantala & Tantala (2005) performed a correlational study that showed that advertising billboards at the roadside have no statistically significant influence on crashes. In a 'before and after' study by the same authors, again, no effect on crashes was found. In a 'before and after' study by Smiley et al. (2005), that compared the effects of moving versus non-moving advertising billboards, no effects on crashes were found. A Swedish 'before and after' study by Dukic et al. (2011) also found no indication of a crash effect in crash numbers or police reports although statistical testing of data was not possible in this study.

5.6 Risk car drivers versus truck and bus drivers

Based on the review by Stelling and Hagenzieker (2012), Table 11 presents change in crash risk (odds-ratio) for different distractive activities as estimated in epidemiological crash research and naturalistic driving studies. An odds-ratio higher than 1 signifies that a distractive activity is

associated with greater risk than 'normal' driving, whereas an odds-ratio lower than 1 indicates a lower risk. Odds-ratios that are significantly different from 1 are printed in bold.

Insofar as it concerns car drivers, the ND-studies in Table 10 show that only two of the distracting activities are associated with increased risk i.e. applying make-up and entering a number in a mobile phone.

Interestingly, studies examining the effects of passengers on driver distraction have yielded mixed results. For example, a number of studies presented odds ratios ($OR = < 1$) which suggest that the presence of passengers have a protective effect (Klauer et al., 2006; Olsen et al., 2009), whereas others suggest that the presence of passengers can increase driver distraction (e.g. Chen et al., 2000). A contributing factor that can be derived from the discordant results regards the age of the driver, with younger drivers being more likely to be distracted or engage in risk-taking behaviour when in the presence of other young passengers (Caird et al., 2014). These authors also contend that, for older drivers, the presence of passengers may mitigate distraction as they provide aid in identifying hazards and anticipating traffic contexts.

Interestingly, having a conversation with a passenger has been found to have a positive, risk decreasing effect (odds-ratio smaller than 1). It is possible that passengers support drivers by actively scanning the environment for possible dangers that the drivers may have missed. However, research among young, novice drivers shows that this positive facilitating effect of passengers is not found. Several studies, both observation and crash studies, have found an increased crash risk of young, novice drivers due to the presence of passengers of the same (Simons-Morton et al., 2005; Williams et al., 2005). This negative effect is not necessary caused by conversation itself; other factors such as risk taking to impress peers may play a role here.

Two ND-studies have looked at the crash risks associated with different distracting activities among truck and bus drivers (Olsen et al., 2009; Hickman et al., 2010). Table 10 shows that texting is the most dangerous activity for these drivers, with high odds-ratios (23,2 in Olsen et al. study; 163,6 in Hickman et al. study). Truck and bus drivers who are texting while driving have a 23 times or even a 160 times higher chance of a crash or near crash than when they are not texting. The difference between odds-ratios may have to do with the fact that Hickman et al. calculated the crash risk by looking at combined activities texting, e-mailing and internet-use.

Other distracting activities that increased risk for truck and bus drivers were entering a number in a mobile phone, reaching for objects, and personal care (applying makeup, hair care). Eating and drinking and having a conversation using a handheld phone did not increase risk and, as in the case with ND-studies on car drivers, conversing with a passenger appeared to reduce risk of a crash or near crash.

Table 11. Estimates of relative risk (odds-ratios) of distractive activities among car drivers and truck-/bus drivers. Odds-ratios that are statistically significant different from 1 are in bold.

Source of distraction	Distractive activity	Naturalistic Driving-studies	
		Person car drivers	Truck-/ bus drivers
Talking and listening	Conversation by mobile phone		
	• Hands-free		0,44 [b] 0,65 [c]
	• Handheld	1,3 [a]	1,04 [b] 0,9 [c]
	Conversation with a passenger	0,5 [a]	0,35 [b]
Handling equipment	Texting		23,2 [b] 163,6 [c]
	Entering number	2,8 [a]	5,93 [b] 3,5 [c]
	Handling a music device	0,6 [a] (radio) 2,3 [a] (cd player)	
	Reach for phone or locate to answer	3,74 [c]	
		3,65 [i]	
		7,05 (novice drivers) [j]	
		1,37 (experienced drivers) [j]	
Other	Looking at advertising		
	Eating and drinking		1,1 [c]
	• Eating	1,6 [a]	1,01 [b]
	• Drinking	1,03 [a]	0,97 [b]
	Reaching for objects (general)	1,4 [a]	3,1 [b]
	• Reaching for specific objects		3,43/3,73/6,72 [b]
	Beauty care	0,7 [a]	4,48 [b]
• Applying makeup	3,1 [a]		

References: [a] Klauer et al. (2006); [b] Olson et al. (2009); [c] Hickman et al. (2010); [d] Redelmeier & Tibshirani (1997); [e] McEvoy et al. (2005); [f] Violanti & Marshal (1996); [g] Laberge-Nadeau et al. (2003); [h] Backer-Grøndahl & Sagberg (2009); [i] Fitch, Soccolich et al. (2013); [j] Klauer et al. (2014)

Having a conversation using a hands-free phone appears to reduce the crash risk of truck drivers in ND-studies. Some researchers suggest that having a conversation using a hands-free phone may help the truck driver to stay awake and alert during long trips or when night driving (Regan & Hallet, 2011). Field experiments show that phone conversations can help truck drivers to stay awake and alert in monotonous traffic circumstances (Jellentrup et al., 2011)

If ND results for car drivers are compared with those of truck and bus drivers in Table 11, it can be seen that ND-studies generally present similar odds-ratios for a specific type of distracting activity. However, there are some differences in estimates for entering a number, varying from 2,8 to 3,5 to 5,9 depending on the study. These differences may reflect the types of drivers that participated in the study. The 100 Car Study (Klauer et al., 2006) studied driving behaviour of car drivers, whereas the study by Olsen et al. (2009) and Hickman et al. (2010) observed the behaviour of truck and bus drivers amongst whom higher risk estimates have been found for

entering a number. Differences could also be explained by the differing definitions of particular distracting activities used (Hickman et al., 2010).

Table 10 shows that distracting activities of a visual/physical nature, such as typing in a number or applying makeup, are associated with higher crash risk among both car drivers and truck/bus drivers. These tasks require that the driver glances away from the road for a longer time, thus hindering the ability to deal with unexpected events. On the other hand, having a conversation with a passenger appears to have a similar risk reducing effect among both categories of drivers. The effect of a conversation with a hands-free phone cannot be compared between car drivers and truck and bus drivers since the 100 Car Study did not calculate odds-ratios for this activity.

Finally, it can be concluded that some distracting activities, such as reaching for objects, appear to increase risk for car drivers but not for truck and bus drivers.

5.7 Differences in crash risk due to driver age and experience

As discussed previously, driver distraction may be more detrimental to driving performance for young and inexperienced drivers as evidenced by elevated crash rates in this population compared to adults (e.g. Regan & Hallett, 2011).

A recent ND study examined the differences in the risk of safety-critical events deriving from driver distraction between novice and experienced drivers (Klauer et al., 2014). The authors found that, while a range of secondary activities significantly increased the risk for crashes and near-crashes for novices (e.g., phone texting, dialing, reaching for an object, looking at a roadside object, eating etc), only dialing was associated with an increased risk for experienced drivers. This research reinforces the moderating effects of driver experience and further points out that the link between distraction and crash risk is not always clear-cut, but depends on a combination of variables.

In the same vein, a recent ND study looked at the link between distraction duration and crash risk in younger drivers. While past research has shown that glances away from the roadway longer than 2,0s is associated with twice the crash risk for adult drivers (Klauer et al., 2006). Simons-Morton et al. (2014) showed that glances of this same length are associated with almost four times the risk of a crash for teenage drivers. This suggests that younger and novice drivers are not as adept as experienced drivers at managing secondary activities.

5.8 Risk of electronic device use among pedestrians and cyclists

Recent studies have extended research on the possible safety effects of electronic devices on other road users, such as pedestrians and cyclists.

Pedestrians

A number of studies indicate that pedestrian behaviour becomes more hazardous when pedestrians use devices, especially mobile phones, while crossing the street (Hatfield & Murphy, 2007; Nasar et al., 2008; Neider et al., 2010; Stavrinou et al., 2009, 2011). Hatfield and Murphy (2007) detected a difference between men and women: women using a mobile phone while crossing the street paid less attention to traffic than men. A study by Nasar et al. (2008) showed

that pedestrians who used mobile phones while walking behaved more dangerously on street crossings than non-users, but also more dangerously than users of audio-devices. Using a virtual traffic environment, Neider et al. (2010) again showed that phone use had a higher impact on successfully and safely crossing a street than listening to music. In other simulator research, it was shown that college students behaved more dangerously when crossing a street while using a mobile phone compared to non-users. This applied to all students irrespective of experience in phone use, attentiveness, or content of conversation (Stavrinou et al., 2011).

A recent observational study showed that wearing headphones, talking on a mobile, and/or looking down at an electronic device increased the propensity of walkers to engage in unsafe intersection crossings (crossing during 'Don't Walk' signals) at a number of dangerous and busy intersections (Basch et al., 2015).

