Assessing the empirical evidence on the safety impact of Electronic Static Displays

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Abstract

As technologies advance and pressure from the advertising industry increases, regulatory bodies around the world are looking to the research on the safety impact of electronic roadside advertising to guide policy. Unfortunately, research in this area is not straight forward. This paper discusses the range of complex issues that confront both researchers and consumers of research as they seek to understand the effects of Electronic Static Displays (ESDs) on driver distraction and safety. The nature of distraction and the complex relationship between distraction, driving performance and crashes contribute to the problems. To illustrate, the paper will draw on examples from the international research literature on ESDs. The implications for policy will be discussed.

Keywords

Driver Distraction, Electronic Roadside Advertising, Safety, Policy, Regulation

Introduction

Electronic Static Displays (ESDs)[1] present high quality, electronic or digital images. They are typically large (over 4 square metres; Outdoor Media Association Inc., 2010) and can fulfil the functions of traditional roadway billboards and outdoor signage. Each image on an ESD can contain pictures and/or text similar to traditional roadway advertisements (see Figure 1) and each image is static during display; that is, it does not contain or imply motion[2]. ESD images can be created and uploaded electronically and remotely without the need for slow and costly printing and physical installation. The images can also be programmed to alternate at very short intervals allowing one ESD to present many different images in a period of time.

Installed strategically along roadways, ESDs can be used by road authorities to communicate important traffic management information to road users in a timely way. However, the main interest in ESDs comes from outdoor advertising bodies. Among other commercially attractive features, ESDs offer advertisers the ability to expose the 'captive', driver audience to multiple advertising images in a single passing and to target images by time of day to maximise the likely impact.

[1] ESDs have also been referred to as Commercial Electronic Variable Message Signs (CEVMSs), Digital Billboards (DBBs) and Electronic Billboards (EBBs).
[2] The technology can also present moving images (video or scrolling text) but use of moving images has been widely restricted.

Figure 1: ESD across roadway at Sydney Domestic Airport (16.1m x 2.6m)

(Source: APN Outdoor http://www.apnoutdoor.com.au/News/Detail.aspx?IdDataSource=32)

Despite their commercial advantages, ESDs share a common problem with all roadside advertising. To achieve their goal, they must attract the attention of passing motorists, but in so doing they reduce the amount of attention that can be paid to driving-relevant information and thus pose a potential risk to safety. "How great is the risk?" and "Under what circumstances does it vary?" are both critical questions for regulators and policy makers looking for a regulatory balance between protecting public safety and satisfying the interests of business.

In seeking answers to these questions, governments around the world have commissioned at least 11 reviews of the research literature on the safety impact of ESDs (and other roadside advertising signs) over the last 10 years (Table 1). These reviews have generally drawn tentative or qualified conclusions that ESDs probably do affect road safety adversely, at least in certain types of circumstances such as at locations that require high levels of attention for safe driving. However, most of the reviews highlight variation in findings between studies, the patchy and limited coverage of relevant issues, and methodological limitations as barriers to drawing firm conclusions. Adding to the confusion, a number of industry-sponsored field studies of ESDs have been conducted but not made widely available for integration and evaluation with the wider body of research (Tantala & Tantala, 2007, 2009a, 2009b, 2010a, 2010b). When these studies have been examined critically, the methods have been questioned (see Wachtel, 2007; Wachtel, 2009).

That the existing body of research does not provide an unambiguous basis for shaping regulation is due partly to the nature of the phenomenon of driver distraction and partly to the difficulty in designing studies to adequately measure it. This paper summarises these influences with the aim of providing research consumers a broad basis for critical analysis of research findings.

Attention and distraction in driving

In order to understand why research on ESDs and safety is methodologically challenging, it is necessary to understand how people attend to and process information while driving and how the distraction posed by ESDs might affect performance and safety.

