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Road lighting and distraction whilst driving: Establishing the significant types of distraction

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There is a body of research showing how changes in lighting conditions affect hazard detection in the context of driving after dark. There is a separate body of research showing that driving is impaired by distraction. The two have yet to be integrated: this is critical for lighting design recommendations because giving consideration to distraction may affect the optimal conditions established in lighting studies. A first step in that process is establishing the critical type(s) of distraction that might then be simulated in lighting research. This paper reviews evidence for the prevalence of driving distractions as recorded by two methods: interviews with drivers following collision and observation of drivers on real roads. These data suggest that auditory distractions such as conversation with passengers and listening to music are prevalent distractions, and are therefore appropriate distractions to incorporate in further research of lighting and hazard detection experiments.

1. Introduction

Hazard visibility is a contributory factor to road traffic collisions (RTCs).¹ After dark, there is a deterioration in visual performance, for example, sensitivity to contrast is diminished and motion-based perception is impaired.² Road lighting is installed to offset this deterioration in vision and improve a driver's ability to detect and recognise potential hazards not otherwise revealed by vehicle headlights.

Previous studies have therefore examined how changes in lighting conditions affect detection and identification performance. Some studies are laboratory based and use abstract targets such as Landolt rings or discs presented on screens.^{3–6} It is usually found in

peripheral detection experiments, for example, that increases in luminance and scotopic/photopic (S/P) luminance ratio lead to increases in detection probability and reductions in reaction time to detection following onset of the target. At some point, the benefit of these increases reaches a plateau, with further increase in luminance and/or S/P ratio bringing negligible improvement in visual performance, and this point provides a useful estimate of optimal lighting conditions.

In these studies, the test participant is required to focus on the specific task as instructed by the experimenter. For example, to look towards a static fixation mark and press a button when a target is detected at a peripheral location. This does not resemble driving in natural situations. A driver's point of visual fixation is not static,⁷ reflecting the need to deal with varied tasks – steering, speed control, monitoring other road users and giving attention to road signs and other sources of information.⁸ Furthermore, drivers

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are frequently distracted from their primary task of driving. Despite driving being a highly complex and responsible task, with mistakes or risk-taking having potentially fatal consequences,⁹ drivers regularly engage in supplementary non-driving related activities.^{10,11} There are many forms of distraction, including manual distraction such as operating the radio, visual distraction such as advertising hoardings, cognitive distraction such as thoughts and auditory distraction such as passenger conversation.¹² Driver distraction is recognised as a contributing factor for up to 25% of all RTCs in EU countries,¹³ and in the USA 6% of all fatal RTCs are attributed to distraction.¹⁴ Due to under-reporting, these may be underestimates of the effect of distraction.¹⁵ Driving distraction is therefore a growing international road safety concern.¹⁶

The ecological validity of lighting research has been increased in some studies by having test participants engage in a driving video game^{17,18} or driving simulator^{6,19} whilst recording target detection in parallel. In a small number of studies, the test participant is actually driving.^{5,20} These studies confirm that for detection of peripheral targets, lighting of higher S/P ratio reduces reaction time and increases detection probability. However, they do not account for distraction by tasks that are not related to driving. For example, driving along a closed road and being accompanied by the experimenter mean there were no other vehicles or pedestrians to negotiate and the participant–driver would be less likely to engage in conversation with passengers or to use their mobile phone.

Driving distraction is defined as the situation when drivers' cognitive resources are not sufficient for them to adequately or safely perform the driving task.²¹ An interaction between distraction and the benefits of road lighting after dark is expected. For example, auditory distractions cause an increase of gaze concentration towards the road centre²² and thus away from hazards in the peripheral

field. Road lighting of higher luminance and S/P ratio may be able to offset the detrimental effect of auditory distraction by enhancing peripheral detection.

The validity of road lighting design recommendations therefore requires evidence of the degree to which those recommendations are influenced by driving distractions. To do that first requires an understanding of the critical form(s) of distraction. The aim of the current review is, therefore, to identify the types of distractions taking place during driving. Two sorts of data are employed: interviews with drivers following collision and observation of drivers on real roads. The paper also compares the prevalence of real world distractions with drivers' perceptions of risk.