Cyclists

A few studies have investigated the possible road safety implications of the use of devices by cyclists. The results of a Japanese questionnaire study on the use of mobile phones among young cyclists indicated the possibility of an increased risk effect from their use (Ichikawa & Nakahara, 2008). However, this study did not correct its results for other potentially relevant factors such as the extent to which cyclists were exposed to hazardous traffic situations thus limiting its usefulness.

Further evidence concerning device use as a risk factor for cycling comes from a study in the Netherlands. Goldenbeld et al. (2012) estimated changes in crash risk as a consequence of using a device while cycling. Teenage cyclists (12–17 years) and young adult cyclists (18–34 years) were more frequent users, and also more indiscriminate users of portable devices while cycling than middle-aged and older cyclists (35–49 years; 50+ years). After statistical correction for influences on crash risk of urbanisation level, weekly time spent cycling, and cycling in more demanding traffic situations, the odds of being involved in a crash were estimated to be higher for teenage cyclists and young adult cyclists who used electronic devices on every trip compared to same age group cyclists who never used these devices. The authors estimated that for teenage cyclists who reported listening to music, making calls, and answering calls during every trip, the crash odds were a factor of 1.6 greater than for cyclists of the same age who reported never using phones or devices while cycling. Similarly, for young adult cyclists, it was estimated that the crash odds were a factor of 1.8 greater for every trip for users than for those who never used such devices.

5.9 Overview results distraction and risk

Based on a review by Stelling and Hagenzieker (2012), Table 12 presents a summary overview of change in crash risk (odds-ratio) for different distractive activities, as estimated in epidemiological crash research and naturalistic driving studies. An odds-ratio higher than 1 signifies that a distractive activity is associated with greater risk than 'normal' driving, whereas an odds-ratio lower than 1 indicates a lower risk. Odds-ratios that are significantly different from 1 are printed in bold. The results of Table 11 were discussed in Sections 5.3 to 5.7.

Table 12. Estimates of relative risk (odds-ratios) of distractive activities among drivers of personal cars and trucks/buses). Odds-ratios that are statistically significant different from 1 are in bold.

Source of distraction	Distractive activity	Naturalistic Driving-studies		Crash studies
		Person car drivers	Truck-/ bus drivers	
Talking and listening	Conversation by mobile phone			4,34 [b] 4,15 [c] 5,6 6 [b] 1,1 (males) [g] 1,2 (females) [g]
	• Hands-free		0,44 [b] 0,65 [c]	5,94 [b] 3,85[c]
	• Handheld	1,3 [a]	1,04 [b] 0,9 [c]	3,94 [b] 4,95[c]
	Conversation with a passenger	0,5 [a]	0,35 [b]	
Handling equipment	Texting		23,2 [b] 163,6 [c]	
	Entering number	2,8 [a]	5,93 [b] 3,5 [c]	
	Handling a music device	0,6 [a] (radio) 2,3 [a] (cd player)		
Other	Looking at advertising billboard			16,95 [h]
	Eating and drinking		1,1 [c]	
	• Eating	1,6 [a]	1,01 [b]	
	• Drinking	1,03 [a]	0,97 [b]	
	Reaching for objects (general)	1,4 [a]	3,1 [b]	
	• Reaching for specific objects*		3,43/3,73/6,72 [b]	
	Beauty care	0,7 [a]	4,48 [b]	
• Make oneself up	3,1 [a]			
References: [a] Klauer et al. (2006); [b] Olson et al. (2009); [c] Hickman et al. (2010); [d] Redelmeier & Tibshirani (1997); [e] McEvoy et al. (2005); [f] Violanti & Marshal (1996); [g] Laberge-Nadeau et al. (2003); [h] Backer-Grøndahl & Sagberg (2009)				
* odds-ratio 3,43 concerns reaching for a head set; 3,73 concerns reaching for a mobile phone; 6,72 concerns reaching for or use of an electric device				

Data derived from naturalistic driving studies and other methodologies used to examine the link between driver distraction and crash risk need to be interpreted with some level of caution.

Firstly, definitions of driver distraction and safety critical events vary considerably and therefore may encourage researchers to adopt different operational definitions for these constructs (Regan et al., 2009), which may account for why the prevalence of distraction varies across studies (Gordon, 2009). In addition, these varying operational definitions could entice the use of different coding systems between studies. For example, some researchers may only code distractions as being in-vehicle events or objects and neglect outside sources, or perhaps define behaviours that would be typically categorised as driver inattention (e.g., fatigued state) as a driver distraction instead (Beanland et al., 2013).

Secondly, naturalistic studies often fail to capture certain types of distraction such as mind wandering (e.g., stress, daydreaming) (Gordon, 2009).

Finally, the associations between engagement with technology such as mobile phones and risk of a safety critical event may be confounded by such variables as time of day or traffic state. Methods for controlling confounders, such as the use of multivariate regression or by stratification, have only been recently used in the naturalistic driving studies (e.g. Fitch et al., 2015).

However, despite these potential methodological and theoretical issues, the link between driver distraction and the risk of safety-critical events is hard to refute based on the converging evidence derived from naturalistic studies and other methodologies.

5.10 Summary of main points on driver distraction and crashes

- In epidemiological research about 5 to 25% of car crashes have been attributed to driver distraction. In one study of truck drivers, a much higher estimate of 70% has been found. Differences in estimates between studies may be connected with differences in operational definitions, in research methods and driver populations. Both crash studies and naturalistic driving studies have shown that distraction contributes to a substantial number of crashes and consequently poses a serious safety problem. Activities that cause visual distraction – e.g., looking away from the road during texting – appear to be the most dangerous according to odds-ratio estimates.
- Various sources of distraction appear to enhance crash risk but studies differ in estimates of effects. The evidence concerning the influence of mobile phone use on crash risk is mixed. Case-crossover-crash studies have demonstrated an increased crash risk for mobile phone use while driving at about a factor 4 higher. Case-control crash studies also show higher crash risk for mobile phone users. However, naturalistic driving studies show no increased risk. The method of naturalistic driving research is still relatively new and the divergence between results for mobile phone use has not yet been resolved.
- There are various reasons why the negative effect of mobile phone use on driver performance as has been demonstrated in laboratory, simulator and field studies does not fully transfer to real traffic conditions. When using the phone either the driver or other road users may adjust their behaviour and road users and drivers learn to use a device and need less attention to handle it effectively.
- Distracting activities of a visual/physical nature, such as typing in a number or applying make-up are associated with higher crash risk among both car drivers and truck and bus drivers. These tasks require drivers to glance away from the road for a longer time thus hindering the ability to deal with unexpected events.
- For truck and bus drivers distracting activities that increased risk were entering a number in a mobile phone, reaching for objects, and beauty care (applying makeup, hair care, etc.). Eating and drinking and conversing by handheld phone did not increase risk for this group and, as in

the case with ND-studies on car drivers, conversing with a passenger appeared to reduce risk of a crash or near crash.

- Conversing with a passenger has been found to have a positive, risk decreasing effect. It seems possible that passengers support drivers by actively scanning the environment for possible dangers that the drivers may have missed. Research among young novice drivers shows that this positive facilitating effect of passengers does not apply in their case.
- Having a conversation using a hands-free phone appears to reduce risk for truck drivers in ND-studies. Some researchers suggest that having a conversation by hands-free phone may help the truck driver to stay awake and alert during long trips or trips at night. A field experiment indeed showed that a phone conversation can help truck drivers to stay awake and alert in monotonous traffic circumstances.
- The evidence concerning change in crash risk as a consequence of looking at advertising billboards is not yet convincing. No strong conclusions can yet be drawn.
- There is some evidence that pedestrians and cyclists have higher crash risk due to the use of portable devices especially mobile phones. Use of portable devices appears to be a particular risk factor for teenaged and young adult cyclists. Knowledge about the risk of distracting activities among cyclists and pedestrians needs further research.
- Finally, it should be pointed out that risk estimates by odds-ratios only present part of the picture, namely the tasks which are associated with increased risk of crash or near-crash. The duration and frequency of sub-tasks is also pertinent. Certain sub-tasks that are performed rarely or that are of short duration are unlikely to lead to a large number of crashes even if they are associated with increased risk. On the other hand, sub-tasks with lower odds-ratios could be more important for numbers of crashes when they are frequently performed or take a long time to carry out. Prevalence data – described in preceding Section 4 – are very important in estimating the risks associated with a particular distracting activity.

6 Driver distraction in future automated driving

Automated vehicles are those in which some aspects of a safety-critical control function (e.g. steering, throttle control) occur without direct driver input (NHTSA, 2013). Today, a greater number of cars are beginning to employ automated systems such as collision warnings and adaptive cruise control. It is predicted that fully autonomous vehicles will be available on the market by 2030 (Walker, Stanton, & Young, 2001). Presently, automated driving systems are not yet 100% reliable and safe. This means that the driver still has an appreciable role in the driving task, especially when required to intervene in the case that automated technology is limited in its capability (e.g. sensor degradation). This can pose a problem for the driver if they are inattentive or distracted.

