The impact of attentional set and situation awareness on dual tasking driving performance

Gemma, F. Briggs*[a], Graham, J. Hole,[b] Jim, A. J. Turner[a]

[a]The Open University, Walton Hall, Milton Keynes, UK,

[b]The University of Sussex, Falmer, Brighton, UK.
Tel: (01273) 606755 ext. 4246, e-mail: G.Hole@sussex.ac.uk

** Corresponding author: Tel: 01908 652734, e-mail: Gemma.Briggs@open.ac.uk*
Address: Gardiner 1, 006, The O.U, Walton Hall, Milton Keynes. MK7 6AA

Highlights

Dual taskers use enduring attentional sets when resources are shared between tasks

Reliance on attentional set contributes to decreased detection of unexpected events.

Distraction leads to longer reaction times for unexpected events, even when they are congruent with driving

The impact of attentional set and situation awareness on dual tasking driving performance

Abstract

The impact of attentional set and situation awareness on event detection and reaction times was investigated in 2 simulated driving experiments. Experiment 1: thirty participants viewed and reacted to thirty driving films containing unexpected items which were either driving congruent or incongruent. Group 1 completed the task without distraction; group 2 completed a concurrent conversation task. Experiment 2: thirty participants viewed and reacted to twenty driving films which contained unexpected yet driving relevant events. Half of the participants completed the task without distraction and half completed a concurrent conversation task. Measures of event detection and reaction time were recorded for both experiments. Compared to undistracted participants, dual-taskers reacted to fewer unexpected events; recorded longer reaction times; and reacted to fewer incongruent and peripheral events, suggesting an enduring attentional set for driving. Dual tasking drivers may adopt a strategy of over-reliance on schema-driven processing when attention is shared between tasks.

Keywords: attentional set, schemas, dual tasking, cognitive workload, driving, situation awareness

Statement of relevance: Dual tasking whilst driving raises significant safety concerns. Identification of the attention allocation strategies employed by dual tasking drivers may help to explain why driving performance deteriorates when a secondary task is introduced. This research suggests that the application of a schema-driven attentional set, when cognitive workload is increased by a secondary task, can lead to failures in visual perception and decreased driving performance.

1. Introduction

There is overwhelming evidence that driver distraction (defined as anything that draws attention away from the primary task of driving, Regan, Lee & Young, 2008) impairs driving performance and is a major factor in road accidents (see Atchley, Tran & Salehinejad, 2017 for an extensive review of distraction-related research, using a wide variety of methodologies). Activities such as texting are obviously risky because they require the driver to look away from the road and take their hands off the steering wheel. However, even if the driver's eyes are on the road and their hands are on the wheel, an activity such as mobile phone use has been shown to be dangerously distracting because it takes the driver's mind away from driving. In the absence of detailed normative data on the prevalence and duration of distractions, it is difficult to accurately assess their riskiness. Possibly the best risk estimates so far come from Dingus et al's (2016) case-control study of naturalistic driving. Data recorded from 3,500 drivers of instrumented cars over a three-year period provided information on the contribution of distraction to 905 crashes. Overall, drivers were found to be engaging in distracting activities for more than half of the time they were driving, doubling their risk of crashing compared to when they were driving undistracted. Different distractors were associated with different levels of risk. Interacting with devices such as touchscreens increased the risk of a crash approximately five-fold. Using a hand-held mobile phone was associated with an approximately four-fold increase in crash risk, which is highly consistent with the findings of an early study by Redelmeier and Tibshirani (1997) on increased risk of accidents amongst phone-using drivers.

These epidemiological data are consistent with a large body of research findings showing that drivers conversing on a phone - whether hand-held or hands-free - show significant impairments in driving performance. The behavioural manifestations of mobile phone use whilst driving are now well documented: drivers notice fewer hazards, and are slower to respond to the ones that they do detect

(Strayer, Drews and Johnson, 2003; Strayer & Drews, 2007; Hyman et al., 2009; Fisher and Strayer, 2014; Strayer and Fisher, 2016). As Young, Salmon and Cornelissen (2013) point out, the aim of research now should be to develop theoretical models of *why* these deficits occur, elucidating the underlying cognitive and perceptual processes responsible for them. The concept of Situation Awareness (SA) is potentially very useful in this context. There are many definitions, conceptions and models of SA, and this is not the place for a detailed evaluation of them (see e.g. Salmon et al., 2008, Salmon, Stanton & Young, 2012; Endsley, 2000, 2015,; Plant & Stanton, 2016). For the purposes of this paper, we use Smith and Hancock's (1995) definition, that SA is 'At a very simple level, an appropriate awareness of a situation (p.146)' (noting, as they do, that the emphasis is on 'appropriate', since not all elements of a situation will need to be attended to).

