Driver distraction without presence of secondary tasks: Inattention, cognitive overload and factors outside the vehicle – an overview.

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Abstract

Distraction is induced through a variety of sources that can be present both inside and outside the vehicle, and may involve a secondary task (e.g. mobile phone use, conversation with passenger, use of navigation or other in-vehicle systems etc.). The objective of this study is to provide an assessment and critical review of the effects of distraction induced without the presence of a secondary task, which can be categorized in two different groups. The first group is driving under an improper state of mind, which includes inattention and distractions through cognitive overload. The second group consists of factors outside the vehicle, which include static objects or advertising signs, vision-impairing glare caused by sun or other vehicles' lights and observing people or situations outside the vehicle. For inattention and distraction through cognitive overload, eight high quality studies regarding were reviewed and it was found that inattention has a mostly detrimental effect on road safety. The specific impacts of these distractions vary, but they are negative and can be deduced that driver behavioral variables such as perception and braking performance are affected. There are some positive results that show reduced injury severity or increased perception, but these occur mainly due to overcompensation effects. The majority of the studies were observational studies which investigated past accident data. For distraction factors outside the vehicle, twelve high quality studies were reviewed. It can be argued that these factors create mostly negative impacts on road safety, with all statistically significant effects being detrimental. Both accident numbers and various driver behavioral variables such as lateral control and speeding are affected. There were cases, however, that reported no statistically significant effects. Based on the sample of countries of the reviewed studies, the results appear to be generally transferable with caution, especially for industrialized countries.

Keywords

Road Safety; Distraction; Inattention; Cognitive overload; Distraction outside vehicle

1. Introduction

Inattention (daydreaming and distraction through state of mind such as pondering etc.) and cognitive overload (collectively referred to solely as 'inattention' in this paper) while driving is a common phenomenon. It can occur aided by the repetitive and automated tasks that driving a vehicle involves, the particular state of mind (mood) of the driver, or the cognitive overload (mental stress) from outside stimuli at any given time. In the context of road safety, inattention in a certain way induces a level of distraction to the person driving, which is a major risk factor in road safety. The extra amount of mental workload and cognitive functions that drivers have to undertake if a need arises reduces their reflexes and slows reaction times to events (both the time to mentally register the effect and the time to physically react to it). Driver state of mind or mood has been proven to influence behavior on the road, making it more aggressive (increased speeding, speed variations and acceleration, reduced allowed spatial headways and generally more reckless driving) or defensive ("fear" of driving/other vehicles, speed variations, excessive braking reactions etc.). In a few cases, overcompensation effects from the driver are observed, similar to those observed in other distraction research, for instance in Beratis et al., 2017. Drivers are aware that they are not driving to the best of their abilities, and thus feel the need to balance the loss. However, this usually leads to acceleration, speed and position variations within the traffic flow which are proven causes of road accidents.

On the other hand, distraction by individuals, objects or situations outside the vehicle while driving (referred hereby as 'outside factors') is a common phenomenon. It can originate from the surroundings, such as an extraordinary scenery or an unusual occurrence (e.g. a separate road accident). Environmental factors, such as intense sun glare (or fog) might hinder the driver as well. Moreover, static objects designed to capture the attention of the driver, such as road and/or advertising signs succeed in doing so, thus reducing drivers' engagement with the actual activity of operating the vehicle. There are three main areas of distraction factors outside the vehicle that are examined in this paper. These are: the presence of static objects such as advertisements, traffic management information and others, watching persons and situations outside the vehicle, and the presence of sun glare or vehicle lights that might distract drivers. In the context of road safety, outside factors increase the levels of distraction to the person driving, and driver distraction is a major risk factor in road safety. The extra amount of mental workload and cognitive functions that drivers have to undertake if a need arises reduces their reflexes and slows reaction times to events (both the time to mentally register the effect and the time to physically react to it).

In this framework, the aim of the present study is to investigate the effect of i) inattention and ii) distracting factors outside the vehicle on road safety. More specifically, the objective of this study is to provide an assessment and critical review of the effects of distraction induced without the presence of a secondary tasks, which can be categorized in two different groups. The first group is driving under an improper state of mind, which includes inattention and distractions through cognitive overload. The second group consists of factors outside the vehicle, which include static objects or advertising signs, vision-impairing glare caused by the sun or the lights of other vehicles, and observing landscapes, people or situations outside the vehicle while driving.