Automation is expected to reduce the effort of manual driving, but may inadvertently reduce workload to a dangerously low level. During long periods of automation, the driver may suffer from passive fatigue, which usually derives from situations of low arousal (Desmon and Hancock, 2001). While driver inattention may not have consequences during periods of automation on less

demanding roads, situations which require sudden human input may be met with a late response and therefore may fail to relieve the critical situation effectively and safely. Simulator studies reiterate this point, showing that drivers in high levels of automated driving are more likely to have longer reaction times to braking and steering corrections in the face of a sudden emergency event (Neubauer, Matthews, Langheim & Saxby, 2012; Saxby, Matthews, Warm, Hitchcock & Neubauer, 2013). It is believed that drivers may have difficulty dealing with the sudden increase in workload created by an automation failure event, especially if the driver is not concentrating on the driving task, (Young & Stanton, 1997), which could result in a crash.

Periods of automated driving may also encourage drivers to engage in secondary activities that are more stimulating (e.g. mobile phone texting) as opposed to monitoring the road context. Driving simulator studies support this premise, showing that drivers are more likely to partake in other non-driving-related activities and spend more time looking away from the forward roadway at higher levels of automation (Merat et al., 2012; Carsten et al., 2012). Again, this higher propensity to become distracted during automation will be especially dangerous in situations in which the driver is suddenly required to regain control of the car (e.g. Merat et al., 2012).

Driver inattention (including distraction) may degrade the ability of a driver to manually intervene an automated driving system as it may reduce the driver's situational awareness (SA). Colloquially, SA is the drivers understanding of the surrounding environment and it requires monitoring of both the vehicle state and road context (Endsley, 1995). If a driver's level of SA is too low, actions and requests by the automated system can be unanticipated and surprising to the driver (i.e. automation surprise), which can suddenly increase driver workload and impair a quick response (Hollnagel & Woods, 2005). On the other hand, a low level of SA may leave the driver unsure about what modes are controlled by automation and which are controlled by the driver (i.e. mode confusion; Cummings and Ryan, 2014). For example, this can be especially dangerous as an inattentive driver may incorrectly assume that the vehicle's reverse collision warning sensors are on when in fact they are not, which will be dangerous when reversing as the driver expects the automated system to give warning of objects in close proximity when in fact it won't.

Overall, automated driving systems are aimed at relieving drivers of the effort associated with manual driving. However, drivers in autonomous vehicles that are incapable of driving autonomously in all traffic situations must still stay vigilant to the driving task at hand (i.e., stay attentive and not distracted) as this will degrade the timing and safety of manual re-engagements when automated systems fail or reach their limits of competence.

7 Countermeasures

This chapter describes possible countermeasures to reduce distraction in traffic. Section 7.1 explains the importance of constantly updating knowledge about countermeasures. Subsequent sections describe five categories of countermeasures against distraction, namely legislation and enforcement (Section 7.2), driver training (Section 7.3), publicity campaigns (Section 7.4), technology design and guidelines (Section 7.5.), road infrastructure (Section 7.6). A summary of main points is also presented (Section 7.7).

7.1 Importance of knowledge-based countermeasures

Knowledge about driver distraction is changing rapidly and it is important to stay informed about the latest insights. Countermeasures to distraction should be based on the best available reliable scientific knowledge regarding the underlying mechanisms of distraction, the prevalence of different distractive activities and the risks that go together with these activities.

Knowledge about driver distraction has changed in recent years. For example, it was originally thought that handheld mobile phone use was dangerous because it draws visual attention away from the road. However behavioural studies have shown that, even when looking at the road, having a conversation by phone can negatively influence driving performance by taking concentration away from driving. Another development is that having a conversation by mobile phone may be less dangerous than originally thought. Naturalistic driving observations show lesser or no negative effects in contrast to classic crash studies although some caution is needed in interpreting these results, since study methodologies are quite new. The precise risks of using a mobile phone while driving have yet to be determined.

7.2 Legislation and enforcement

Some sources of distraction are best countered with legislative measures and guidelines. In the case of distraction by advertising billboards, a legal ban on positioning them close to the road is likely to be much more effective than a general publicity campaign. Guidelines for the safe use and positioning of these billboards can also be formulated using knowledge about distraction. For instance, billboards should not move, nor attract attention for too long and should not be placed in the centre of the field of vision (SWOV, 2009).

Device-related distraction has also been tackled by a legislative approach with new legislation to regulate use while driving being introduced in the EU, USA and Australia.

EU Legislation

In the EU, legislation against the use of devices in vehicles can be specific or general (Avenoso, 2012). Articles refer specifically and explicitly to a Nomadic Device (ND) and restrict its use (e.g. "hand-held mobile phone use is not allowed"). Articles of general law also implicitly address the use of NDs whilst driving (e.g. through the broader issue of "driver distraction", or "careless or dangerous driving", or similar phrases). In the EU, all countries (except Sweden) have adopted specific regulations concerning the use of mobile phones (Avenoso, 2012). 13 countries have general legislation in place concerning the use of personal navigation devices (PNDs) with 4 countries adopting specific regulations; 7 countries have general legislation in place for music players with 6 countries adopting specific regulations; 10 countries have general legislation in place for TV and video players with 6 countries adopting specific regulations.

Legislation in Europe

Legislation for mobile phones

All EU countries (except Sweden) require use of hands-free equipment. Most commonly a headset or wireless equipment (e.g. Bluetooth) is sufficient. Some countries additionally require that a phone must be fixed in a mounting (Greece, Italy, Luxembourg, Malta, and Slovenia). Luxembourg and Slovenia have more demanding regulations in place that restrict the use or fixing of mobile phones in various ways (e.g. functions that involve continuous handling are prohibited).

Legislation for personal navigation devices (PND)

Manual interaction with a PND when driving is prohibited in some EU countries. France, Italy and the UK responded that they will prohibit the use of the media player function of this device. In Germany, requirements for PND use derive from a specific ban on radar warning equipment in which it is prohibited to use Points Of Interest (POIs) to indicate stationary speed cameras. The POI data/software must be deleted from the device's memory. The majority of countries have regulations in place that affect the location of mounting (e.g. field of view)

Legislation for music players

12 EU countries have restrictions in place either on manual interaction with music players and/or on headphone use. In 5 countries (Finland, Italy, Slovenia, Slovakia and Switzerland) manual interaction with music players is not allowed for the driver when the vehicle is moving. 9 EU countries are addressing the use of headphones while driving, 7 countries prohibit headphone use and 2 countries have limits on the sound level. Italy and Slovenia intervene most severely with their regulations affecting both the manual handling of music players and the use of headphones.

Legislation for TVs and video players

For the driver, both manual interaction and watching TV/video are prohibited when the vehicle is moving. Estonia, Greece, Spain, Finland, Italy, Portugal, and Slovenia have restrictions on the use of TVs/Video players in which both the manual handling and watching TV/video are specifically addressed. TV/video players used by passengers in Spain, Italy, and Portugal stipulate must not be visible to the driver.

Source Janitzek et al., 2010; summary Avenoso, 2012

Enforcement

Legislation against the use of devices while driving requires enforcement. Enforcement against the illegal use of electronic devices is technically more difficult when compared to traditional offences. The extent of distraction is practically impossible to assess from outside the vehicle and the miniaturisation of devices makes their detection difficult. Enforcement is non-automated and carried out by police officers. In about half of the European countries targeted checks are applied. In some jurisdictions offences outnumber traditional offences such as driving in an impaired condition or unbelted notwithstanding the presence of specific enforcement albeit at low levels (Avenoso, 2012).

7.3 Training

In regular driver training and in special driver training programs attention should be paid to strategies to recognise and avoid driver distraction.

Several studies have documented that the failure of drivers to pay attention to the road ahead for a period of more than 2-3 seconds is a major cause of road crashes. Moreover, several studies have demonstrated that novice drivers are more likely to glance away from the road for

extended periods when attempting to do a task inside the vehicle when compared to experienced drivers.

A study by Pradhan et al. (2011) examined the efficacy of a training program designed to teach novice drivers not to glance away for these extended periods of time. A PC-based training programme, 'FOrward Concentration and Attention Learning' (FOCAL), was developed to limit the duration of the glances that novice drivers make away from the road ahead to under 2 seconds. This training programme used error learning as a key component and took about one hour to complete. Specifically, the participants could make errors (glance for too long at a simulated in-vehicle task) and then correct these errors after receiving feedback. In the study, the FOCAL-trained group was compared with a placebo-trained group in an on-road test. The FOCAL-trained group, as predicted, made significantly fewer glances away from the road that lasted more than 2 second than the placebo-trained group.

7.4 Publicity campaigns

Given the difficulty in removing the causes of distraction, such as the use of mobile phones, and in enforcing laws related to particular sources of distraction, the use of strong campaigns to promote awareness of risk and change behaviour is a necessary part of a program of countermeasures.