Table 1: Reviews of the literature on roadside signage and road safety, 2001-2010

Reference	Country [a]	Focus [b]	Review of:
Wachtel (2009)	US	ESDs	2001-2009 - Empirical literature, Literature reviews, International/US Regulations
Molino et al. (2009)	US	All electronic signs	2001-2008 - Empirical literature
SWOV (2009)	NED	All roadside advertising signs	Recent empirical studies and literature reviews
Hatfield (2008)	AUS	All electronic signs	Empirical literature
Spiers, Winmill & Kazi (2008)	UK	All roadside advertising signs	Selected empirical studies, UK Regulations
SRF Consulting Group Inc (2007)	US	Dynamic signs	Selected empirical studies and literature reviews, US Regulations/ordinances
Hatfield (2005)	AUS	All roadside advertising signs	Empirical literature, Literature reviews
Finnish Road Administration (2004)	FIN	All roadside advertising signs	Empirical literature, Literature reviews
Wallace (2003a, 2003b)	UK	All roadside advertising signs	Empirical literature, Literature reviews
Coetzee (2003)	SAfrica	All roadside advertising signs	Empirical literature
Farbry, Wochinger, Shafer, Owens, & Nedzesky (2001)	US	All electronic signs	1980-2001 - Empirical literature, US regulations/practices

[a] AUS=Australia, CAN=Canada, UK=United Kingdom, US=United States of America, SAfrica=South Africa, FIN=Finland, NED=Netherlands
[b] Dynamic sign=any sign that appears to have movement or that appears to change during display, regardless of the mechanism.

Driver distraction has been defined as *"…a diversion of attention away from activities critical for safe driving toward a competing activity"* (Lee, Young, & Regan, 2009, p. 34). Attention allows us to select and process manageable amounts of sensory information from the enormous array impinging on us all the time, and to focus on things that are important, relevant or interesting.

Apart from physical feedback about the movement and location of our body parts, the majority of the information that is important and relevant for driving is attended visually (Sivak, 1996). Visual information is processed in the relatively small, central or foveal region of the visual field and in the peripheral region. The neural wiring of cells in the retina and later brain pathways (e.g., Milner & Goodale, 2008) means that an object must be fixated centrally in order for us to extract sufficient detail to identify it, to read text, to resolve a complex, high-definition image and so on. That is, to read a roadside sign, we must redirect our gaze so that the sign is fixated centrally. Peripheral (or 'ambient') information processing is more sensitive to temporal variations in stimuli, among other things, and thus to motion. Safe driving seems to involve both types of processing in complementary roles (e.g., Schieber, Schlorholtz, & McCall, 2009). Routine vehicle guidance, like lane-keeping, is probably accomplished using automatic peripheral information processing, whereas hazard scanning, hazard identification and forward planning rely more heavily on central visual processing.

Some types of visual information can elicit a reflexive, involuntary shift in attention (Trick & Enns, 2009). Sudden salient changes in peripheral stimulation, such as abrupt stimulus onsets, have been shown in well-controlled, laboratory studies to 'capture' attention, with the result that people's gaze is diverted to the distraction and responses on a simultaneous task are slowed (Forster & Lavie, 2008; Irwin, Colcombe, Kramer, & Hahn, 2000; Theeuwes & Godijn, 2001). Performance is usually more affected the closer the distractor is to the task stimulus. Importantly, Theeuwes and Godijin (2001) also reported findings showing a peripheral distractor can be processed sufficiently to interfere with ongoing task performance even when people do not divert their gaze to it. That is, distraction is not merely the redirection of a person's gaze, but also the redeployment of cognitive information processing capacity. The phenomenon of attentional capture has contributed to concern about the potential of image changeovers on ESDs to draw drivers' attention. The number of changeovers that drivers can safely be distracted by, and therefore, the minimum acceptable display duration or dwell time of each image, has been a topic of debate between industry and regulators.

Most often, the direction of visual attention is controlled and goal driven rather than 'captured' or stimulus driven. This 'top down' allocation of attention allows us to strategically sample the available sensory information within the limits of our attentional and processing resources. Our eyes continually scan and fixate on features in the visual field to build and to update a summary of the important information. Salient features in the scanning environment (e.g., high contrast, high luminance, large size, bright colour, flashes, etc) will tend to attract attention more than less salient features (e.g., Itti & Koch, 2000). With experience in an environment, expectations develop about what information is important and where it will be located, which allows attentional resources to be used more efficiently (Underwood, Chapman, & Crundall, 2009).