2. Methodology

This analysis is carried out within the framework of the SafetyCube project which aims to identify and quantify the effects of risk factors and measures related to behavior, infrastructure or vehicle, and integrate the results in an innovative road safety Decision Support System (DSS) that will enable policy-makers and stakeholders in Europe to select and implement the most appropriate measures to address road safety problems (SafetyCube, 2016).

The methodology consists of three distinct stages. The first stage comprises thorough international literature database searches, in order to identify relevant studies, and screening and selecting relevant studies to be included in the assessment analysis on the basis of rigorous selection criteria; priority is given to studies reporting quantitative results, recent studies over older studies (before 1990), and European studies as opposed to overseas ones. More specifically, for each of the identified risk factor topics a standardized literature search was conducted in order to identify relevant studies to include in the Decision Support System (DSS) and to form a basis for a concluding summary (synopsis) and further analyses. The structure underlying the DSS consists of (1) a taxonomy identifying risk factors and measures and linking them to each other, (2) a repository of studies, and (3) synopses summarizing the effects estimated in the literature for each risk factor and measure, and (4) an economic efficiency evaluation. The DSS is implemented in a modern web-based tool with a highly ergonomic interface, allowing users to get a quick overview or go deeper into the results of single studies according to their own needs. In some cases, however, a lack of supporting literature was identified and some risk factors could not be evaluated.

The literature searches were carried out between May and September 2016. Each literature search, study coding and synopses creation for a particular risk factor was completed within the same SafetyCube partner organization. The process was documented in a standard format to make the gradual reduction of relevant studies transparent. The main databases used for behavioral risk factors were the following: Scopus, TRID, Google Scholar, Science Direct. Taylor & Francis Online, Springer Link etc. The aim was to find studies that provided an estimate of the risk of being in a crash due to the presence of the risk factor. Therefore, studies considering crash data were designated the most important. However, while the actual occurrence of crashes can be seen as the ultimate outcome measure for road safety, Safety Performance Indicators (SPIs) have in recent years been taken into consideration to quantify the road safety level (Gitelman et al., 2014). SPIs include driving behavior, like speed choice and lane positioning. These metrics give an indication of safe (or unsafe) driving behavior. The SPI variables included for analysis are those for which there is some scientific evidence of an association with increased crash risk. For some risk factors, studies considering SPIs are included in addition to those focusing directly on crashes. However, where possible the coding of studies including crash data was prioritized.

The second stage involves analysis of the studies in terms of design, analysis methods and limitations. For the full list of information provided per study the reader is referred to Martensen et al (2017). For each study the following information was coded:

- Road system element (Road User, Infrastructure, Vehicle) and level of taxonomy
- Basic information of the study (title, author, year, source, origin, abstract)
- Road user group examined
- Study design
- Measures of exposure to the risk factor
- Measures of outcome (e.g. number of injury crashes)
- Type of effects (within SafetyCube this refers to the numerical and statistical details of a given study in a manner to quantify a particular association between exposure (either to a risk factor or a countermeasure) and a road safety outcome)
- Effects (including corresponding measures e.g. confidence intervals)
- Limitations

• Summary of the information relevant to SafetyCube (this may be different from the original study abstract).

The third stage concerns the synthesis - and meta-analysis, when feasible - or research results per topic, for the estimation of overall effects, general trends and the assessment of the transferability of results. The syntheses of studies for each topic were made available in the form of a 'synopsis' indicating the main findings for a particular risk factor derived from meta-analyses or another type of comprehensive synthesis of the results (e.g. vote-count analysis), according to the guidelines and templates available in Martensen et al. (2017).

Synopses were then created for several risk factors on different levels of the risk factor taxonomy, thus, for different levels of detail, mainly dependent on the availability of studies for a certain topic. The synopses contain contextual information for each risk factor from literature that could not be coded (e.g. literature reviews or qualitative studies). However, not all the coded studies are included in the analysis of the synopsis. For some risk factors it was possible to code only a few studies, but there was not enough information to write a full synopsis.