In preparing campaigns to reduce driver distraction it is useful to understand prevailing social norms for behaviours such as texting and phoning while driving. Research by Atchley et al. (2016) examined this issue by asking younger drivers to read car crash scenarios and rate the responsibility of the driver for the crash and to levy fines and assign jail time, as a function of whether the driver was sufficiently attentive, had been drinking, or was distracted by phoning or texting. In the first experiment ratings were performed in the absence of information about laws against drunk and driver distraction (injunctive norms). Descriptive norms refer to whether behaviour is typical or atypical, while injunctive norms refer to whether behaviour is typically met with approval or disapproval. In the second experiment, injunctive norm information was included. Impaired drivers were viewed as more responsible in both experiments, with texting drivers viewed as the most responsible. However, drunk drivers received the most fines and jail time. When compared to data from the 1970s, the results show that anti-drunk driving campaigns have changed how younger drivers view drunk driving but that norms have not yet changed for driver distraction in spite of consistent results showing that risks are known. The research data support the idea that driver distraction is not connected to the lack of perceived risk but rather a disconnection between the norms underlying the behaviour and knowledge of risk. These data, along with data showing that norms have changed in younger drivers with respect to drinking and driving, suggest that driver distraction campaigns cannot simply focus on risk-awareness strategies, but should instead use an approach that deals with both descriptive and injunctive norms. Strict law enforcement further enhances these norms.

7.5 Technological countermeasures

Driver distraction caused by technology is a serious problem but if technology is part of the problem it can also be part of the solution. The approach to date has mainly been through the introduction of national laws and their enforcement supported by awareness campaigns,

although some organisations have started to develop guidelines and standards to make in-vehicle information and communication systems less distracting.

Many efforts have been made to develop guidelines for in-vehicle devices (NHTSA, 2010, Adolph, 2011). NHTSA sponsored a cooperative agreement with the CAMP (Crash Avoidance Metrics Partnership) industry consortium to develop workload metrics (measures of driver performance). In addition, several European countries have conducted metrics development efforts under the HASTE (Human Machine Interface and the Safety of Traffic in Europe) program. Several manufacturers have also developed metrics under the ADAM (Advanced Driver Attention Metrics) program. Transport Canada proposed a Memorandum of Understanding with automotive manufacturers with regard to adherence to industry-developed performance guidelines relating to telematics device design and development. These guideline efforts have subsequently supported many current and continuing research programmes.

Considering the increasing number of options a driver has to stay informed, entertained and/or connected, it is recognised that technology standards should not make a distinction between OEMs (Original Equipment Manufacturers) and other products, or between permanently installed and carry-in devices (Adolph, 2011). In-vehicle systems must be easy to learn, intuitive to use and include design features that individually address the four types of distraction described above. Tasks, such as entering a destination into the route guidance system need to be resumable (or 'chunkable'). Users should be able to control the pace of interaction with the system and completing a task should neither be time limited nor adversely affect driving (Hammer et al., 2007).

These and other principles of basic ergonomics as well as the interplay of in-vehicle information and communication systems with other in-car and driver assistance systems (e.g., adaptive cruise control, lane keeping assistance, collision warning) have been outlined in standards and guidelines issued by standards bodies and automobile organizations, including International Standards Organisation (ISO), Society of Automotive Engineers (SAE), Alliance of Automobile Manufacturers (AAM), Japan Automobile Manufacturers Association (JAMA), and the UK's Transport Research Laboratory (TRL). The European Commission issued a recommendation on safe and efficient in-vehicle information and communication systems (EC, 1999). See also Erso web text on eSafety.

Future approaches and standards to reduce driver distraction could include continuously updated status information provided by both, fixed and nomadic devices and vehicles (Adolph, 2011). Most smartphones and other devices are equipped with different kinds of sensors and GPS receivers; this information could be combined with data obtained from a vehicle's on-board units and driver assistance systems, or with traffic updates received from external service providers or traffic police. Based on parameters such as the car's velocity, location, density of traffic or driving style and driver experience, the in-vehicle information and communication system can decide (and enable or disable) which feature is safe enough to be used in a particular situation. Adolph (2011) provides the following examples: a mobile phone may allow a hands-free call when driving on a highway outside the city but prohibit a call in hectic traffic situations and temporarily suspend the call when turning right (with a message to the other end – 'call temporarily suspended owing to driving conditions') and not allow a ring tone when overtaking (message on the other end – 'please wait for driving conditions to improve').

In addition to distraction-specific technologies, several driver assistance technologies (e.g., lane departure warning, crash-imminent braking, forward collision warning) have the potential to reduce the negative impact of driver distraction.

Driver distraction mitigation strategies

One major project dealing with distraction mitigation and adaptation of other warnings to driver state was the US project SAVE-IT. The main participants were Delphi Electronics & Safety, UMTRI, the University of Iowa, General Motors, Ford and Seeing Machines. Within SAVE-IT a taxonomy for distraction mitigation strategies was developed that classifies themes having a high, moderate or low level of automation and as being driving-related or non-driving related. Within these, system-initiated or driver-initiated system were distinguished.

One example of a system initiated, driving-related distraction mitigation strategy is a system that provides real-time visual feedback regarding drivers' off-road glances. Donmez et al. (2007) investigated whether real-time visual feedback regarding drivers' off-road glances can alter drivers' interactions with in-vehicle information systems and enhance driving performance. Drivers receiving direct feedback on their visual behaviour during their interaction with in-car technology, spent less time looking at the device and more time looking at the road (Donmez et al., 2007). Feedback did not result in longer mean durations of glances at the in vehicle display, so there was no evidence to suggest that feedback imposed an additional distraction on the driver. This is important because there is a possibility that concurrent feedback can interfere with ongoing task performance.

In addition, studies have also shown that head-monitoring systems can reduce driver distraction event frequency by almost 80% through the use of real-time distraction alerts and dispatcher feedback (Croke & Cerneaz, 2009).

7.6 Road infrastructure measures

It has been estimated that around 30% of driver-distracted crashes derive from the driver being distracted by sources outside the vehicle (Regan et al., 2009). Sources outside the vehicle that can lead to driver distraction and contribute to crashes include landmarks, road signs, advertising billboards, animals, architecture, construction zones, traffic incidents (Regan et al., 2009). The potential impact of these sources of distraction can be moderated to varying degrees through road design.

Relative to the amount of research on sources of distraction deriving from inside the vehicle, far less has been done in relationship to external sources of distraction (Regan et al., 2009). Methods are needed for identifying external sources of distraction on or near roads that have the potential to adversely affect driving performance and safety. Preferably, road safety audits and assessment protocol should include criteria for the identification and assessment of road-way related activities, objects and events that can distract drivers and degrade driving performance and safety.

For some specific distractions such as advertising billboards or rumble strips some evidence is available. Studies have shown that it is better not to place advertising and information billboards at busy traffic spots (SWOV, 2009). It is also essential that they should not resemble traffic signs or other traffic indicators to avoid confusion. Furthermore, blinking and moving objects have proven to be difficult to ignore and should therefore be avoided. Different levels of

government all have their own guidelines for the placing advertising and other objects on or alongside the road. Unambiguous guidelines are advisable (SWOV, 2009).

A road infrastructure safety measure that reduces inattentive driving is the installation of rumble strips. Rumble strips are raised or grooved patterns on the roadway shoulder that provide both an audible warning (rumbling sound) and a physical vibration to alert drivers that they are leaving the driving lane. In addition to warning inattentive or distracted drivers, rumble strips help drivers to stay on the road during difficult weather conditions when visibility is poor. Research has shown rumble strips to be a very cost-effective measure (Erso web text on Fatigue).

7.7 Summary of main points on countermeasures

- Knowledge of the problem of distraction is undergoing constant revision. For example it was initially thought that use of handheld mobile phone is risky because drivers look away from the road while using a phone. Accordingly, many countries introduced a ban on the use of handheld phones. Recent behavioural studies have provided a new insight and show that even a phone conversation where the driver keeps looking at the road can negatively affect driving performance by taking concentration away from the driving task. Another example of new insight is that having a conversation by mobile phone might be less risky than originally thought. Naturalistic driving studies show that mobile phone use has little or even no negative effects on driving task performance. At the moment there is some lack of clarity about the specific risk associated with mobile phone use and its specific sub-tasks.
- There are several possible countermeasures against distraction in traffic: legal ban on certain distracting activities, legal ban on positioning of advertisements too close to the road, publicity campaigns targeting specific distractive activities, focus on responsible use of devices during driver training, changes to road infrastructure, changes to the design of technology used in cars (either fixed or nomadic devices), and the application of warning systems.
- It is possible to inform road users about the dangers of specific activities. A promising intervention is training based on error learning that motivates young drivers to use devices more safely while driving. In this training drivers are allowed to make mistakes then they are made aware of mistakes and can subsequently improve their performance. The road environment can also be adjusted, for example, by enabling car drivers to stop at a safe place to phone or to text. The installation of rumble strips is another way of stimulating the continued attentiveness of drivers. Technology itself can be adjusted so that more user friendly designs draw less attention from the driver. Warning systems can be applied that warn the distracted driver or even intervene when risk increases.
- The effects of driver distraction on the driving task and crash risk have been well researched. However, few evaluations exist of countermeasures. In view of the interest in driver distraction among both policymakers and the general public, and in view of the higher quality of recent data-collection techniques, it can be expected that knowledge concerning driver distraction will grow considerably in the future. Knowledge has already changed substantially over recent years and will continue to change in the coming years. Knowledge about risk in relationship to various sources of distraction and knowledge about effective countermeasures are both important.