Implicit in the preceding discussion is the notion that attention and cognitive processing capacity are limited resources that are divided between current tasks (e.g., Lavie, Hirst, de Fockert, & Viding, 2004; Salvucci & Taatgen, 2008; Wickens, 2002). More difficult, complex or demanding tasks require more resources. Multiple tasks can be accomplished to the extent that they do not exceed the available resources. When a task or tasks exceed the available resources, performance will become slower and/or more error-prone. Although multiple tasks drawing on the same resources can be accomplished via efficient task switching, it is not clear under what conditions and to what extent they can actually be done simultaneously. Some simultaneous processing does occur when information is handled by distinct physiological systems (e.g., visual versus auditory perception; peripheral versus central visual processing) but when shared processes, like conscious awareness or working memory, are involved, processing bottlenecks seem to occur (Salvucci & Taatgen, 2008).

Much of the time, driving does not fully occupy a driver's attentional or processing capacity. Studies of driver eye movements suggest that people spend a significant amount of time directing their attention to things that are not related to the driving task (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006) yet they still control the vehicle and negotiate the road and traffic conditions successfully. This can occur because the vehicle, the road and the traffic behave predictably. As a result, expectations provide a reliable basis for allocating visual attention across space and to different tasks across time, and decisions and responses can be planned ahead so that attentional resources are not taxed. Decisions to attend to distracting stimuli can be made strategically and involuntary distraction can be accommodated within the schedule of driving tasks. Problems are likely to arise, however, when unpredictable events happen (e.g., the traffic ahead suddenly stops, a pedestrian or vehicle suddenly crosses into our path) or when the attentional demands of the driving task are high (e.g., a driver must make quick decisions about a route, then change lanes and negotiate an unfamiliar, busy intersection). In these cases, periods of inattention to the driving task can mean: that a driver does not notice an important change in the conditions in time to respond; that processing important information is slowed by the competing demands of the distractor; or that poor decisions are made because insufficient information about the situation has been sampled. A number of researchers have attempted to determine empirically the maximum time it is safe for drivers to have their gaze distracted from the driving task. Values ranging from 0.75 (individual glance duration) to 2 seconds (total time with eyes off the forward roadway) have been derived from calculations of required brake times and recorded crashes (e.g., 1.6s, Wierwille, 1993, cited in Horrey & Wickens, 2007; 2s, Klauer, et al., 2006; 0.75s, Smiley, Smahel, & Eizenman, 2004).

As well as null and adverse effects, it is possible that distractors may sometimes have a positive impact on driving safety. People are not good at maintaining attention to a monotonous stimulus environment. Under these circumstances, performance typically declines with time on task. However, recent laboratory studies suggest that the decline in performance can be stalled or reduced when people engage in simple cognitive tasks during the monotonous task (Ariga & Lleras, 2011; Oron-Gilad, Ronen, & Shinar, 2008). These findings raise the possibility that ESD or other advertising images might be beneficial for driving performance and safety under certain circumstances (e.g., in monotonous driving environments such as night drives on rural roads). Of course, this hypothesis has yet to be tested and the result is likely to depend critically on the content of the particular images used and the extent of cognitive engagement they provoke.

This brief discussion of attention and information processing in driving starts to suggest why studies of the effects of ESDs might yield inconsistent results. Clearly, the extent to which an ESD (or other sign) distracts from and affects driving can be influenced by many properties of the images including the extent to which they change (from not at all to frequently changing), the perceptual quality of the images (e.g., from unlit, low quality images to very bright, high quality images), and the physical dimensions and location of the image relative to the driver (e.g., from small to extremely large; low mounted to high mounted). Specific properties include: the dwell time or length of time that each image is continuously displayed; the transition time between two consecutive images; the speed limit of road which interacts with dwell time to predict the number of images presented to each driver and the distance travelled while the driver is distracted looking at the sign; the spacing between signs on the roadway; the image luminance (or perceived brightness); the sign size; the lateral position (relative to a drivers field of view); the elevation (relative to a drivers typical field of view); the salience of the images themselves (e.g., colour, size, complexity) and the extent to which they resemble other important information such as traffic signs and signals; the content of images, particularly the amount of information that must be processed and the amount of thought the images elicit; and message sequencing where two or more consecutive images are meaningfully related. These characteristics may influence i) whether the image attracts involuntary attention or voluntary attention, ii) how long a driver's gaze will be focussed on the image, iii) whether some part of the roadway ahead can be perceived at the same time as the image, and iv) whether the image commands active consideration, and for how long.