3. Analysis and Results

3.1. Inattention and distraction through cognitive overload

For the risk factor of inattention and distraction through state of mind, and after appropriate use of various search tools and databases, nine high quality studies were selected and analyzed. Several studies investigated accidents, either the numbers of accidents (McEvoy et al., 2007; Wang et al., 1996) or accident injury severity (Donmez and Liu, 2015; Neyens and Boyle, 2008). There were also more unconventional methods, such as comparisons between different violation types (e.g. signaling versus speeding violations) while drivers were inattentive (Fu et al., 2011). Other studies focused on analyzing various behavioral factors to capture the effect of inattention, such as driver attention to environment, (Berthié et al., 2015), blinking variables, (Faure et al., 2016), safety-critical variables (such as ignoring traffic lights) and perception (Harbluk et al., 2007).

In order to examine the relationship between the various inattention (exposure) and outcome indicators, the studies either deployed multivariate statistical analysis models (such as the ordered logit and the multinomial logistic regression model) or utilized forms of analyses of variance (ANOVA) statistical models, or at least conducted non-model statistical analysis and compared differences or proportions. Sometimes other independent variables were present as well, with some models controlling for them and others studying them independently.

Crash counts are reported through descriptive statistics, with no direct statistical analysis to determine whether inattention is a variable significant enough to relate to accident causes (McEvoy et al., 2007; Wang et al., 1996). The findings for injury severity are somewhat ambiguous as well. One study found increased accident injury severity for two of the age groups participating, namely young and middle-aged drivers, but non-significant results for older drivers (Donmez and Liu, 2015). In contrast, another relevant study discovered a positive impact of inattention on accident injury severity (Neyens and Boyle, 2008). The last two findings can be explained by overcompensation on the part of the drivers, with conservative behavior which dramatically reduces the chance of serious or fatal injury.

When comparing the violation types caused by inattention, there was a clear trend of inattentive drivers committing more speeding violations when compared to turning-signaling-yielding and sign-related violations (Fu et al., 2011). While this provides significant insights into the crashes that inattentive drivers are involved in, it does not illuminate the direct impacts on the usual road safety indicators (crashes, injuries) because no type of violation is inherently and collectively worse than the other. Regarding the rest of the behavioral variables, inattention (or 'mind wondering', as the relevant study called it), was reported to change driving behavior by significant portions of drivers as they were not paying attention to their driving environment (Berthié et al., 2015).

As for other perception variables, in a simulation study the mean eye blink frequency and duration were both affected in various environments. There were three different environments tested (motorway, rural and urban roads), and the experiment presented mixed results. For blinking frequency, all results were detrimental apart from one positive one for driving while performing a mental arithmetic task on a rural road. On the other hand, for blink duration, driving while performing a mental arithmetic task on an urban road and both tasks in a motorway environment were found to have a beneficial effect by reducing mean blink durations by 3 to 6 ms, and the rest of variables were found to be detrimental (Faure et al., 2016). Once again, those discrepancies can be explained by overcompensation effects. The last study found negative impacts to all of its variables (some outward views, inspection of objects, braking performance, perception of workload and safety reduction and others) except for inspections of the central area (Harbluk et al., 2007).

A few limitations can be arguably found in the current literature for the effects of inattention and cognitive distractions on road safety. The first one lies in the nature of the design of the studies themselves: Either past data, along with their lack of detail, general limitations and underlying biases have to be relied upon to reach a conclusion, or the researchers must resort to simulators. Simulations are known to either underrepresent real world conditions, making them less believable environments which the drivers may not take entirely seriously, or sometimes cause dizziness or nausea on the participants, which are forms of added discomfort. Both of these aspects might skew data from relevant experiments. Secondly, there might be times when this particular risk factor does not affect driving performance, such as a driver being absentminded while immobile at a red light, and then falsely reporting this to the authorities after a crash that occurred later when he was focused. Databases of past accidents might not be detailed enough to account for such cases, and again alter results in an undesired manner. There is also a noticeable lack of studies that focus on the indirect effects of this particular risk factor. A common example of this is the case of a non-driver road user, such as a pedestrian crossing the street while inattentive, and the impacts of this activity on road safety. Finally, as the human brain is extremely complex and, as of yet, highly uncharted scientifically, sometimes it might be hard to draw the line on when a driver is inattentive or distracted through state of mind or cognitive overload. There is also the possibility that some people are better at multitasking than others, and therefore the tests created to approximate cognitive overload (e.g. simultaneous driving and mental calculations) might not be completely objective.