Endsley's (1995) model of SA is also relevant here. It postulates the existence of three levels: perception (Level 1), comprehension (Level 2) and projection (Level 3). Subsequent models (e.g. Smith and Hancock, 1995) have emphasised the cyclical nature of these processes, in line with Neisser's (1976) 'Perceptual Cycle Model', and questioned the apparent hierarchical relationship between them that is implied by calling them 'levels'. Nevertheless, at a descriptive level, Endsley's (1995) model corresponds well with the tasks that drivers have to perform in order to function effectively. An experienced, undistracted driver needs to rapidly acquire information relevant to the primary driving tasks of navigation and hazard-avoidance. Full SA requires a detailed, accurate and up to date mental model of the driving environment as it is now, and how it is likely to be in the near future. Drivers cannot merely respond to events as and when they occur. Therefore a vital aspect of their mental model is prediction of what is likely to happen next, based on the current state of the driving environment. Drivers need to evaluate information, and use it to plan what they will do next as well as what other road-users are likely to do. Driving is a fast-paced and fast-changing activity, so the evaluation of information and execution of plans are likely to change the nature of the information that the driver needs to obtain, from moment to moment, which in turn will change the plans, and so on.

Many aspects of the behaviour of mobile phone-using drivers are consistent with the idea that they show reduced SA: (1) They make fewer eye-movements, which are largely restricted to the area immediately ahead (Recarte and Nunes, 2000; Victor, Harbluk & Engstrom 2005; Briggs, Hole and Land, 2016). This means they are less able to detect any potential hazards that might occur to the sides of the vehicle (such as a pedestrian about to step into the road) because they are not scanning these regions. (2) Even though their eyes are positioned straight ahead, drivers show reduced awareness of information from that direction, due to 'inattentional blindness': visual imagery from the phone conversation competes with the external world for processing resources, increasing the risk of inattentional blindness (Mack and Rock, 1998) and hence 'looked but failed to see' errors (Strayer & Drews 2007; Briggs et al. 2016; Bergen et al. 2013). (3) In order to maintain performance in what are seen as the 'primary' tasks in driving, such as lane-keeping and collision avoidance, drivers divert resources from other tasks (cf. Hockey's 1997 'compensatory control' model, 1997). They drive slower (sometimes inappropriately so, compared with the rest of the traffic), and use their indicators and mirrors less (Reed & Robbins, 2008). Reduced use of mirrors means that they are largely unaware of the state of the traffic behind them.

A few studies have examined SA in distracted drivers. For example, in their driving simulator study Heenan et al (2014) found that conversation impaired drivers' SA more for vehicles located behind the driver than for those that were ahead. Gugerty, Rakauskas and Brooks (2004) and Ma and Kaber (2005) questioned participants to probe their SA as they drove in a simulator. In both studies, drivers who were also conversing showed poorer SA than undistracted drivers. As such, an interesting issue is how a mobile phone-using driver can achieve any semblance of SA when their processing resources are also being used for maintaining a conversation: both activities are processing-intensive and therefore are likely, in combination, to exceed the driver's processing capacity. The answer may lie in the fact that for an experienced driver, aspects of vehicle control are fairly automatized (Shinar, Meir & Ben-Shoham, 1998)), and the driving environment is generally quite predictable. A clear set of rules dictates how drivers should behave (e.g., keep to one side of the road, stop at red traffic lights, give way at junctions, etc.). Most of the time, these rules are followed by vehicle users and pedestrians. The predictability of the driving environment and the highly repetitive nature of many driving scenarios are both factors that encourage road-users to make extensive use of schemas. As with SA, the concept of ’schema’ has many subtly different definitions, but essentially schemas are mental templates of situations that are based on repeated prior encounters with similar events. Norman and Shallice's (1986) model of executive control suggests that many routine behaviours could be performed by recruiting appropriate schemas. They suggest that a relatively low-level process called ‘contention scheduling’ activates schemas in response to appropriate environmental triggers, with higher-level executive processes intervening only if the situation is unusual, or if schemas need to be overridden for some reason. Neisser's (1976) Perceptual Cycle Model emphasises how schemas can facilitate interaction with the world: they guide the processes of perception and attention that acquire information about the environment. This information then modifies and updates the schemas, in a cyclical process. Schemas encourage the use of an ‘attentional set’, a bias to search for task-relevant sensory information whilst paying less attention to task-irrelevant information. Thus, in normal driving an individual is likely to pay more attention to road signs, relevant to driving, than to names of shops that they pass, which are irrelevant to the task at hand.