The impact of ESDs will also be a function of: (1) characteristics of the drivers that influence their attention and how demanding they find the driving task (including age, experience, physical and mental state, and familiarity with the driving location); (2) the demands of the driving task, as determined by, for example, traffic density, traffic speed, weather conditions, and the complexity of the road and traffic environment; and (3) the driver's self-regulatory behaviour, such as ignoring the distractor or making compensatory changes in other behaviours, such as reducing speed (Young, Regan, & Lee, 2009).

Methodological considerations

The research bearing on the effect of ESDs on driver distraction and safety spans a range of methods including real-world studies conducted under normal traffic conditions, laboratory studies of simulated driving, and experimental studies of basic perceptual and cognitive processes. Each method has limitations that need to be understood when applied to the study of the effects of ESDs.

(i) On-road versus laboratory studies

On-road studies incorporate the complexity of real driving conditions and driving behaviour which makes them an important potential contributor to our knowledge about road safety issues. Unfortunately, the measures used in on-road studies are rarely able to fully capture that complexity. So, despite their potential, on-road studies often provide only a gross or partial picture of the phenomenon of interest.

As we have seen, real driving conditions are quite tolerant of human information processing limitations most of the time. During routine, predictable driving, drivers generally can and do accommodate a degree of distraction without causing harm. However, when the amount of attention paid to the driving task or the demands of the driving environment change, safety may be threatened. The former might occur, for example, if attention is distracted involuntarily away from the roadway or if the driver is motivated to direct attention away from the road by something more interesting. Similarly, if the demands of the environment increase, for example, the traffic density increases or it starts to rain heavily and visibility is reduced, then the amount of attention required to maintain safe performance also increases. In these circumstances, the critical functional balance may be lost between the attention paid and that required. Measuring ongoing changes in both the attention paid and the attention required by the driving task would be extremely difficult.

Many influences on driving behaviour and safety on the road are transient and uncontrollable (e.g., the behaviour of other road users, traffic conditions, current weather conditions etc). This variability and lack of control is problematic for on-road studies because it introduces noise into the data. On the other hand, it is precisely those times when unpredictable and unexpected transient factors occur that the risk of crashing due to distraction is likely to be highest yet these events are relatively rare. Extended periods of driving may be required to capture these events and even then their effects may be masked by the preponderance of uneventful conditions.

Driving simulator and laboratory studies, on the other hand, cannot easily represent large, changeable roadside signs with any degree of realism (Molino, et al., 2009). As a result, very few simulator and laboratory studies have assessed the impact on drivers of ESDs or other types of changeable signs (i.e., scrolling signs, tri-vision signs, animated or moving video signs).

These study methods allow much better control over extraneous influences on behaviour than on-road studies so that the effects of a particular condition or event of interest can be studied in isolation and with a high level of precision. In so doing, however, laboratory studies simplify the environment, change the temporal and task demands on the driver, and cannot provide the same motivational imperative as real driving. Importantly, these studies often do not allow drivers to self-regulate their behaviour towards a distractor because it requires some response. In these cases, the study design effectively forces drivers to be distracted when this may not be their response on-road. The precision of laboratory studies also means that quite small effects can be detected, raising questions about their importance on the road.

(ii) On-road control conditions

The design of on-road studies requires careful consideration of appropriate control conditions. A number of the on-road studies of ESDs did not use appropriate control conditions (Tantala & Tantala, 2007, 2009a, 2009b, 2010a; Tantala & Tantala, 2005). To evaluate the effect of an ESD, the minimum design requires measurement of outcome variables before and after installation under conditions where, as far as possible, nothing else at the site changes. When other factors at the installation site also change (e.g., an ESD is installed coincident with the removal of a number of other signs) it is difficult to attribute any effect or lack of it to the ESD. To rule out the possibility that the outcome measures would have changed over time regardless of the ESD (for example, due to improvements in safety features in the vehicle fleet over time), time locked measures at comparable control sites without the ESD are also required. Identifying truly comparable control sites is difficult because differences in traffic load, usage patterns, road geometry, visual clutter and other factors may affect the outcome. A number of the on-road studies of ESDs have compared sites with ESDs to sites with other types of advertising signs. When these signs share common perceptual features with ESDs (e.g., changeable tri-vision signs), interpreting a null finding is impossible. Sign-free control sites are needed and ESDs should be (but usually aren't) installed in a previously unsigned location to minimise the number of potential confounding factors at play and to get a true assessment of the impact of the sign.