After considering the previous points it was decided that a meta-analysis could not be carried out in order to find the overall effect of inattention while driving. The quantitative results of the selected studies through their various effects are summarized in Table 1. There is evidence to support that overcompensation occurs by certain drivers, but whether the overall, collective effects of this risk factor are negated is still unclear. In conclusion, the overall impact of inattention is characterized as probably risky.

Table 1: Quantitative results of selected studies and impacts on road safety for inattention factors.
Key: ↑ increased risk; - not significant change; ↓ decreased risk.

No.	Author(s); Year; Country;	Outcome indicator	Quantitative estimate	Effect on road safety risk
1 [In]	Donmez B., Liu Z.; 2015; USA	Injury severity - Categorical [Odds ratio]	Young: OR=0.960, p<0.0001, CI [95%] = [0.95, 0.96]	↑
			Middle-aged: OR=0.86, p<0.0001, CI [95%] = [0.86, 0.87]	↑
			Old: OR=1.00, p=0.6900, CI [95%] = [0.99, 1.02]	-
2 [In+ Cg]	Fu, C., Pei, Y., Wu, Y., & Qi, W.; 2013; USA	Inattention comparison between 3 violation types [Slope]	TSS vs SR violations: β=-1.360, s.e.=0.280, p<0.0001	-
			TYS vs SR violations: β=-1.090, s.e.=0.230, p<0.0001	-
			TYS vs TSS violations: β=0.260, s.e.=0.240, p>0.050	-
		Cognitive distraction comparison between 3 violation types [Slope]	TSS vs SR violations: β=0.240, s.e.=0.240, p>0.050	-
			TYS vs SR violations: β=0.760, s.e.=0.210, p=0.0010	-
			TYS vs TSS violations: β=0.530, s.e.=0.160, p=0.0010	-
3 [In]	McEvoy, S. P., Stevenson, M. R., & Woodward, M.; 2007; Australia	Crash count [Absolute proportion frequency]	Lack of concentration: Crash proportion: 0.1120	-
4 [In]	Neyens, D. M., & Boyle, L. N.; 2008; USA	Injury severity [Categorical - slope]	Slope (between injury categories) β=-0.58, s.e.=0.010, p<0.001	↓
5 [In]	Wang, J. S., Knipling, R. R., & Goodman, M. J.; 1996; USA	Crash count [Absolute proportion frequency]	Looked but did not see: frequency=0.089	-
6 [Cg]	Berthié, G., Lemercier, C., Paubel, P. V., Cour, M., Fort,	Impact of MW episodes on driving behaviour [Absolute proportion frequency]	Driver proportion: 0.2140, p<0.010	↑

No.	Author(s); Year; Country;	Outcome indicator	Quantitative estimate	Effect on road safety risk
6 [Cg]	A., Galéra, C., Lagarde, E., Gabaude, G., & Maury, B.; 2015; France	Attention to environment during MW [Absolute proportion frequency]	Driver proportion: 0.6900, p<0.010	↑
7 [Cg]	Faure, V., Lobjois, R., & Benguigui, N.; 2016; France	Mean eye blink frequency [Absolute difference]	Motorway: Dual-task low vs. Single task: Abs.dif.=1.100, p<0.010	↑
			Motorway: Dual-task high vs. Single task: Abs.dif.=5.600, p<0.010	↑
			Urban Road: Dual-task low vs. Single task: Abs.dif.=0.300, p<0.010	↑
			Urban Road: Dual-task high vs. Single task: Abs.dif.=5.400, p<0.010	↑
			Rural Road: Dual-task low vs. Single task: Abs.dif.=-1.300, p<0.010	↓
			Rural Road: Dual-task high vs. Single task: Abs.dif.=3.200, p<0.010	↑
		Mean blink duration [One-way ANOVA]	Motorway: Dual-task low vs. Single task: Abs.dif.=-6.000, p<0.010	↓
			Motorway: Dual-task high vs. Single task: Abs.dif.=-6.000, p<0.010	↓
			Urban Road: Dual-task low vs. Single task: Abs.dif.=-3.000, p<0.010	↓
			Urban Road: Dual-task high vs. Single task: Abs.dif.=5.000, p<0.010	↑
			Rural Road: Dual-task low vs. Single task: Abs.dif.=4.000, p<0.010	↑
			Rural Road: Dual-task high vs. Single task: Abs.dif.=18.000, p<0.010	↑
8 [Cg]	Harbluk, J. L., Noy, Y. I., Trbovich, P. L., & Eizenman, M.; 2007; Canada	Outward view - Central Area [Absolute difference]	Difficult task vs. No task: Abs.dif.=0.0405, t-test(20)=2.20, p<0.05	↓
			Easy task vs. No task: Abs.dif.=0.0221, t-test(20)=1.52, p>0.05	-
		Outward view - Peripheral Area [Absolute difference]	Difficult task vs. No task: Abs.dif.=-0.0071, t-test(20)=2.18, p<0.05	↑
			Easy task vs. No task: Abs.dif.=0.0002, t-test(20)=0.97, p>0.05	-
		Instrument inspection [Absolute difference]	Difficult task vs. No task: Abs.dif.=-0.0085, χ^2-test(2)=16.38, p<0.001	↑
			Easy task vs. No task: Abs.dif.=-0.0030, χ^2-test(2)=16.38, p<0.001	-
		Mirror inspection [Absolute difference]	Difficult task vs. No task: Abs.dif.=-0.0075, χ^2-test(2)=7.25, p<0.05	↑
			Easy task vs. No task: Abs.dif.=-0.0019, χ^2-test(2)=7.25, p<0.05	↑
		Glances at traffic lights [Absolute difference]	Difficult task vs. No task: Abs.dif.=-0.9300, p<0.001	↑
			Easy task vs. No task: n/a	-