Driver Distraction

- Since sources of distraction can be varied and since not everything is yet known about the distracting activities which are associated with risk, a combination of countermeasures seems appropriate consisting of legal measures, publicity and training, technology-based countermeasures, and last but not least, a change in the way of thinking about behaviour that is acceptable. The gradual development of new social norms for behaviours such as texting or phoning while driving could be one of the most important factors in decreasing risk of driver distraction in the coming decades.
- In addition to distraction-specific technologies, several driver assistance technologies (e.g., lane departure warning, crash-imminent braking, forward collision warning) have the potential to reduce the negative impact of driver distraction.
- Some sources of distraction require different types of countermeasure. In the case of advertising billboards, it makes more sense to prohibit the placement of billboards close to the road than to implement a publicity campaign warning road users of the risks of looking at them.

References

- AAA Foundation for Traffic Safety (2008) Cell phones and driving: research update. AAA Foundation for Traffic Safety, Washington, DC.
- Adolph, M. (2011) Decreasing Driver Distraction ITU-T Technology Watch Report. August 2010. ITU Telecommunication Standardization Bureau, Geneva.
- Alosco, M.L., Spitznagel, M.B., Fischer, K.H., Miller, L.A., Pillai, V., Hughes, J., et al. (2012) Both texting and eating are associated with impaired simulated driving performance. *Traffic Injury Prevention*. 13 (5), 468–475.
- Anderson, C. and Horne, J. A. (2013) Driving drowsy also worsens driver distraction. *Sleep Medicine*, 14(5): 466-468.
- Atchley, P., Hadlock, C. & Lane, S. (in press) Stuck in the 70s: The role of social norms in distracted driving. *Accident Analysis and Prevention*.
- Avenose, A. (2012) European Progress. Presentation at the Driven to Distraction Conference, March 1st 2012, Toronto. ETSC, Brussels.
- Backer-Grøndahl, A. & Sagberg, F. (2009) Relative crash involvement risk associated with different sources of driver distraction. Paper presented at Driver Distraction and Inattention Conference 2009, Gothenburg, Sweden.
- Barr, L.C., Yang, C.Y.D., Hanowski, R.J. & Olson, R. (2010) An Assessment of Driver Drowsiness, Distraction, and Performance in a Naturalistic Setting. FMCSA-RRR-11-010. U.S. Department of Transportation, Federal Motor Carrier Safety Administration, Washington.
- Basacik, D., Reed, N. & Robbins, R. (2011) Smartphone use while driving: A simulator study, report no. PPR592, TRL, Wokingham.
- Basch C., Ethan, D., Zybert, P., & Basch C. (2015) Pedestrian behaviour at five dangerous and busy Manhattan intersections. *Journal of Community Health*, 40(4), 789-792.
- Beanland, V., Fitzharris, M., Young, K. L., & Lenné, M. G. (2013) Driver inattention and driver distraction in serious casualty crashes: Data from the Australian National Crash Indepth Study. *Accident Analysis & Prevention*, 54, 99-107.
- Beijer, D., Smiley, S. & Eizenman, M. (2004) Observed driver glance behaviour at roadside advertising signs. *Transportation Research Record: Journal of the Transportation Research Board* TRB, 1899, pp. 96-103.
- Brodsky, W. (2002) The effects of music tempo on simulated driving performance and vehicular control. In: *Transportation Research Part F: Traffic Psychology and behaviour*, 4f (4), pp. 219-241.

Brouwer, R.F.T. & Martens, M.H. (2007) Internal distraction and driving: does it show? In: The Fourth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, pp 68-74. Stevenson, Washington.

Burns, P.C., Parkes, A.M. & Lansdown, T.C. (2003) Conversations in cars: the relative hazards of mobile phones. In: XVth Triennial Congress of the International Ergonomics Association. Seoul, Korea.

Caird, J.K., Willness, C.R., Steel, P. & Scialfa, C. (2008) A meta-analysis of the effects of cell phones on driver performance. *Accident Analysis & Prevention*, 40(4), pp. 1282-1293.

Caird, J.K., Johnston, K.A., Willness, C.R., Asbridge, M. & Steel, P. (2014) A meta-analysis of the effects of texting on driving, *Accident Analysis & Prevention*, vol. 71, pp. 311-318.

Callens, V. (1997) De invloed van luidemuziek op het rijgedrag. Faculteit Lichamelijke Opvoedingen Kinesitherapie. Katholieke Universiteit Leuven, Leuven.

Carsten, O., Lai, F. C. H., Barnard, Y., Jamson, A. H., & Merat, N. (2012) Control task substitution in semi-automated driving: Does it matter what aspects are automated? *Human Factors*, 54, 747-761.

Chan, E., Pradhan, A., Pollatsek, A., Knodler, M., & Fisher, D. (2010) Are driving simulators effective tools for evaluating novice drivers' hazard anticipation, speed management, and attention maintenance skills? *Transportation Research Part F: Traffic Psychology and Behaviour*, 13(5), 343-353.

Chan, M., Madan, C., & Singhal, A. (2014) The effects of taboo-related distraction on driving performance. In: *Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting*.

Chen, L-H., Baker, S. P., Braver, E. R. & Li, G. (2000) Carrying passengers as a risk factor for crashes fatal to 16-and 17-year old drivers. *Journal of the American Medical Association*, 283, 1578- 1582.

Chattington, M., Reed, N., Basacik, D., Flint, A., et al. (2009) Investigating driver distraction: the effects of video and static advertising. RPN256. Transport Research Laboratory, London.

Chiang, D.P., Brooks, A.M. & Weir, D.H. (2004) An experimental study of destination entry with an example automobile navigation system. In: *Society of Automotive Engineers Special Publication*, vol. SP-1593.

Chisholm, S.L., Caird, J.K. & Lockhart, J. (2008) The effects of practice with MP3 players on driving performance. *Accident Analysis and Prevention*, 40(2), pp. 704-713.

Chrisler, M.C. (2010) Are distracted drivers aware that they are distracted? Exploring awareness, self-regulation and performance in drivers performing secondary tasks. Dissertation Graduate School Clemson University. South Carolina.

Consiglio, W., Driscoll, P., Witte, M. & Berg, W.P. (2003) Effect of cellular telephone conversations and other potential interference on reaction time in a braking response. In: *Accident Analysis & Prevention*, 35 (4), pp. 495-500.

Croke, D., & Cerneaz, N. (2009) Real time distraction detection and warning system improves safety on public roads: A case study. Paper presented at the First International Conference on Driver Distraction and Inattention, Göteborg, Sweden.

Crundall, D., Van Loon, E. & Underwood, G. (2006) Attraction and distraction of attention with roadside advertisements. *Accident Analysis & Prevention*, 38 (4), p. 671-677.

Cummings, M. L., & Ryan, J. (2014) POINT OF VIEW: Who Is in Charge? The Promises and Pitfalls of Driverless Cars. *TR News*, 292, 25-30.

Davidse, R.J., Doumen, M.J.A., Duijvenvoorde, K. van & Louwse, W.J.R. (2011) Bermongevallen in Zeeland: karakteristiekenoplossingsrichtingen. R-2011-20. Institute for Road Safety Research SWOV, Leidschendam.

De Waard, D., Westerhuis, F. & Lewis-Evans, B. (2015) More screen operation than calling: the results of observing cyclists' behavior while using mobile phones. *Accident Analysis and Prevention*, 76, 42-48.

Decker, J., Stannard, S., McManus, B., Wittig, S., Sisiopiku, V., & Stavrinou, D. (2014) The Impact of Billboards on Driver Visual Behavior: A Systematic Literature Review. *Traffic Injury Prevention*, 16(3), 234-239.

Desmond P.A. & Hancock P.A. (2001) Active and passive fatigue states. In: Hancock PA, Desmond PA, editors. *Stress, workload, and fatigue*. Mahwah, NJ: Lawrence Erlbaum. pp. 455-465.

Dingus, T., McGehee, D., Hulse, M., Jahns, S., Manakkal, N., Mollenhauer, M. & Fleischman, R. (1995) TravTek evaluation task C3 camera car study. Pub. No. FHWARD-94-076. Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration.

Divekar, G., Pradhan, A., Pollatsek, A., & Fisher, D. (2012) Effect of External Distractions. *Transportation Research Record: Journal of The Transportation Research Board*, 2321(1), 15-22.

Donmez, B., Boyle, L.N. & Lee, J.D. (2007) Safety implications of providing real-time feedback to distracted drivers. *Accident Analysis and Prevention*, 39, p. 581-590.

Drews, F.A., Pasupathi, M. & Strayer, D.L. (2008) Passenger and cell phone conversations in simulated driving. *Journal of Experimental Psychology: Applied*, 14 (4), pp. 392-400.