The duration of the pre- and post- installation measurement periods is also critical. Many road safety outcomes are relatively rare, so a lengthy period (often years) might be required to amass sufficient observations to properly power statistical tests.

The length of roadway over which the effects of signs are measured is also important. Although some studies have used a constant distance (e.g., Tantala & Tantala, 2010b used a maximum of 0.5miles or 805m) or time (e.g., Lee, McElheny, & Gibbons, 2007 used 8s), an accurate estimate of the impact of an ESD would require measures over the entire distance from which the sign may be seen and this distance will vary according to the size and location of each sign.[3] Studies that measure distraction on approach to the signs, but not on departure may not adequately tap the effect of any remnant cognitive distraction after passing the sign.

(iii) Gaze as an outcome measure

[3] Of the three main candidates for a definition of sight distance (sign legibility, the ability to focus the image, and the ability to see the sign) the third is preferable because image changes that do not require focus (e.g., colour changes) may still attract attention.

Measures of gaze behaviour are increasingly being used in research to index distraction but commonly used measures like glance duration, glance frequency, and total glance time towards a distractor are imperfect measures of distraction (Victor, Engström, & Harbluk, 2009). Implicit in the use of these measures is the assumption that if the eyes are directed at the road then the person is not distracted. However, the occurrence of looked-but-failed-to-see crashes is clear evidence that people can direct their gaze to driving-relevant locations without attending to the visual information in view (Herslund & Jørgensen, 2003). Further, a number of studies have now documented that when drivers divide their attention (for example, between the driving task and a cognitive distraction) gaze becomes more rigidly concentrated on the centre of the road ahead and hazard scanning is reduced (e.g., Recarte & Nunes, 2003). Under these circumstances, traditional glance metrics will give the false impression that a person is fully attending the road ahead, when in fact they are not. Persistent cognitive distraction after gazing at or passing a sign might be expected when the content of the sign is emotive (Most, Chun, Widders, & Zald, 2005), clever or interesting, ambiguous or poses unanswered questions. More sophisticated measures of gaze, such as Percent Road Centre (the percent of gaze time per minute within 8^o of the centre of the lane ahead) and the variability in radial gaze angle, can be used to identify the 'gaze concentration' effect described above and their use is recommended to properly assess roadside sign distraction (Victor, et al., 2009; Victor, Harbluk, & Engström, 2005). If traditional glance measures are used, Horrey and Wickens (2007) have argued against the use of average glance times. Instead, they recommend that longer or more unsafe glances (i.e., those in the 'tail' of the glance time distribution) are the most appropriate focus of analysis.

(iv) Driving behaviour as an outcome measure

Driving performance measures, such as lane keeping and steering, speed maintenance and headway distance, rapid braking or errors, can provide an indication of impairment caused by distraction. However, different measures of driving are not equally affected by distraction and some measures are differentially sensitive to different types of distraction. For example, movement of the eyes away from the road to a distractor can impair lateral vehicle control (e.g., lane keeping, steering metrics) and hazard scanning and detection. However, during 'gaze concentration' which is associated with cognitive distraction, lane keeping is maintained or improved, but scanning and reactions to roadway events (such as diminishing distance to the cars ahead) are impaired (Engström, Johansson, & Östlund, 2005; Recarte & Nunes, 2003; Victor, et al., 2009). Poor choice of driving measures could thus bias the conclusions drawn from distraction studies.

(v) Crashes as an outcome measure

A number of studies, including those conducted by Tantala and Tantala (2007, 2009a, 2009b, 2010a, 2010b; 2005) have looked at the impact of ESDs and other roadside signs on crash numbers or crash rates. Although this strategy looks directly at the links between advertising signs and safety outcomes, there are a number of problems with crash measures.

Crashes are typically caused by a sequence of events – that is they are multi-causal. Using Reason's (e.g., 2000) famous 'Swiss Cheese' analogy, a crash occurs when a number of 'system' failings (or holes in the cheese) align. None of the individual failings would necessarily produce a crash but together they do. So, a distracted driver may not crash until there is an unexpected change in traffic conditions. Together these two events still may not yield a crash unless the transient traffic conditions block the driver from making an effective last-minute avoidance manoeuvre, and so on. Consequently, crash data tells more about the number and frequency of latent risks in the system than about the risk posed by any particular element in the system (e.g., distraction by ESDs). This means that crash data collected at one location and time may say very little about the likely impact of ESDs on crashes at another location and time where the latent risk profile is different. Naturalistic driving studies (e.g., Klauer, et al., 2006) which allow behaviour and other driving circumstances to be sampled across many situations, so that the relative risk of their association with crashes and near crashes can be calculated, help to address this problem. In other on-road study designs, measures of driving and gaze distraction may provide better metrics of the risk posed by roadside signs than crash data.