Most research to date has investigated the use of schema-driven attentional set in undistracted drivers. The use of schemas has benefits for drivers in terms of reducing their mental workload and enabling them to focus on information that is relevant to their current situation. However, reliance on schemas has potential costs too; if the schema encourages the use of an inaccurate or inadequate attentional set, the end result can be diminished SA. An attentional set can lead to a biased selection of information for processing whilst other, highly relevant, information goes unnoticed (Fracker, 1988). Indeed, once an ‘attentional set’ has been selected, it may not be continually evaluated to ensure it is the most efficient strategy to employ (Leber and Egeth, 2006), potentially leading to reduced SA. For example, the attentional set that allows for efficient driving in an open-road environment may not be appropriate in an urban environment, but a driver may not switch strategies when moving from one to the other. When a secondary task is introduced, in order to reduce distraction, drivers may be even less likely to change their attentional set (Bacon and Egeth, 1994; Pammer and Blink, 2012).

An early example of the costs of an inappropriate attentional set comes from a study by Hole and Tyrell (1995). After repeated exposure to images of traffic scenes depicting motorcyclists using daytime headlights, drivers were slow to respond to an unlit motorcyclist. Some even failed to detect him altogether. This implies that the drivers were looking for headlights rather than motorcyclists *per se*. This induced attentional set was effective for rapid detection of headlight-using motorcyclists, (obviating the need to process perceptual information from the oncoming motorcyclist in any detail) but at a cost of reducing the detectability of unlit motorcyclists. In a driving simulator study, Most and Astur (2007) similarly induced an attentional set by asking participants to follow signposts, with yellow and blue arrows on them, at ten junctions on the route. Half of the participants were instructed to follow the yellow arrows (inducing a yellow attentional set) and half were instructed to follow the blue arrows (blue attentional set). At the tenth junction a motorcycle, which was either yellow or blue in colour, unexpectedly swerved into the path of the participant’s vehicle and then stopped. Participants were required to react to this event by braking in order to avoid a collision. When the colour of the motorcycle was incongruent with the participant's attentional set, braking latencies were on average 186ms longer than when the bike matched the attentional set. Furthermore, 36% of the participants in the incongruent condition collided with the motorcycle compared with only 7% in the congruent condition. Most and Astur (2007) argue that this demonstrates the strength of an individual's attentional set and its ability to decrease SA, resulting in deteriorated driving.

Borowsky et al. (2008) looked at the role of experience in the development of schemas, by presenting experienced and novice drivers with images in which they varied the position of road signs. Signs were either shown on the correct (right) or incorrect (left) side of the road. Experienced drivers were both more likely to notice the road signs presented on the correct side of the road, and less likely to detect those on the incorrect side of the road. Novice drivers were unaffected by the positioning of the signs. Borowsky et al. (2008) claim that experienced drivers had a clear attentional set which novice drivers were yet to develop. This notion is supported by similar investigations looking at the effects on hazard detection of variation in driving environment (urban vs. residential). More recently, Salmon, Young and Cornelissen (2013) have used the schema concept (together with SA) in order to understand why conflicts occur between different groups of road-users. They showed that motorcyclists, cyclists and car-drivers had very different, and incompatible, schemas about junctions. The drivers' schemas were 'car-centric', leading them to direct their attention towards sampling other cars in their environment, rather than looking for cycles and motorcycles. Their predisposition to look for other cars led them to attend more to the regions ahead and behind the car, rather than to the sides, where cyclists and motorcyclists were likely to be positioned (see also Walker, Stanton & Salmon 2011; Salmon, Young & Cornelissen 2013).

As mentioned earlier, all of these studies have investigated the use of schemas and attentional set in undistracted drivers. They do not consider the added cognitive workload imposed by the introduction of a secondary task. Laboratory-based research on 'inattentional blindness' (Mack and Rock, 1998) suggests that when attention is focused on one task, unexpected yet salient items in a scene can go unnoticed, particularly if they share common features (e.g. colour, shape, size) with the items that are the main focus of attention (Neisser and Becklen, 1975; Most, Simons, Scholl and Chabris, 2000; Kovivisto and Revonsuo, 2008). While task-relevant items have been shown to be more likely to be detected as primary task complexity increases (Rensink O'Regan and Clark, 1997), so too does the likelihood of an unexpected item going undetected (Cartwright-Finch and Lavie, 2007). Taken together, these findings support the notion of participants applying a feature-based attentional set when completing dynamic tasks. When task demands increase, through introduction of a secondary task, information which is incongruent to the primary task can go undetected. However, unexpected items which are personally salient to participants, such as their name or a smiley face, appear to 'pop out' and grab attention (Mack and Rock, 1998) supporting the suggestion of semantic-based attentional sets. If this is the case, it is easy to see how a personally-salient stimulus, such as a personalised alert tone from a phone, could capture a driver's attention.