No.	Author(s); Year; Country;	Outcome indicator	Quantitative estimate	Effect on road safety risk
8 [Cg]	Harbluk, J. L., Noy, Y. I., Trbovich, P. L., & Eizenman, M.; 2007; Canada	Times ignoring traffic lights [Absolute difference]	Difficult task vs. No task: Abs.dif.=0.1410, χ^2-test(1)=8.07, p<0.01	↑
			Easy task vs. No task: n/a	-
		Braking performance [Absolute difference]	Difficult task vs. No task: Abs.dif.=1.820, p=0.05	↑
			Easy task vs. No task: Abs.dif.=1.250, p=0.05	↑
		Perception of workload [Absolute difference]	Difficult task vs. No task: Abs.dif.=3.790, χ^2-test(2)=32.67, p<0.0001	↑
			Easy task vs. No task: Abs.dif.=1.610, χ^2-test(2)=32.67, p<0.0001	↑
		Perception of safety reduction [Absolute difference]	Difficult task vs. No task: Abs.dif.=2.960, χ^2-test(2)=27.07, p<0.0001	↑
			Easy task vs. No task: Abs.dif.=1.760, χ^2-test(2)=27.07, p<0.0001	↑
		Perception of distraction [Absolute difference]	Difficult task vs. No task: Abs.dif.=5.290, χ^2-test(2)=34.05, p<0.0001	↑
			Easy task vs. No task: Abs.dif.=3.340, χ^2-test(2)=34.05, p<0.0001	↑

3.2 Distracting factors outside the vehicle

For the risk factors outside the vehicle, and after appropriate use of various search tools and databases, twelve high quality studies were selected and analyzed. Several studies investigated accidents, either as numbers of accidents (McEvoy et al., 2007; Mitra, 2014; Mitra and Washington, 2012; Wang et al., 1996; Yannis et al., 2013) or crashes and near misses (Klauer et al., 2014). Furthermore, one study focused on accident injury severity (Donmez and Liu, 2015). Other studies focused on analyzing various behavioral factors to capture the effects of factors outside the vehicle, such as tailgating times and speeding occurrences (Bendak and Al-Saleh, 2010) or time to change lanes (Edquist et al., 2011). Headway and braking distance and braking reaction time were also investigated by Terry et al. (2008), while Young et al. (2009) examined time spent out of lane, lane excursions, times to contact and fixations. Finally, one study investigated lighting effects using speeding and detection distance measurements (Theeuwes et al., 2002).

In order to examine the relationship between the various outside factors (exposure) and outcome indicators, the studies would either deploy multivariate statistical analysis models (such as the ordered logit and the mixed effects logistic regression model), or utilized forms of analyses of variance (ANOVA) statistical models, or conducted non-model statistical analysis and compared differences or proportions. Sometimes other independent variables were present as well, with some models controlling for them and others studying them independently.