Crashes are relatively rare events. This can pose problems for the interpretation of statistical tests conducted on crash data. Low numbers of crashes do not provide enough power to reliably detect real changes in crash rates over time. So, if a study finds that a change in crash rates following the installation of an ESD is not statistically significant, it is difficult to know whether there really is no change or whether the statistical test was underpowered. The problem of low crash numbers also has implications for the length of time over which crash data must be gathered before and after a sign is installed.

Studies that use crash outcome data and compare point estimates of crash rates before and after the installation of an ESD are problematic. The difficulty arises because this analysis fails to account for any existing trend in crash rates that could hide the effect of the sign. For example, suppose that crash rates before and after an intervention do not differ significantly. If crash rates had been declining over time before the intervention, the result would mean that the sign had actually increased the crash rates. In this case the increase is not obvious because it was superimposed on the underlying declining trend. Analyses (e.g., Bayesian estimation techniques) that compare observed crash rates in the post-intervention condition to expected values extrapolated from the trend in pre-intervention crash rates yield more accurate conclusions. Very few of the on-road studies of ESDs have used methods that account for pre-existing trends in crashes but the two that have (Massachusetts Outdoor Advertising Board, 1976; Tantala & Tantala, 2010b) reported statistically significant effects of sign installation that were not apparent when simple pre-post analyses were used. In both studies, crashes increased after sign installation compared to the numbers predicted by the pre-installation trend.

Official crash data sets provide a relatively small subset of the population of dangerous events on the road. Crash data sets are limited to crashes with more serious outcomes because people tend not to report the less serious ones to police. Similarly, crash data sets do not contain information about near-crashes yet these may have the same causal mechanisms as actual crashes despite having different outcomes. As discussed earlier, whether or not a crash occurs at the end of a sequence of causal events may simply reflect the presence or absence of other latent risks at that particular time. Indeed, Klauer et al. (2006) analysed recordings of crashes and near-crashes experienced by drivers in the 100-car Naturalistic Driving Study and confirmed that the preceding events were similar but there were 11 times more near-crashes than crashes. On the other hand, crash data sets include crashes that are not distraction-related, as well as those that are. Some ESD researchers have attempted to minimise this noise in the data by analysing only certain types of crashes and removing crashes that the authors believed were not distraction-related. For example, Tantala and Tantala (2007) conducted some analyses after removing crashes due to other causes (including speeding, alcohol, teen and senior drivers). Clearly, this strategy has the potential to result in inappropriate data reduction (e.g., removing crashes involving speeders, drunks, teens or seniors who were distracted by an ESD).

(vi) Study participants

The effect of roadside advertising on distraction and driving performance may vary between different groups of people, so the nature of study samples must be considered critically. For example, there is good evidence showing that older drivers are less able than younger drivers to hone in on important information when a scene is cluttered by irrelevant distractors, like roadside advertising, and are slower to respond under conditions of high attention demand (see Edquist, 2008a; Koppel, Charlton, & Fildes, 2009). Further, novice drivers have been found to use suboptimal hazard detection strategies (Chan, Pradhan, Pollatsek, Knodler, & Fisher, 2010; Crundall & Underwood, 1998; Patten, Kircher, Östlund, Nilsson, & Svenson, 2006; Pradhan, et al., 2005) which may, conceivably, put them at a disadvantage when re-orienting to the traffic conditions following distraction. Of course, because advertisers target their material to specific consumer groups, the content and style of an advertisement may be differentially distracting to those being targeted. This aspect of distraction has not been systematically studied.

Conclusion

Based on an understanding of attention and its role in driving, this paper has identified factors that are likely to affect the relationship between ESDs, distraction and safe driving. The paper has also highlighted methodological limitations that might compromise the validity of research findings. These factors need to be considered when designing or using research on ESDs.

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