Fisher and Strayer's (2014) SPIDER information processing model highlights the cognitive processes that can be impaired in dual tasking drivers, leading to decreased SA. They suggest that the addition of a secondary task can negatively affect *Scanning*, *Predicting*, *Identifying*, *Decision making* and *Executing a Response* whilst driving. To drive safely, an individual needs to adequately scan (*perception*) the scene to identify any dangers or objects that require action. This information needs to be combined with previous knowledge to ensure it is understood (*comprehension*) which feeds into the ability to make informed decisions regarding movements in the scene. The ability to make decisions, which result in executing 'safe' driving responses is, in turn, affected by the ability to make predictions, based on previous knowledge and experience, about the near future in a given driving situation (*projection*). Fisher and Strayer (2014) found that interruption to any of the SPIDER processes can result in degraded SA, which is brought about by a cascading effect throughout the remaining processes. Thus, a driver who fails to adequately scan the scene, due to answering a phone call, may fail to identify a pedestrian stepping off the curb, resulting in them failing to make the decision to brake, therefore increasing the likelihood of an accident. This model is supported by numerous empirical investigations demonstrating decreased driving performance in dual tasking drivers (Strayer and Fisher, 2016; Gugerty and Falzetta, 2005; Lee, Morgan, Wheeler, Hulse and Dingus, 1997; Ma and Kaber, 2005; Parkes and Hooijmeijer, 2001).

Our hypothesis is that drivers conversing on a mobile phone will attempt to cope with the resultant excessive processing demands by resorting to a greater use of schemas, coupled with an increased propensity to adopt an attentional set. The effects of dual-tasking are to exaggerate a tendency which is already present in undistracted drivers: i.e., to detect hazards via schema-driven attentional sets that are developed through experience of the driving environment. The first experiment investigates the extent to which dual tasking drivers employ an attentional set when asked to detect hazards. Based on research showing that dual tasking drivers show decreased visual awareness, it considers the relevance of the position in the scene of an unexpected yet personally relevant item. The second experiment focuses on the impact of driving events which are incongruent with expectations for 'normal' driving.

2. Experiment 1

2.1. Method

2.1.1. *Participants*

Thirty participants (14 male, 16 female) from the Open University were recruited for participation via an e-mail campaign. They ranged in age from 17 to 51 years (*M* = 29.6 years, *S.D* = 8.5 years), all held a valid driving licence, had an average of 8.7 years driving experience (range 1-25 years). Participants were randomly assigned to a condition, but to protect against the possible confounding effect of driving experience (in years) comparisons between conditions were made. No significant differences in driver experience were found between control (*M* = 10.7 years, *S. D*. = 6.7 years) and experimental (*M* = 7.07, *S. D*. = 6.9) conditions (t (28) = 1.43, p >.05). All participants claimed to have normal or corrected to normal vision and gave full informed consent prior to taking part.

2.1.2. Design

An independent measures experimental design with two conditions was used: 'driving' undistracted (control) and dual tasking (experimental). Participants in the control condition watched short video clips of driving situations and were required to respond to unexpected images appearing in the scene. These images were either driving congruent (e.g. road signs) or driving incongruent (e.g. icons of faces, or 'emoticons'). Participants in the experimental condition completed the same task whilst simultaneously performing a secondary task of conducting a hands free phone conversation with the experimenter.