Dukic, T., Ahlström, C., Björketun, U., Kettwich, C., et al. (2011) Effects of billboards on traffic safety – A study on the motorway E4 in Stockholm. VTI, Linköping, Sweden.

Dzubak, C.M. (2008) Multitasking: The good, the bad, and the unknown. *Synergy*, vol. 1, nr. 2, found at: http://atp.jsu.edu/Synergy_1/Syn_6.pdf.

EC (1999) Recommendation of the Commission of the European Communities to the Member States and Industry on Safe and Efficient In-Vehicle Information and Communication Systems: A European Statement of Principles on Human

Edquist J. (2008) The Effects of Visual Clutter on Driving Performance [dissertation]. Melbourne, Australia: Monash University.

Edquist, J., Horberry, T., Hosking, S., & Johnston, I. (2011) Effects of advertising billboards during simulated driving. *Applied Ergonomics*, 42(4), 619-626.

Elvik, R. (2011) Effects of Mobile Phone Use on Accident Risk: Problems of Meta-Analysis When Studies Are Few and Bad. *Transportation Research Record*, 2236, pp. 20-26.

Elvik, R., Høye, A., Vaa, T. & Sørensen, M. (2009) The handbook of road safety measures. Second revised ed. Emerald Group Publishing, Bingley, United Kingdom.

Endsley, M.R. (1995) Toward a theory of situation awareness in dynamic systems. *Human Factors*, 37, 32-64.

Fitch, G., Bowman, D., & Llaneras, R. (2014) Distracted Driver Performance to Multiple Alerts in a Multiple-Conflict Scenario. *Human Factors*, 56(8), 1497-1505.

Fitch, G., Hanowski, R. & Guo, F. (2015) The risk of a safety-critical event associated with mobile device use in specific driving contexts. *Traffic Injury Prevention*, vol. 16, 124-132.

Fofanova, J., & Vollrath, M. (2011) Distraction while driving: The case of older drivers. *Transportation Research, Part F*, 14, 638-648.

Garay-Vega, L., Pradhan, A.K., Weinberg, G., Schmidt-Nielsen, B., Harsham, B., Shen, Y., Divekar, G., Romoser, M., Knodler, M. & Fisher, D.L. (2010) Evaluation of different speech and touch interfaces to in-vehicle music retrieval systems, *Accident Analysis and Prevention*, vol. 42, pp. 913-920.

Goldenbeld, C., Houtenbos, M., Ehlers, E. & de Waard, D. (2012) The use and risk of portable electronic devices while cycling among different age groups. *Journal of Safety Research*, 43 (1), pp. 1-8.

Gordon, C. (2009) Crash studies of driver distraction. In: Regan, M.A., Lee, J.D. & Young, K.L. (Ed.), *Driver Distraction: Theory, Effects and Mitigation*. CRC Press, Boca Raton, Florida.

Groeger, J.A. (2000) *Understanding driving: applying cognitive psychology to a complex everyday task*. Psychology Press, Taylor & Francis Group, East Sussex, UK.

Hallett, C., Lambert, A., Regan, M.A. (2012) Text messaging amongst New Zealand drivers: Prevalence and risk perception. *Transportation Research Part F*, 15, pp. 261-271.

Hammer, M., Douglas, F., & Tobin, D. (2007) Technology and driver distraction—the need for industry guidelines. In I. Faulks, M. Regan, M. Stevenson, J. Brown, A. Porter, & J. Irwin (Eds.) *Distracted driving* (pp. 525-576). Sydney, NSW: Australasian College of Road Safety.

Hanowski, R.J., Olson, R.L., Hickman, J.S. & Bocanegra, J. (2009) Driver distraction in commercial vehicle operations. Paper presented at Driver Distraction and Inattention Conference 2009, Gothenburg, Sweden.

Harrison E., & Fillmore M. (2011) Alcohol and distraction interact to impair driving performance. *Drug and Alcohol Dependence*, 117, 31–37.

Hatfield, J., & Murphy, S. (2007) The effects of mobile phone use on pedestrian crossing behaviour at signalised and unsignalised intersections. *Accident Analysis & Prevention* 39(1), pp 197-205.

He, J., Chapparo, A., Nguyen, B., Burge, R., Crandall, J., Chaparro, B., Ni, R. & Cao, S. (2013), Texting while driving: Is speech-based texting less risky than handheld texting? Proceedings of Automotive User Interfaces and Interactive Vehicular Applications, Eindhoven, Netherlands.

He, J., Choi, W., McCarley, J.S., Chaparro, B. & Wang, C. (2015) Texting while driving using Google Glass: promising but not distraction-free, *Accident Analysis & Prevention*, vol. 81, pp. 218–229.

Hickman, J.S., Hanowski, R.J. & Bocanegra, J. (2010) Distraction in commercial trucks and buses: assessing prevalence and risk in conjunction with crashes and near-crashes. Federal Motor Carrier Safety Administration, Washington D.C.

Horberry, R., Anderson, J., Regan, M., Triggs, Y. & Brown, J. (2006) Driver distraction: the effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance, *Accident Analysis & Prevention*, vol. 38, pp. 185–191.

Horrey, W. J., & Wickens, C. D. (2003) Multiple resource modeling of task interference in vehicle control, hazard awareness and in-vehicle task performance. In Proceedings of the Second International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design (pp. 7–12). Iowa City: Human Factors Research Program, University of Iowa.

Horrey, W. & Wickens, C. (2006) The impact of cell phone conversations on driving using meta-analytic techniques, *Human Factors*, vol. 48, 196–205.

Horrey, W.J. & Wickens, C.D. (2007) In-vehicle glance distribution, tails, and models of crash risks. *Transportation Research Record*, vol. 2018, pp. 22-28.

Hosking, S.G., Young, K.L. & Regan, M.A. (2009) The effects of text messaging on young drivers. *Human Factors*, 51 (4), pp. 582-592.

Huemer, A.K. & Vollrath, M. (2011) Driver secondary tasks in Germany: Using interviews to estimate prevalence. In: *Accident Analysis & Prevention*, 43 (5), pp. 1703-1712.

Huisingh, C., Griffin, R., & McGwin, G. (2014) The prevalence of distraction among passenger vehicle drivers: a roadside observational approach. *Traffic Injury Prevention*, ePub.

Hunton, J. & Rose, J.M. (2005) Cellular phones and driving performance: the effects of attentional demands on motor vehicle crash risk. *Risk Analysis*, 25, p. 855-866.

Hurts, K., Angell, L.S. & Perez, M.A. (2011) The distracted driver: mechanisms, models and measurement. In: *Reviews of Human Factors and Ergonomics*, 7(1), pp. 3-57.

Hyman, I.E., Boss, S.M., Wise, B.M., McKenzie, K.E., et al. (2010) Did you see the unicycling clown? Inattentional blindness while walking and talking on a cell phone. In: *Applied Cognitive Psychology*, 24 (5), pp. 597-607.

Ichikawa, M., & Nakahara, S. (2008) Japanese High School Students' Usage of Mobile increase injury risk for college pedestrians. *Journal of Safety Research*, 42, pp. 101–107.

IntomartGfK (2008) Handheldbellen Juli 2008: Een internet onderzoek in opdracht van het Bureau VerkeershandhavingOpenbaarMinisterie. IntomartGfK, Hilversum.

Jäncke, L., Musial, F., Vogt, J. & Kalveram, K.T. (1994) Monitoring radio programs and time of day affect simulated car driving performance, *Perceptual Motor Skills*, vol. 79, pp. 484–486.

Janitzek, T., Brenck, A., Jamson, S., Carsten, O., Eksler, V. (2010) Study on the regulatory situation in the member states regarding brought-in (i.e. nomadic) devices and their use in vehicles Study tendered by the European Commission (SMART 2009/0065). IGES, Berlin.

Jellentrup, N., Metz, B. &Rothe, S. (2011) Can talking on the phone keep the driver awake? Results of a field-study using telephoning as a countermeasure against fatigue while driving. Paper presented at Driver Distraction and Inattention Conference 2011, Gothenburg, Sweden

Kahneman, D. (1973). *Attention and effect*. Englewood Cliffs, NJ: Prentice Hall.

Kettwich C., Klinger K., Lemmer U. (2008) Do advertisements at the roadside distract the driver? *Proc. SPIE*. 7003:1–5.

Klauer, S.G., Dingus, T.A., Neale, V.L., Sudweeks, J., et al. (2006) The impact of driver inattention on near-crash/crash risk: An analysis using the 100-Car Naturalistic Driving Study data. Virginia Tech Transportation Institute, Blacksburg, Virginia.

Koppel, S., Charlton, J., Kopinathan, C., & Taranto, D. (2011) Are child occupants a significant source of driving distraction? *Accident Analysis and Prevention*, 43, pp. 1236– 1244.

Kujala, T. (2013) Browsing the information highway while driving: Three in-vehicle touch screen scrolling methods and distraction, *Personal and Ubiquitous Computing*, vol. 17, pp. 815–823.