After considering the previous points it was decided that neither a meta-analysis nor a vote-count analysis could not be carried out in order to find the overall estimate of outside factors while driving. Therefore it was decided that a qualitative review-type analysis will be conducted for this paper.

Crash counts are reported as elevated both by sun glare (Mitra, 2014; Mitra and Washington, 2012) and by advertising signs (Yannis et al., 2013; Klauer et al., 2014). In studies about watching outside persons and situations, however, these variables are reported through descriptive statistics, with no direct statistical analysis to determine whether outside factors is a variable significant enough to relate to accident causes. They appear to be elevated in one case and reduced in another (McEvoy et al., 2007; Wang et al., 1996). The findings for injury severity are negative as well. A relevant study found increased accident injury severity across all three age groups participating, namely young, middle-aged and old drivers, when watching persons or situations outside the vehicle (Donmez and Liu, 2015).

When examining the aforementioned behavioral factors, advertising and road signs were found to have some detrimental effects. Studies reported increased drifting from lane instances, recklessly crossing dangerous intersections, time to change lanes or spent out of lane, braking distance and reaction time, fixations and other relevant variables (Bendak and Al-Saleh, 2010; Edquist et al., 2011; Terry et al., 2008; Young et al., 2009). Finally, Theeuwes et al. (2002) reported increased detection distance and more missed targets when the drivers are under the effect of glare from lights, and also claimed that the speeding variations they found are due to different road widths and not the effect of sun glare.

A few limitations can be arguably found in the current literature for the effects of the aforementioned outside factors on road safety. The first one lies in the nature of the design of the studies themselves. Studies used either past data, which along with their lack of detail, rely upon general limitations and underlying biases to reach a conclusion. Alternatively the researchers can use simulators. Simulations are known to either underrepresent real world conditions, making them less realistic environments which the drivers may not take entirely seriously, or sometimes cause dizziness or nausea on the participants, which are forms of added discomfort. Both of these aspects might skew data from relevant experiments. Secondly, there might be times when some of those particular risk factors do not affect driving performance, for instance a driver being blinded by a vehicle lights while immobile at a red light, and then falsely reporting this to the authorities after an unrelated crash that occurred later when he was focused. Databases of past accidents might not be detailed enough to account for such cases, and again alter results in an undesired manner. There is also a noticeable lack of studies that focus on the indirect effects of those particular risk factors. A common example of this is the case of a non-driver road user, such a pedestrian crossing the street while blinded by sun glare, and the impacts of this distraction in road safety. Finally, as the human brain is extremely complex and, as of yet, highly uncharted scientifically, sometimes it might be hard to clearly identify when a driver is actually distracted by watching individuals or situations, instead of glancing at them and not registering them.

Overall, our analysis showed that outside factors have a mostly negative impact on road safety. In absolute numbers a lot of the effects of these risk factors are detrimental, although a considerable number of variables remain statistically non-significant (not sufficiently related) to sun glare or vehicle lights, watching persons or situations, and static objects. There is little evidence to support the statement that overcompensation occurs with certain drivers, and in all likelihood the overall collective effects of this risk factor are not negated by this phenomenon. In conclusion, the overall impact of the aforementioned outside factors is characterized as probably risky. The quantitative results of the selected studies through their various effects are summarized in Table 2. The studies are marked with [SO], [SVL] or [WP] to denote whether they originally belonged to the static object [SO] (advertisement and road signs), sunlight or vehicle light [SVL] or watching persons and situations [WP] study groups.

Table 2: Quantitative results of selected studies and impacts on road safety for outside-vehicle factors. Key: ↑ increased risk; - not significant change; ↓ decreased risk.