2.1.3. *Apparatus*

2.1.3.1. Driving Task

A series of thirty video clips displaying everyday driving scenarios were used. The videos were filmed from within a car and included engine sounds and part of the steering wheel and dashboard to give the illusion of being within the vehicle. Each film displayed typical driving events, such as negotiating junctions and roundabouts, and were filmed in a range of different urban areas when weather conditions were fair and visibility was clear. The clips did not contain hazardous events that would ordinarily require a response from a driver. However, participants were asked to watch the clips from the perspective of a driver being vigilant for hazards. Prior to the experiment the clips were viewed by 5 independent assessors, who had a minimum of 10 years driving experience and were unaware of the aims of the study. Only those clips which were unanimously deemed not to contain an obvious hazard, requiring a response from a driver were included in the experiment. Each film lasted a maximum of 60 seconds, and clips were divided with intervening blue screens which announced the onset of each film. In twenty of the films an unexpected image appeared on screen and remained present for a duration of 5 seconds. Ten of these images were congruent with the task of driving (e.g. road signs) and ten were incongruent with the driving task (e.g. icons of faces, or 'emoticons', as used in Mack and Rock, 1998), see Fig. 1. All images were black and white to ensure colour-based attentional sets were not implemented. Half of these images were presented in the centre of the screen and half in the peripheral areas (5.2° from the centre, half to the left and half to the right), only one image was displayed in any one clip, all images were matched for size, and order of presentation of was randomised for each participant. Note that it was not possible to treat congruence and position independently, as each unexpected image appeared only once, and therefore in only one position (either central or peripheral). This was done to minimise the possibility of participants intentionally looking out for a second appearance of an unexpected image. The remaining ten clips contained no unexpected images. Participants were required to watch the films, from the perspective of a driver, and instructed to watch for potential hazards. Participants pressed a button on a key pad if they saw an unexpected image appear during any of the clips.

The videos were digitally projected onto a 3m x 2m screen, at a refresh rate of 60 Hz. Participants were tested individually and sat 2m in front of the screen in a driving simulator apparatus, comprising steering wheel and accelerator and brake pedals. The key pad for responding to images was positioned on the steering wheel and when pressed recorded participant reaction time, in milliseconds, from the onset of each appearing image. Half of the participants completed this task without distraction and half were required to complete a concurrent conversation task (see below).

Fig.1: Representative examples of congruent (left) and incongruent (right) central images.

A video-based approach was used in this investigation largely due to ethical considerations regarding participant safety. Due to the distraction imposed on participants in the dual tasking condition, on road investigation would present a significant safety risk. Whilst future simulator-based investigations would be beneficial, the lab-based video approach taken here allows for greater experimental control. Stimuli of this type are frequently used in distracted driving research, and have also been used for investigations specifically focusing on situational awareness (e.g. Underwood, 2002) and schema (Borowsky et al., 2012). Whilst a fully immersive driving environment may offer greater ecological validity in terms of activation of driving schema or attentional set, the current set up replicated key aspects of driving (e.g. monitoring the scene, searching for hazards, reacting to unexpected events) as well as the driving environment (e.g. use of driving seat, pedals and steering wheel and large projection of the driving scene).

2.1.3.2. Conversation Task

Participants in the dual tasking condition were asked to hold a conversation with the experimenter on the topic of anti-social behaviour. This topic was selected as, at the time of data collection, it was an issue which most individuals were aware of and one which most people felt happy to discuss. For the purposes of maintaining consistent levels of conversation throughout presentation of the films, information regarding legislation was gathered and formed into questions. Participants then held a conversation on this topic with the experimenter (who was out of sight of the participant, positioned 1m behind them). Performance in this task was not recorded, as it was merely intended as a distraction from the primary ‘driving’ task, however the experimenter used prompts throughout to ensure consistent, active engagement in the conversation by participants.

2.1.4. Procedure

Prior to data collection ethical approval was granted for the investigation by the ethics board of The Open University. Participants completed the experiment individually in a 40-minute session. After providing informed consent, they were randomly assigned to a ‘driving’ condition: undistracted (no conversation task) or dual tasking (with conversation task). They were then informed that they would see a series of short clips of driving scenes, which they should watch from the perspective of a driver, looking for hazards (as noted above, no hazards were presented). Participants were told that some of the clips may show images appearing, and if they detected an image they should press the button on the steering wheel. After making a response, the rest of the clip would continue to play, before moving to the next film. Those in the dual tasking condition were told that they would also be asked to have a conversation with the experimenter whilst completing the ‘driving’ task. These participants were told that their primary task was responding to the driving task, but that the experimenter would prompt them to respond to the conversation throughout. To ensure that participants also followed the content of the driving films, they were instructed that they would be asked some questions about their content at the end of the experiment. Participants were then given a chance to complete a series of 5 practice trials, before progressing to complete the full experiment. On completion, participants answered some brief questions on their driving experience before being debriefed.