2. Distraction at the time of collision

One approach to identifying critical distractions is to identify the distraction (if any) occurring at the moment of a collision. This has been established using three methods in past studies: self-report, where drivers were interviewed when attending hospital after an RTC^{23–25}; naturalistic driving data as recorded by in-vehicle video cameras^{26,27}; and secondary data such as police roadside reports of RTCs.²⁸ The top three most prevalent driving distractions in each of six studies are shown in Table 1.

Conversing with passengers was the most prevalent reported distraction associated with RTCs, this being the most frequent distractor in five studies and the second most frequent in the remaining study. This is followed by cognitive distractions (such as a lack of concentration and feeling stressed), and distractors which include visual and physical distraction (using a mobile phone and adjusting vehicle/radio systems). That conversation with passengers is the most prevalent distraction at the time of an RTC confirms the earlier review of Young and Salmon²⁹ who

Table 1 The top three most prevalent distractions associated with RTCs, as reported by hospital attendees, police and naturalistic longitudinal studies, with corresponding percentages

| Study | Sample period | Location | Method | Sample (n) | Most prevalent distractions associated with reported RTCs (% of events reported in study) | | |
|--------------------------------------|---------------|-------------|--------------------------|------------|---|--------------------------------|---|
| | | | | | First | Second | Third |
| Beanland <i>et al.</i> ²⁴ | 2000–2011 | Australia | Self-report ^a | 54 | Conversing (22.22%) | Feeling stressed (11.20%) | Using mobile phones (5.17%) |
| Dingus <i>et al.</i> ²⁶ | Not reported | US | In-vehicle cameras | 124 | Conversing (19.33%) | Using mobile phones (16.87%) | Eating/drinking (8.81%) |
| Dingus <i>et al.</i> ²⁷ | Not reported | US | In-vehicle cameras | 1694 | Conversing (28.08%) | Using mobile phone (12.32%) | Entertainment systems (radio use) (4.26%) |
| Gordon ²⁸ | 2002–2003 | New Zealand | Police-reported RTCs | 878 | Conversing (25.0%) | Using mobile phone (12.0%) | Entertainment systems (radio use) (12.0%) |
| McEvoy <i>et al.</i> ²³ | 2002–2004 | Australia | Self-report ^a | 539 | Conversing (28.43%) | Lack of concentration (26.10%) | Distacted by an outside event (22.14%) |
| Née <i>et al.</i> ²⁵ | 2010–2015 | France | Self-report ^a | 851 | Listening to music (50.53%) | Conversing (7.14%) | Following GPS indication (1.88%) |

^aSelf-report: Participants were interviewed when attending hospital after the RTC.

considered only three of the studies^{23,26,28} in Table 1.

This finding is in contrast with the driving distraction literature which primarily focuses on the use of mobile phones. For example, the recent review of Huemer *et al.*³⁰ included 41 observation studies which purposefully sought to record the use of mobile phones whilst driving and did not record instances of other types of distraction.

It is possible that Table 1 under-reports the frequency of mobile-phone related distractions. Three of the studies^{23–25} in Table 1 used self-reported distraction – the subjects being interviewed whilst attending hospital following an RTC. One possible reason why mobile phone use was not more frequently reported as the distraction taking place at the time of an RTC is that mobile phone use may be illegal whilst driving.³¹ It is, therefore, possible that drivers misreported the actual distraction to avoid self-incriminating unlawful activity whilst driving.³²

In the two studies by Dingus *et al.* RTCs were captured using cameras which were installed in the participants’ own vehicle to monitor their behaviour.^{26,27} An advantage of this method is that no instructions are imposed on the driver which might affect their behaviour. In contrast, the installation of a video camera could cause experimenter-demand effects, resulting in changes in drivers’ behaviour due to what they think constitutes appropriate behaviour.³³ However, when a camera is installed in a driver’s vehicle, the study usually runs for an extended period of time, with Dingus *et al.*^{26,27} recording drivers natural driving behaviour for one year. It is therefore thought that the behaviours recorded over this time period are habitual behaviours and responses.³⁴

Née *et al.*²⁵ reported that the most prevalent distraction was listening to music, with a higher percentage (50.53%) than for conversing with passengers in their study (7.14%) and in other studies (19.63% to 28.57%).