Laberge-Nadeau, C., Maagb, U., Bellavance, F., Lapierre, S.D., et al. (2003) Wireless telephones and the risk of road crashes. *Accident Analysis and Prevention*, 35, pp. 649-660.

Lansdown, T. (2009) Frequency and severity of in-vehicle distractions: a self-report survey. Paper presented at Driver Distraction and Inattention Conference 2009, Gothenburg, Sweden.

Lee SE, McElheny MJ, Gibbons R. (2007) *Driving Performance and Digital Billboards: Final Report*. Blacksburg, VA: Virginia Tech Transportation Institute.

Lee SE, Olsen ECB, DeHart MC (2004) Driving Performance in the Presence and Absence of Billboards. Blacksburg, VA: Virginia Tech Transportation Institute.

Lees, M. N., & Lee, J. D. (2007) The influence of distraction and driving context on driver response to imperfect collision warning systems. *Ergonomics*, 50(8), 1264-1286.

Lee, J.D. (2007) Technology and teen drivers. *Journal of Safety Research*, 38 (2), p. 203- 213.

Lee, J.D., Young, K.L. & Regan, M.A. (2008) Defining driver distraction. Regan, M.A., Lerner, N. D. (2008) Driver strategies for engaging in distracting tasks using in-vehicle technologies: final report. National highway traffic safety administration, Washington, DC.

Lee, J.D., Roberts, S.C., Hoffman, J.D., Angell, L.S. (2012) Scrolling and driving: how an MP3 player and its aftermarket controller affect driving performance and visual behavior. *Human Factors* 54, 250–263.

Machine Interface. European Commission, Brussels.

Madden, M. &Lenhart, A. (2009) Teens and distracted driving: Texting, talking and other uses of the cell phone behind the wheel. Pew Research Center, Washington, D.C.

McCartt, A.T., Hellinga, L.A. &Braitman, K.A. (2006) Cell phones and driving: Review of research. *Traffic Injury Prevention*, 7(2), pp. 89-106.

McEvoy, S.P., Stevenson, M.R. & Woodward, M. (2006) The impact of driver distraction on road safety: results from a representative survey in two Australian states. *Injury Prevention*, 12 (4), p. 242-247

McEvoy, S.P., Stevenson, M.R., McCartt, A.T., Woodward, M., et al. (2005) Role of mobile phones in motor vehicle crashes resulting in hospital attendance: a case-crossover study. *British Medical Journal*, 331, pp. 428-430.

Meesmann, U., Boets, S. &Tant, M. (2009) MP3 players and traffic safety; State of the art. Belgian Road Safety Institute, Brussels.

Megías, A., Maldonado, A., Catena, A., Di Stasi, L.L., et al. (2011) Modulation of attention and urgent decisions by affect-laden roadside advertisement in risky driving scenarios. *Safety Science*, 49 (10), pp. 1388-1393.

Merat, N., Jamson, H., Lai, F., & Carsten, O. (2012) Highly automated driving, secondary task performance and driver state. *Human Factors*, 54, 762–771.

Nasar, J., Hecht, P., &Wener, R. (2008) Mobile telephones, distracted attention, andNeale, V.L., Dingus, T.A., Klauer, S.G., Sudweeks, J., et al. (2005) An overview of the 100-car study and findings. Paper No. 05-400. U.S. Department of Transportation DOT, National Highway Traffic Safety Administration NHTSA, Washington, D.C.

Neider, M. B., McCarley, J. S., Crowell, J. A., Kaczmarek, H., & Kramer, A. F. (2010) Pedestrians, vehicles, and cell phones. *Accident Analysis & Prevention*, 42(2), pp. 589–594.

Neubauer C., Matthews G., Langheim L., & Saxby D. (2012) Fatigue and voluntary utilization of automation in simulated driving. *Human Factors* 54(5): 734–46.

NHTSA (2010) Overview of the National Highway Traffic Safety Administration's Driver Distraction Program. National Highway Traffic Safety Administration, Washington.

National Highway Traffic Safety Administration (NHTSA) (2013) Preliminary statement of policy concerning automated vehicles. National Highway Traffic Safety Administration, Washington DC, National Highway Traffic Safety Administration.

OECD Scientific Expert Group (1990) Road transport research-behavioural adaptations to changes in the road transport system. OECD Publications, Paris.

Olson, R.L., Hanowski, R.J., Hickman, J.S. & Bocanegra, J. (2009) Driver distraction in commercial vehicle operations. US Department of Transportation, Washington, DC.

Stavrinos D., Byington, K., Schwebel, D. (2009) Effect of Cell Phone Distraction on Pediatric Pedestrian Injury Risk. *Pediatrics*, 123(3), pp. 179–185.

Oron-Gilad, T., Ronen, A. & Shinar, D. (2008) Alertness maintaining tasks (AMTs) while driving. *Accident Analysis and Prevention*, 40, pp. 851-860.

Owens, J.M., McLaughlin, S.B. & Sudweeks, J. (2011) Driver performance while text messaging using handheld and in-vehicle systems. In: *Accident Analysis and Prevention*. 43 (3), pp 939-947.

Pashler, H. (1994) Dual-task interference in simple tasks: Data and theory. *Psychological Bulletin*, 116, 220-244.

Pêcher, C., Lemercier, C. & Cellier, J.-M. (2009) Emotions drive attention: Effects on driver's behaviour. *Safety Science*, 47 (9), p. 1254-1259.

Pradhan, A.K., Divekar, G., Masserang, K., Romoser, M., et al. (2011) The effects of focused attention training on the duration of novice drivers' glances inside the vehicle. *Ergonomics*, 54 (10), 10, pp. 917-931.

Perez WA, Bertola MA, Kennedy JF, Molino JA. (2012) Driver Visual Behavior in the Presence of Commercial Electronic Variable Message Signs (CEVMS). Washington, DC: NHTSA; Report No. FHWA-HRT-.

Pérez-Núñez R., Hidalgo-Solorzano E., Vera-Lopez J.D., Lunnen J.C., Chandran A., Hajar M., et al. (2014) The prevalence of mobile phone use among motorcyclists in three Mexican cities. *Traffic Inj Prev* 2014; 15:148-50.

Pradhan, A.K., Li, K., Bingham, Simons-Morton B.G., Ouimet, M.C., Shope, J.T. (2014) Peer passenger influences on male adolescent drivers' visual scanning behavior during simulated driving. *Journal of Adolescent Health*, 54, S42-S49.

Redelmeier, D.A. & Tibshirani, R.J. (1997) Association between cellular-telephone calls and motor vehicle collisions. In: *The New England Journal of Medicine*, 336, pp. 453-458.

Reed, N. & Robbins, R. (2008) The effect of text messaging on driver behaviour, report no. PPR 387, Transport Research Laboratory, England.

Regan, M.A., Lee, J.D. & Young, K.L. (2008) *Driver Distraction: Theory, Effects and Mitigation*. CRC Press, Boca Raton, Florida.

Regan, M. & Hallett, C. (2011) Driver distraction: definition, mechanisms, effects, and mitigation. In: Porter, B. (Ed.), *Handbook of Traffic Psychology*. Elsevier, Amsterdam.

Regan, M.A., Hallett, C. & Gordon, C.P. (2011) Driver distraction and driver inattention: Definition, relationship and taxonomy. *Accident Analysis & Prevention*, 43 (5), p. 1771-1781

Regan, M.A., Trent, W.V., Lee, J.D. & Young, K.L. (2009) Driver distraction injury prevention countermeasures – Part 3: Vehicle, technology and road design. In: Regan, M.A., Lee, J.D. & Young, K.L. (Ed.), *Driver Distraction: Theory, Effects and Mitigation*, pp. 579-601. CRC Press, Boca Raton, Florida.

Rogers, R.D. & Monsell, S. (1995) Costs of a predictable switch between simple cognitive tasks. *Journal of experimental Psychology: General*, 124, pp. 207-231.

Roney L, Violano P, Klaus G, Lofthouse R, Dziura J. (2013) Distracted driving behaviors of adults while children are in the car. *Journal of Trauma and Acute Care Surgery*

Royal, D. (2003) National survey of distracted and drowsy driving attitudes and behavior: 2002 Volume I: Findings. National Highway Traffic Safety Administration, Washington, DC.

Saxby, D.J., Matthews, G., Warm, J.S., Hitchcock, E.M., & Neubauer, C. (2013) Active and passive fatigue in simulated driving: Discriminating styles of workload regulation and their safety impacts. *Journal of Experimental Psychology: Applied*, 19(4): 287-300.

Scott, J.J. & Gray, R. (2008) A comparison of tactile, visual, and auditory warnings for rear-end collision prevention in simulated driving. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 50, p. 264.

Simons-Morton, B., Lerner, N. & Singer, J. (2005) The observed effects of teenage passengers on the risky driving behavior of teenage drivers. *Accident Analysis & Prevention*, 37(6), pp. 973-982.