3. Results

3.1. Number of unexpected images detected

A 2 (‘driving’ condition) x 4 (type of unexpected image, combining congruence/incongruence and central/peripheral positioning) mixed ANOVA revealed a significant difference in number of images reacted to dependent on ‘driving condition, F (1, 28) = 23.33, $p < .001$, $\eta_p^2 = .45$, with undistracted participants detecting more images than their dual tasking counterparts (see Fig. 2). A significant main effect of type of unexpected image was also found, F (3, 84) = 8.17, $p < .001$, $\eta_p^2 = .23$, as well as an interaction between the two, F (3, 84) = 3.37, $p < .05$, $\eta_p^2 = .11$. Post hoc tests revealed significant differences in dual taskers between congruent images presented in the centre and in the periphery ($p < .01$), as well as between congruent images presented in the centre and incongruent images presented in the periphery ($p < .001$), and incongruent images presented in the centre and those presented in the periphery ($p < .05$), see Fig. 2

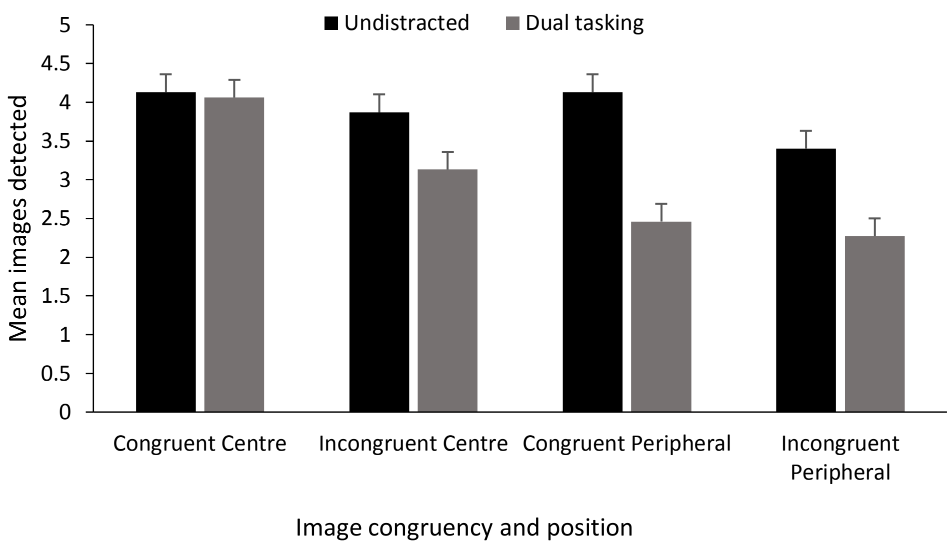


Figure 2: Mean number of images detected dependent on position and congruency of item. Error bars show standard error.

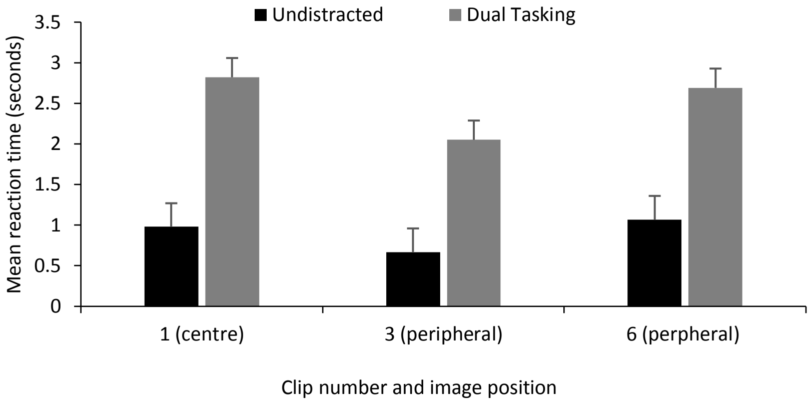
As shown above, undistracted participants responded to more images than dual tasking participants across conditions of position and congruency of images. Dual tasking participants, however, detected fewer images presented in the peripheral areas, and detection was lessened more so for incongruent images. Whilst no significant difference was found between congruent and incongruent images presented in the centre, for either undistracted or dual tasking participants, dual taskers detected fewer incongruent central images than congruent central items.

3.2. Reaction times for detection of images

For each of the images presented, the participant's reaction time (in milliseconds) was calculated from the latency between their button press and the actual time in the clip when the image first appeared. As dual tasking participants reacted to fewer images than their undistracted counterparts, only those events which gained responses from comparable numbers of participants in each condition were included in the analysis. From the 20 clips presented, 4 were excluded from analysis on this basis (two were congruent peripheral, one was congruent central and another was incongruent peripheral).

Individual independent t-tests were carried out on reaction time data for the remaining 16 clips. For the congruent images, significant differences in reaction times between undistracted and dual tasking participants were found for 3 of the 7 clips: clip 1, congruent centre, t (24) = 4.73, p < .001, r = .22; clip 3, congruent peripheral, t (28) = -4.66, p < .001, r = .17; clip 6, congruent peripheral t (28) = -1.62, p < .001, r = .06, see Fig. 3a. In all cases, dual tasking participants took longer to react than undistracted participants. For the incongruent images, all of the 9 clips analysed revealed significant differences in reaction times between undistracted and dual tasking participants, with dual taskers taking longer to react than undistracted participants, see Fig. 3b.