Listening to music, however, did not appear as a distraction type in any of the other studies. This difference may be associated with the methods by which observations were recorded and categorised: the other studies in Table 1 did not include listening to music as a potential distraction. Beanland *et al.*²⁴ created a list of potential distracting behaviours that could occur just before a crash, and coded drivers' responses in relation to these broad categories. Similarly, McEvoy *et al.*²³ tailored the interview questions to ask about 14 specific activities. In both of these studies, these categories generally included outside events, adjusting in-vehicle systems, eating/drinking, conversing with passengers, use of a mobile phone and lack of concentration, but did not include listening to music. Although Née *et al.*²⁵ also presented respondents with a pre-defined list of distracting events and asked them to recall whether they were engaged in any of these activities before the crash, this list was more extensive, with 31 activities (including listening to music), and drivers could comment on as many as they wanted from the list.

One explanation as to why passenger conversation and listening to music are associated with a high proportion of reported RTCs could be due to increased exposure to this activity.³⁵ The greater the time spent on the road (annual mileage), the greater the number of traffic incidents experienced.³⁶ Therefore, if drivers are engaging more often in passenger conversations or listening to music than in other distracting activities, the increased exposure may explain the increase in reported RTCs.

3. Observation of driving behaviour

An alternative approach to establish the prevalence and willingness to engage in distracting tasks is to observe drivers' behaviour in their natural driving environment, using roadside observation of passing vehicles.

In effect, these data measure exposure. Table 2 shows the top three most prevalent distractions as reported in each of seven road observations studies. Conversing with passengers again appears to be the most prevalent distraction, being the most frequent distraction in six studies and third most frequent in the seventh. This confirms the conclusion drawn from post-collision data (Table 1). Listening to music does not appear in Table 2. One explanation for this is that it is not possible to observe whether a driver is listening to music.

The studies in Tables 1 and 2 report conversing when a passenger was present, but do not report whether they were with single or multiple passengers. In one study, consideration was given to conversation when there were no passengers.³⁷ This being a roadside observation study, it is not known whether that was talking to oneself, a hands-free telephone conversation, or other activity. Kidd *et al.* concluded that passenger presence did not affect the overall prevalence of distracted driving (22.5% passenger present, 23.7% passenger not present); however, by far the most common distraction for drivers with passengers was talking to a passenger, with phone-related distractions being much less frequent.

Mobile phones can be used in hand-held or hands-free manners. Née *et al.*²⁵ distinguished between hand-held and hands-free mobile phone use (this distinction was not made in the other studies of Table 1). The percentage of reported RTCs associated with the use of a hands-free kit (0.59%) was slightly higher than hand-held mobile phone use (0.47%); however, the self-report of mobile phone use at the time of an RTC was low in both cases. Two roadside observation studies (Table 2) also distinguished between hands-free and hand-held mobile phone use. Kidd *et al.*³⁷ found that hands-free was less frequently observed (5.5%) than hand-held mobile phone use (39.74%). In contrast,

Table 2 The top three most prevalent distractions observed in roadside observation studies, with corresponding percentages

| Study | Sample period | Location | Sample (n) | Most prevalent distractions (% of events reported in study) | | |
|---------------------------------------|---------------|----------|------------|---|-------------------------------|--|
| | | | | First | Second | Third |
| Gras <i>et al.</i> ³⁹ | 2009 | Spain | 1268 | Conversing (69.67%) | Smoking (18.72%) | Using a mobile phone (7.12%) |
| Huisingh <i>et al.</i> ⁴⁰ | 2012 | US | 1069 | Conversing (53.2%) | Using a mobile phone (31.4%) | Disturbed by an outside event (20.4%) |
| Kidd <i>et al.</i> ³⁷ | 2014 | US | 3874 | Using a hand-held mobile phone (39.74%) | Eating or drinking (13.25%) | Conversing (11.54%) |
| Prat <i>et al.</i> ⁴¹ | 2011 | Spain | 1250 | Conversing (59.35%) | Smoking (19.78%) | Using a mobile phone (6.95%) |
| Sabzevari <i>et al.</i> ⁴² | 2011 | Iran | 1022 | Conversing (46.29%) | Using a mobile phone (11.80%) | Reaching for object in vehicle (9.83%) |
| Sullman ⁴³ | 2011 | UK | 1035 | Conversing (51.38%) | Smoking (15.28%) | Using a mobile phone (15.28%) |
| Sullman <i>et al.</i> ³⁸ | 2012 | UK | 1845 | Conversing (52.38%) | Smoking (11.31%) | Using a hands-free phone (10.12%) |