Simons-Morton, B., Guo F., S.G. Klauer, J.P. Ehsani, A.K. Pradhan (2014) Keep your eyes on the road: young driver crash risk increases according to duration of distraction. *J. Adolesc. Health*, 54 (2014), pp. S61-S67

Smiley, A., Smahel, T., & Eizenman, M. (2004) Impact of Video Advertising on Driver Fixation Patterns. *Transportation Research Record*, 1899(1), 76-83.

Smiley, A., Persaud, B., Bahar, G., Mollett, C., Lyon, C. & Smahel, T. (2005) Traffic safety evaluation of video advertising signs. Paper presented at the 84th Annual Meeting of the Transportation

Research Board TRB, Washington, D.C., 9-13 January 2005. National Research Council NRC, Transportation Research Board TRB/National Academy Press, Washington D.C.

Srinivasan, R. & Jovaris, P.P. (1997) Effect of in-vehicle route guidance systems on driver workload and choice of vehicle speed: finding from a simulator experiment. In: Noy, Y.I. (Ed.), Ergonomics and Safety Intelligent Driver Interfaces. Lawrence Erlbaum Associates, Mahwah, NJ.

Stavrinos, D., Byington, K. W., & Schwebel, D. C. (2009) Effect of cell phone distraction.

Stavrinos, D., Byington, K. W., & Schwebel, D. C. (2011) Distracted walking: Cell phones

Stelling, A., en Hagenzieker, M.P. (2012) Afleiding in het verkeer. Report R-2012-4. Institute for Road Safety Research SWOV, Leidschendam.

Strayer, D.L., Watson, J.M. & Drews, F.A. (2011) Cognitive distraction while multi-tasking in the automobile. *Psychology of Learning and Motivation*, 54, pp. 29-58.

Strayer, D.L., Drews, F.A. & Johnston, W.A. (2003) Cell phone induced failures of visual attention during simulated driving, *Journal of Experimental Psychology: Applied*, vol. 9, pp. 23-32.

Stutts, J., Feaganes, J., Reinfurt, D., Rodgman, E., et al. (2005) Driver's exposure to distractions in their natural driving environment. *Accident Analysis & Prevention*, 37 (6), 6, pp. 1093-1101.

Stutts, J.C., Feaganes, J., Reinfurt, D., Rodgman, E., et al. (2003) Distractions in everyday driving. AAA Foundation for Traffic Safety, Washington, D.C.

SWOV (2009) Roadside advertising and information. SWOV factsheet, January 2009. Institute for Road Safety Research SWOV, Leidschendam.

Talbot, R., Fagerlind, H., Morris, A. (2012) Exploring inattention and distraction in the SafetyNet Accident Causation Database. *Accident Analysis and Prevention*.

Tantala, M.W. & Tantala, P.J. (2005) An examination of the relationship between advertising signs and traffic safety. Paper presented at the 84th Annual Meeting of the Transportation

Telstra (2003) Police and NRMA Insurance join forces to target mobile phone use on Australian roads. Retrieved September 30, 2009, from

http://www.telstra.com.au/abouttelstra/media/announcements_article.cfm? ObjectID=26961

Theeuwes, J. (2008) Visuele afleiding in het verkeer. Vrije Universiteit, Amsterdam.

Tijerina, L., Parmer, E. & Goodman, M.J. (1998) Driver workload assessment of route guidance systems destination entry while driving: A track test study. In: Proceedings of 5th ITS World Congress. Seoul, Korea.

Törnros, J.E.B. & Bolling, A.K. (2005) Mobile phone use—Effects of handheld and handsfree phones on driving performance. In: *Accident Analysis & Prevention*, 37(5), pp. 902-909.

Trick, L. M. and Enns, J. T. (2009) A two-dimensional framework for understanding the role of attention selection in driving. In *Human Factors of Visual and Cognitive Performance in Driving*, Edited by: Castro, C. 63–72. Boca Raton, FL: CRC Press.

Violanti, J.M. & Marshall, J.R. (1996) Cellular phones and traffic accidents: an epidemiological approach. In: *Accident Analysis & Prevention*, 28, pp. 265-270.

Waard, D. de, Schepers, P., Ormel, W., & Brookhuis, K. (2010) Mobile phone use while cycling: Incidence and effects on behaviour and safety. *Ergonomics*, 53(1), pp. 30–42.

Waard, D. de, Edlinger, K., & Brookhuis, K. (2011) Effects of listening to music, and of using a handheld and handsfree telephone on cycling behaviour. *Transportation Research Part F: Traffic Psychology and Behaviour*, 14(6), 626–637.

Walker, G., Stanton, N., & Young, M. (2001) Where Is Computing Driving Cars? *International Journal of Human-Computer Interaction*, 13(2), 203-229.

White, C. and Caird, J. (2010) The blind date: The effects of change blindness, passenger conversation and gender on looked-but-failed-to-see (LBFTS) errors, *Accident Analysis and Prevention*, 42, 1822–1830.

WHO (2011) Mobile phone use: A growing problem of driver distraction. World Health Organization, Geneva.

Wickens, C.D., Lee, J., Liu, Y. & Gordon-Becker, S.E. (2004) *An Introduction to Human Factors Engineering*. Pearson-Prentice Hall, Upper Saddle River, New Jersey

Williams, A.F., Ferguson, S.A. & Wells, J.K. (2005) Sixteen-year-old drivers in fatal crashes, United States. *Traffic Injury Prevention*, 6, p. 202-206.

Williams, A.F., Ferguson, S.A. & Wells, J.K. (2005) Sixteen-year-old drivers in fatal crashes, United States. *Traffic Injury Prevention*, 6, pp. 202-206.

Young, M. S. & Stanton, N. A. (1997) Automotive automation: Investigating the impact on drivers' mental workload. *International Journal of Cognitive Ergonomics*, 1(4), 325–336.

Young, K.L., Regan, M.A., Lee, J.D. (2008). Factors moderating the impact of distraction on driving performance and safety. In: Regan, M.A., Lee, J.D., Young, K.L. (Eds.), *Driver Distraction: Theory, Effects, and Mitigation*. CRC Press Taylor & Francis Group, Boca Raton, FL, USA, pp. 335–352.

Young, K.L. & Lenné, M.G. (2010) Driver engagement in distracting activities and the strategies used to minimise risk. In: *Safety Science*, 48 (3), pp. 326-332.

Young, K.L. & Salmon, P.M. (2012) Examining the relationship between driver distraction and driving errors: A discussion of theory, studies and methods. *Safety Science*, 50, pp. 164- 175.

Driver Distraction

Young, K.L., Mitsopoulos-Rubens, E., Rudin-Brown, C.M. & Lenné, M.G. (2011) Driver behaviour and task-sharing strategies when using a portable music player. Paper presented at the Driver Distraction and Inattention Conference 2011, Gothenburg, Sweden.

Zwaag, M.D. van der (2012) Music directs your mood. Thesis University Groningen. University of Groningen, Eindhoven
<http://dissertations.ub.rug.nl/faculties/gmw/2012/m.d.van.der.zwaag/?pLanguage=en&pFullItemRecord=ON>.

Notes

1. Country abbreviations

	Belgium	BE		Italy	IT		Romania	RO
	Bulgaria	BG		Cyprus	CY		Slovenia	SI
	Czech Republic	CZ		Latvia	LV		Slovakia	SK
	Denmark	DK		Lithuania	LT		Finland	FI
	Germany	DE		Luxembourg	LU		Sweden	SE
	Estonia	EE		Hungary	HU		United Kingdom	UK
	Ireland	IE		Malta	MT			
	Greece	EL		Netherlands	NL		Iceland	IS
	Spain	ES		Austria	AT		Liechtenstein	LI
	France	FR		Poland	PL		Norway	NO
	Croatia	HR		Portugal	PT		Switzerland	CH

2. This 2015 edition of Traffic Safety Synthesis on Driver Distraction updates the previous version produced within the EU co-funded research project [DaCoTA](#) (2012). This Synthesis on Driver Distraction was originally written in 2012 by Charles Goldenbeld, [SWOV](#) and then updated in 2015 by Mike Regan, [ARRB](#).

3. All Traffic Safety Syntheses of the European Road Safety Observatory have been peer reviewed by the Scientific Editorial Board composed by: George Yannis, NTUA (chair), Robert Bauer, KFV, Christophe Nicodème, ERF, Klaus Machata, KFV, Eleonora Papadimitriou, NTUA, Pete Thomas, Un.Loughborough.

4. Disclaimer

This report has been produced by the National Technical University of Athens ([NTUA](#)), the Austrian Road Safety Board ([KFV](#)) and the European Union Road Federation ([ERF](#)) under a contract with the [European Commission](#). Whilst every effort has been made to ensure that the matter presented in this report is relevant, accurate and up-to-date, the Partners cannot accept any liability for any error or omission, or reliance on part or all of the content in another context.

Any information and views set out in this report are those of the author(s) and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this study. Neither the Commission nor any person acting on the Commission's behalf may be held responsible for the use that may be made of the information contained therein.

5. Please refer to this Report as follows:

European Commission, Driver Distraction, European Commission, Directorate General for Transport, September 2015.