(a) Congruent images



(b) Incongruent images

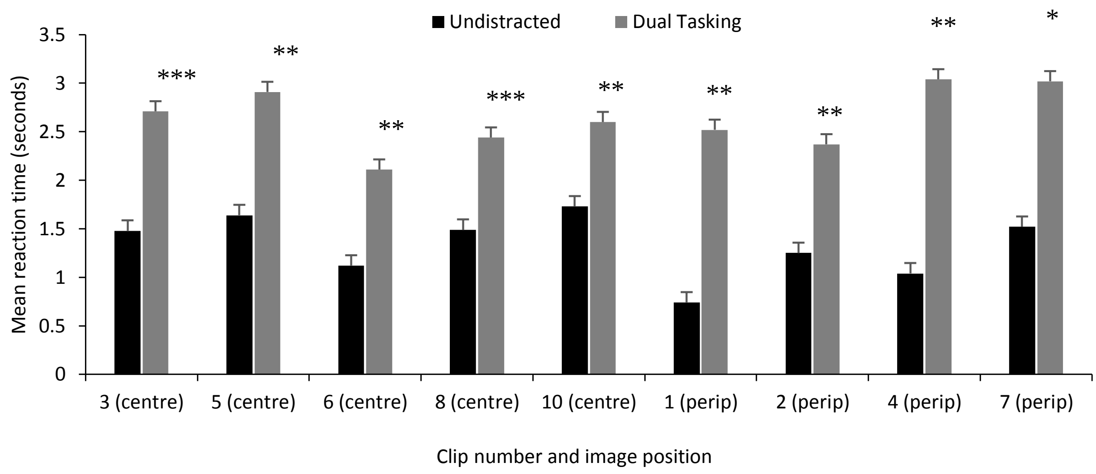


*Fig. 3. (a and b) Mean reaction times for (a) congruent and (b) incongruent images dependent on condition and location of image. Error bars who standard error. * = sig difference from undistracted participants at p < .05, ** = Sig. difference from undistracted participants at p < .01, ***= sig. difference from undistracted participants at p < .001.*

As shown in Fig. 3, dual tasking participants took significantly longer to react to some congruent images, and all incongruent images, than undistracted participants. The longest reaction times were recorded for incongruent images presented in the peripheral areas.

4. Conclusions

These findings suggest that dual tasking participants were more likely to detect and react to images which matched the attentional set of driving (i.e. congruent images), when they were presented in the centre of the scene. Moreover, the dual-tasking participants were less likely than undistracted participants to react to images presented in the peripheral areas, particularly when the images were incongruent to the driving task. When incongruent images were detected, reaction times were significantly longer for dual tasking participants. One interpretation of these findings is that whilst all participants appeared to employ an attentional set for detecting driving-congruent images, the attentional set adopted by dual tasking drivers reduced further their ability to detect and react to unexpected items (driving-incongruent images) in the driving scene. Experiment 2 further investigates this tentative conclusion by measuring reactions of dual tasking drivers to unexpected yet driving relevant events.

5. Experiment 2

5.1. Method

5.1.1. *Participants*

Thirty participants (11 male, 19 female) from the University of Sussex were recruited for participation via an e-mail campaign. Participants received course credits for their involvement in the study and ranged in age from 18 to 32 years (*M*= 22.20 years, *S.D* = 4.4 years). All participants held a valid driving licence, had an average of 6.2 years driving experience (range 1-15 years). Participants were randomly assigned to a condition, but to protect against the possible confounding effect of driving experience (in years) comparisons between conditions were made. No significant differences in driver experience were found between control (*M* =6.7 years, *S. D*. = 3.8 years) and experimental (*M* = 5.7, *S. D*. = 4.7) conditions (t (28) = 0.64, p >.05). All participants claimed to have normal or corrected to normal vision and gave full informed consent prior to taking part

5.1.2. Design

This study used an independent measures experimental design with two conditions: undistracted (control) and dual tasking (experimental). Undistracted participants watched short video clips of driving situations and responded to unexpected events within those clips. Dual tasking participants completed the same task whilst simultaneously performing a secondary task of holding a conversation with the experimenter.