Note: whilst Sullman,⁴⁴ Sullman and Metzger,⁴⁵ and Vollrath *et al.*⁴⁶ also reported observations of distraction whilst driving, these studies are not included here because they only compare mobile phone use with eating/drinking/smoking, whilst having a 'other' category which includes a large range of distractions (passenger conversation, map reading, adjusting in-vehicle controls and reaching for objects). Although the recent review by Huemer *et al.*³⁰ suggested that Asgharabad *et al.*⁴⁷ observed a range of secondary tasks, this study in fact only reported observations of mobile phone use and therefore is also not included.

Sullman *et al.*³⁸ found that hands-free activity (10.12%) was more frequently observed than hand-held phone use (4.17%). This difference between these studies could be attributed to the criteria used to define hands-free use, with Kidd *et al.*³⁷ observing drivers wearing a Bluetooth earpiece or headset, whereas Sullman *et al.*³⁸ observed drivers who were talking and had a mobile phone that was clearly visible on the dashboard. Both studies established definitions of driving distractions which were thought to reduce ambiguity: however, it is hard to draw a conclusion about the difference in prevalence and associated RTC frequency of hands-free and hand-held mobile phone use from these studies.

4. Perceived risk

Drivers' willingness to engage in distracting activity may vary according to the situation. Kidd *et al.* conducted roadside observations at different roadway situations which were reported to vary in cognitive demand.³⁷ Less demanding situations included when a vehicle was stationary (e.g. stopped at traffic lights) and driving along a straight road whereas more demanding situations included navigating around a roundabout or performing a manoeuvre at an intersection. They found that distraction which involved visual and physical components (such as using a hand-held mobile phone, eating, drinking and smoking) were observed more frequently in lower demand situations compared to higher demand situations. The opposite was found for distractors that involve auditory distraction, with talking to a passenger or singing being observed more at roundabouts compared to a straight road.

This pattern of results is supported by Huisingh *et al.*⁴⁰ who found that texting/dialling on a mobile phone was more prevalent on low demand urban roads than high demand urban roads, whereas interacting

with another passenger was similar across road types. Burns *et al.*⁴⁸ also found that drivers' reported use of a mobile phone depended on the traffic situation, with all respondents indicating that they would not use their mobile phone during difficult driving conditions.

Drivers may adjust their behaviour according to the degree of risk they perceive at a specific location; in other words, behavioural adaptation or risk compensation.⁴⁹ Rather than choosing not to engage in a distracting task of high cognitive load in certain situations, drivers may instead choose to reduce the cognitive demand of driving to compensate for their decision to engage in a distracting task, for example, reducing speed or increasing headway when using a mobile phone.⁵⁰

Such risk compensation does not seem to be observed with passenger conversations,⁵¹ which indicates that passenger conversation is not perceived to be a risky activity. This was found by Burns *et al.*⁴⁸ in trials using a driving simulator. Participants were instructed to rate each distraction using a linear rating scale (the Rating Scale Mental Effort⁵²). Conversing with a passenger was considered to be the least distracting task, followed by eating/drinking and tuning the radio: Using a hand-held mobile phone and texting were seen to be the most distracting. This is supported by roadside interviews⁵³: conversing with passengers was deemed distracting by fewer participants (83%) than using a hand-held phone and manipulating the GPS (100%).

Figure 1 shows the contrast between drivers' perception of risk (the results from Burns *et al.*⁴⁸ and Prat *et al.*⁵³) and those distractions associated with reported RTCs (Table 1). For Figure 1, the data were converted to z-scores to aid comparison across different types of dependent variables. For perceived risk data,^{48,53} perceived risk was evaluated using category rating, and the

z-scores shown in Figure 1 were determined using only these four distraction categories. For the frequency of association with an RTC, z-scores were determined for the individual studies of Table 1 for the same four distraction categories as perceived risk, and then averaged across those six studies. Although conversing with a passenger was consistently associated with a high proportion of reported RTCs, it was rated the least distracting activity by drivers. There is a dissociation between the perceived risk of conversing with a passenger, and the reported occurrence of RTCs this distraction causes. In contrast, although the use of a hand-held mobile phone was associated with the lowest rate of reported RTCs, this distraction was perceived the riskiest by drivers.