No.	Author(s); Year; Country;	Outcome indicator	Quantitative estimate	Effect on road safety risk
1 [SO]	Bendak, S., & Al-Saleh, K.; 2010; Saudi Arabia	Tailgating times [Absolute difference]	Abs.dif.=0.250, p=0.140	-
		Overspeeding occurrences [Absolute difference]	Abs.dif.=0.250, p=0.190	-
		Drifting from lane [Absolute difference]	Abs.dif.=1.090, p=0.000	↑
		Not signalling [Absolute difference]	Abs.dif.=0.250, p=0.210	-
		Recklessly crossing dangerous intersections [Absolute difference]	Abs.dif.=0.580, p=0.000	↑
2 [SO]	Edquist, J., Horberry, T., Hosking, S., & Johnston, I.; 2011; Australia	Time to change lanes [Correlation coefficient]	Cor.coeff.=0.460, F-test=35.030, p=0.000	↑
3 [SO]	Klauer, S. G., Guo, F., Simons-Morton, B. G., Ouimet, M. C., Lee, S. E., & Dingus, T. A.; 2014; U.S.A.	Motor vehicle crash or Near crash [Odds ratio]	OR=3.900, CI [95%] = [1.720, 8.810]	↑
			OR=3.900, CI [95%] = [1.720, 8.810]	-
4 [SO]	Terry, H. R., Charlton, S. G., & Perrone, J. A.; 2008; New Zealand	Headway distance [Absolute difference]	Abs.dif.=n/a, p>0.050	-
		Brake reaction time [Absolute difference]	Abs.dif.=0.868,	↑

No.	Author(s); Year; Country;	Outcome indicator	Quantitative estimate	Effect on road safety risk
			F-test(1,75)=11.39, p<0.001 (with outlying data) Abs.dif.=0.890, F-test(1,75)=9.31, p<0.001 (without outlying data)	
4 [SO]	Terry, H. R., Charlton, S. G., & Perrone, J. A.; 2008; New Zealand	Braking distance [Absolute difference]	Abs.dif.=0.832, F-test(1,75)=15.18, p<0.001	↑
		Tau and optic expansion rate [Absolute difference]	Abs.dif.=0.702, F-test(1,75)=31.87, p<0.001	↑
5 [SO]	Yannis G., Papadimitriou E., Papantoniou P., Voulgari C.; 2011; Greece	Crash count [Function]	Str#1: Function [θi=(Xa/Xb)/(Ca/Cb)] estimate=1.017	-
			Str#2: Function [θi=(Xa/Xb)/(Ca/Cb)] estimate=1.491	-
			Str#3: Function [θi=(Xa/Xb)/(Ca/Cb)] estimate=1.165	-
			Str#4: Function [θi=(Xa/Xb)/(Ca/Cb)] estimate=0.988	-
			Overall: Function [θi=(Xa/Xb)/(Ca/Cb)] estimate=1.125	-
6 [SO]	Young, M. S., Mahfoud, J. M., Stanton, N. A., Salmon, P. M., Jenkins, D. P., & Walker, G. H.; 2009; United Kingdom	Time spent out of lane [Relative difference]	Rel.dif.: F-test (1, 47)=4.040, p=0.050	↑
		Number of lane excursions [Relative difference]	Rel.dif.: F-test (1, 47)=3.100, p<0.100	-
		Mean time to contact [Relative difference]	Rel.dif.: F-test (1, 47)=0.110, p=0.919	-
		Minimum time to contact [Relative difference]	Rel.dif.: F-test (1, 47)=9.888, p=0.325	-
		Number of fixations - left [Relative difference]	Rel.dif.: F-test (1, 19)=5.280, p<0.050	↑
		Number of fixations - middle [Relative difference]	Rel.dif.: F-test (1, 47)=6.050, p<0.050	↑
		Number of fixations - right [Relative difference]	Rel.dif.: F-test (1, 47)=6.330, p<0.050	↑
		Subjective mental workload [Relative difference]	Rel.dif.: F-test (1, 47)=4.840, p<0.050	↑
7 [SVL]	Mitra, S.; 2014; U.S.A.	Morning glare crashes (Direction: East) [Odds Ratio]	OR=1.100, CI [0.990, 1.200]	↑
		Evening glare crashes (Direction: West) [Odds Ratio]	OR=1.150, CI [1.080, 1.230]	↑
		Crashes not affected by glare (Direction: North) [Odds Ratio]	OR=0.930, CI [0.880, 0.990]	-
		Crashes not affected by glare (Direction: South) [Odds Ratio]	OR=0.940, CI [0.880, 0.990]	-
8 [SVL]	Mitra S., Washington S.; 2012; U.S.A.	Crash count [Slope]	β=2.202, t-test=7.842, p<0.0001 at 95% sig.lvl.	↑
9 [SVL]	Theeuwes, J., Alferdinck, J. W., &	Driving speed [Relative difference]	Rel.dif.: F-test(3, 63)=30.5, p<0.050	↑