Figure 1 does not imply that mobile phone use is not a dangerous task: but instead that the contrast between reported risk and perceived risk demonstrates the importance of investigating passenger conversations.

Drivers are apparently willing to undertake secondary tasks which they perceive as less distracting. According to the Theory of Planned Behaviour,⁵⁴ a person's behaviour is directly influenced by their attitudes about the outcome of that behaviour, their perceptions about how others would view this behaviour, and the extent to which they feel they can perform the behaviour. Therefore, if a driver believes that conversing with a passenger is a commonly accepted behaviour whilst driving, and that they can complete both tasks adequately, then they are more likely to carry out this activity.

This lack of perceived risk may be problematic when considering cognitive resource capacity. Distractions use up cognitive resource and therefore reduce the amount of cognitive attention drivers are able to allocate to the primary task of driving.⁵⁵ For example, involvement in an auditory task can affect the allocation of cognitive resources in a visual search task.⁵⁶ This sharing of attentional



Figure 1 Drivers' perception of risk for several real-world driving distractions as reported in Burns *et al.*⁴⁸ and Prat *et al.*⁵³ along with an estimate of associated reported road traffic collisions, averaged (mean) from the studies in Table 1. Listening to music was not reported in Burns *et al.*⁴⁸ nor Prat *et al.*⁵³ and therefore is not reported in the figure. These data were standardised by calculating z-scores: Lower z-scores indicate lower ratings of perceived risk and road traffic collision risk, and higher z-scores indicate higher ratings of perceived risk and road traffic collision risk

resources may explain why auditory distractions (such as conversing with a passenger) are associated with high levels of reported RTCs.

5. Conclusion

Tables 1 and 2 reveal that conversation with a passenger is a prevalent form of distraction, being associated with a larger proportion of reported RTCs than other types of distraction and being a frequently observed distraction in field observations. Listening to music may also be a significant distraction: it has been excluded from the majority of past RTC studies by experimental design, and by its nature, as it is difficult to observe in field studies of natural driving.

One limitation of this conclusion is that it considers RTC frequency but not RTC severity. For example, whether RTCs attributed to distraction from passenger conversation are more or less severe than those attributed to mobile phone use. This distinction would provide additional context in which to evaluate the risk of distraction tasks. Further work is required to establish this. A second limitation is that the distraction studies (Tables 1 and 2) did not discriminate between driving in daytime and after dark; it would be interesting to see if there were changes in distractions undertaken and distractions contributing to RTC risk at different times of the day.

Having established prevalent forms of driving distraction, this next needs to be incorporated within visual detection experiments as a concurrent task. Whilst real tasks

could be employed, e.g. the test participant is instructed to engage in conversation, it can be difficult to establish the degree of distraction imposed and ensure similar conditions in all trials.⁵⁷

An alternative approach is the use of standardised laboratory tasks to approximate the interference of real-world distractions: these offer greater consistency between participants.⁵⁷ In previous studies, a number of standardised tasks have been used to simulate the distraction imposed by passenger conversation including the Continuous Memory Task which requires drivers to maintain a count of a 'target' sound heard randomly in a sequence of non-target sounds,⁵⁸ the Count Task which involves hearing a three digit number and counting backwards in units of seven,⁵⁹ and the Word Association Task which requires drivers to free associate using one-word responses to a stimulus word spoken over a speaker.⁶⁰ We propose that the n-back task is considered in further work.⁶¹ This is a delayed digit recall task, an auditory distraction in which a series of digits (or letters) are played over a speaker. In the lowest workload, $n=0$, participants are required to repeat out loud the number just heard. For $n=1$, participants are required to repeat the number before the one just heard: for $n=2$, participants are required to repeat out loud the number that was presented two numbers back. Higher values of 'n' require more items to be held in working memory, and thus vary the degree of cognitive distraction.⁶²

In this work, we focus on the benefit of road lighting to mitigate RTCs after dark. By impairing detection, distraction may influence the estimate of optimal lighting characteristics: by enhancing detection of objects in the peripheral field, lighting may counter the effect of auditory distraction in prompting gaze away from the peripheral field.²² We do not propose, however, that lighting is the only solution to mitigating RTCs nor distraction. One often proposed solution is driver

education, although studies suggest that education has either no effect or is associated with an increase in RTC risk.^{63–65}

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