No.	Author(s); Year; Country;	Outcome indicator	Quantitative estimate	Effect on road safety risk
	Perel, M.; 2002; Netherlands	Detection distance [Relative difference]	Rel.dif.: F-test(3, 63)=9.4, p<0.010	↑
		Missed targets [Relative difference]	Rel.dif.: F-test(3, 63)=2.8, p<0.050	↑
10 [WP]	Donmez B., Liu Z.; 2015; USA	Injury severity - Categorical [Odds ratio]	Young: OR=0.840, p<0.0001, CI [95%] = [0.820, 0.860]	↑
			Middle-aged: OR=0.910, p<0.0001, CI [95%] = [0.900, 0.920]	↑
			Old: OR=0.710, p<0.0001, CI [95%] = [0.680, 0.750]	↑
11 [WP]	McEvoy, S. P., Stevenson, M. R., & Woodward, M.; 2007; Australia	Crash count [Absolute proportion frequency]	Outside person, object or event: Crash proportion: 0.095	-
12 [WP]	Wang, J. S., Knipling, R. R., & Goodman, M. J.; 1996; USA	Crash count [Absolute proportion frequency]	Distracted by outside person, object or event: frequency=0.027	-

4. Conclusions

Driver distraction as a behavioral aspect is a major issue in road safety everywhere. This study presents the assessment and critical review of the aforementioned distraction factors that are induced without any secondary tasks. Both categories (inattention – cognitive overload and outside-the-vehicle factors) appear to be mostly detrimental to several aspects of road safety by increasing accident numbers, accident injury severity and by reducing the performance of several behavioral variables such as perception variables and braking performance. The majority of existing studies focus on distraction due to secondary tasks, while the other forms of distraction have received less attention. The novelty of this research lies in the overview of quantitative impacts that enables policy makers to reach well-informed and supported decisions for measures regarding those distraction factors.

After the results for inattention were reviewed together, it was shown that this risk factor has a mostly negative impact on road safety. In absolute numbers a lot of the effects of inattention are detrimental, although there are some beneficial impacts as well, as well as a considerable number of variables that remain statistically non-significant (not sufficiently related) to inattention. Overall, the following points were observed: firstly, there is an adequate number of studies, however, those studies have not used the same model for analysis but largely different ones. Moreover, there are different indicators, and even when they coincide they are not measured in the same way. It should be noted that lane-keeping and similar established parameters are not included in the examined studies because they are more indirect predictors of road safety. Finally, the various study sampling frames were quite different (e.g. field testing or simulated driving). On a basis of both study and effect numbers, it can be argued that the risk factor of inattention while driving has a likely detrimental effect on road safety. The selected studies have good levels of quality, and the common conclusion that can be drawn for inattention is that either drivers are forced to compensate for its effects or suffer increased accident risks.

The critical review that was carried out showed that outside factors have a mostly negative impact on road safety. In absolute numbers a lot of the effects of these risk factors are detrimental, although a considerable number of variables remain statistically non-significant (not sufficiently related) to sun glare or vehicle lights, watching persons or situations, and static objects. There is little evidence to support the statement that overcompensation occurs with certain drivers, and in all likelihood the overall collective effects of this risk factor are not negated by this phenomenon. In conclusion, the overall impact of the aforementioned outside factors is characterized as probably risky. Overall, the following points were observed: there is an adequate number of studies, however, they are from different research areas. In addition, those studies have not used the same model for analysis but largely different ones. There are different indicators, and even when they do coincide they are not measured in the same manners. Finally, the sampling frames were quite different (e.g. field testing or simulated driving).

Finally, the lack of meta-analyses in these important topics is one major gap of knowledge in the field of driver distraction, however the heterogeneous nature of the literature did not allow such analysis. One last remark is about the sample of countries (comprising European, Australian, US and other studies) of the reviewed studies. In that context the results of the analysis appear to be generally transferable with caution, especially for industrialized countries.

Acknowledgment

This paper is based on work carried out within the SafetyCube project of the H2020 programme of the European Commission (Grant number 633485). The information and views set out in this paper are those of the authors and may not reflect the official opinion of the European Commission. The authors would like to thank all the partners involved in the "Behaviour" Work Package 4 of the SafetyCube project for their valuable comments.

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