5.1.3. *Apparatus*

5.1.3.1. Driving Task

A series of twenty video clips filmed from within a car were used. As in Experiment 1, these films incorporated part of the dashboard, contained engine noises, and were filmed in a range of urban road environments in fair weather conditions. Ten of the driving films showed typical driving situations, such as changing lanes, turning at a junction, etc. and the remaining ten films depicted events which are plausible but generally unexpected in 'normal' driving (i.e. which contradict a driver's expectations), such as stopping at a green traffic light or giving way when the driver has priority[1]. Half of the clips showed the unexpected event in the centre of the scene and half had an event in the periphery (either to the left of the right). Prior to use in the experiment, all clips were viewed by 5 independent assessors, who had a minimum of 10 years driving experience and were unaware of the aims of the study. Only those films which were unanimously deemed to represent events which run contrary to normal driving expectations were used in the experiment. Participants were required to watch the clips, from the perspective of a driver, and press a button if they detected an unexpected event. Each film lasted a maximum of 60 seconds, and clips were divided with intervening blue screens which announced the onset of each film. As in Experiment 1, participants sat in a driving simulator set up and the films were digitally projected onto a 3m x 2m screen. The same method of recording participant reactions was also used.

[1] The full list of unexpected events is as follows: Event one = failing to move when traffic light turns green (peripheral); Event two = giving way when driver has priority (central); Event three = fast approach behind a stationary vehicle (central); Event four = stopping flow of traffic to allow a car to pull out (peripheral); Event five = swerving into the bike lane (central); Event six = stopping at a green traffic light (central); Event seven = allowing a van to pull out at the last minute (peripheral); Event eight = giving way on a roundabout when driver has priority (peripheral); Event nine = stopping at an empty zebra crossing (central); Event ten = a cyclist swerves into driver's lane (peripheral).

5.1.3.2. Conversation Task

The same conversation task as in Experiment 1 was used. Performance in this task was not recorded, but prompts were used by the experimenter to ensure continued engagement with the conversation task for dual tasking participants.

5.1.4. Procedure

Prior to data collection ethical approval was granted for the experiment by the ethics board of The University of Sussex. Each participant completed the experiment individually, in a 30-minute session. After having completed a consent form, they were randomly assigned to a condition (undistracted or dual tasking). Participants were informed that they would be shown a series of driving clips, which they should watch from the perspective of a driver, and should react if something unexpected occurred in the film. Participants made their response by pressing a button on the steering wheel in front of them, and were made aware that after pressing the button the remainder of the clip would continue to play. Those in the experimental condition were asked to concurrently hold a conversation with the experimenter. These participants were informed that their primary task was to watch and react to the driving films. On completion of the driving task, participants provided brief information on their driving experience before being debriefed.

6. Results

6.1. Number of Unexpected Events Detected

A signal detection analysis was carried out on the number of unexpected events detected. This was chosen as a more representative measure of overall detection performance, as not all participants reacted to all of the individual events presented. The resulting d-prime score is a composite measure of performance which takes into account both correct responses (correctly-detected events) and errors (missed events). An independent t-test was then calculated with d-prime score as the dependent variable, revealing a significant difference in number of events reacted to between the two conditions, t (28) = 17.13, $p < .001$, r = .08. Undistracted participants (*M* = .61, *S.D.* = .04) demonstrated better detection of unexpected events than those who were dual tasking (*M* = .46, *S.D.* = .03). These findings suggest that distraction significantly impaired detection of unexpected, driving congruent, events.

6.2. Reaction Times for Unexpected Events

As with Experiment 1, for each of the clips presented the participant's reaction time (in milliseconds) was calculated from the actual time in the clip when the unexpected event began to occur. As dual tasking participants reacted to fewer images than their undistracted counterparts, only those events which gained responses from comparable numbers of participants from each condition were included in analysis. From the 10 clips containing unexpected events 5 were excluded from analysis on this basis (across all of these clips, response rates for undistracted participants greatly outweighed those made by dual taskers). From these 5 clips, participants responded to more unexpected events presented in the centre of the scene (4 events) than those presented in the periphery (1 event).

Reaction time data for the remaining five events (four central, one peripheral) were analysed using individual independent t-tests, revealing significant differences across all events, (event 2, central, giving way when driver has priority, t (21) = -4.53, $p < .001$, r = .03; event 3, central, fast approach behind a stationary vehicle, t (26) = -4.30, $p < .001$, r = .68; event 4, peripheral, stopping flow of traffic to allow a car to pull out, t (19) = -1.89, $p < .001$, r = .19; event 5, central, swerving into the bike lane, t (23) = -7.97, $p < .001$, r = .68; event 9, central, stopping at an empty zebra crossing, t (25) = -3.14, p <

.01, r = .29). In all cases, undistracted participants responded more quickly to events than dual tasking participants, see Fig. 4.

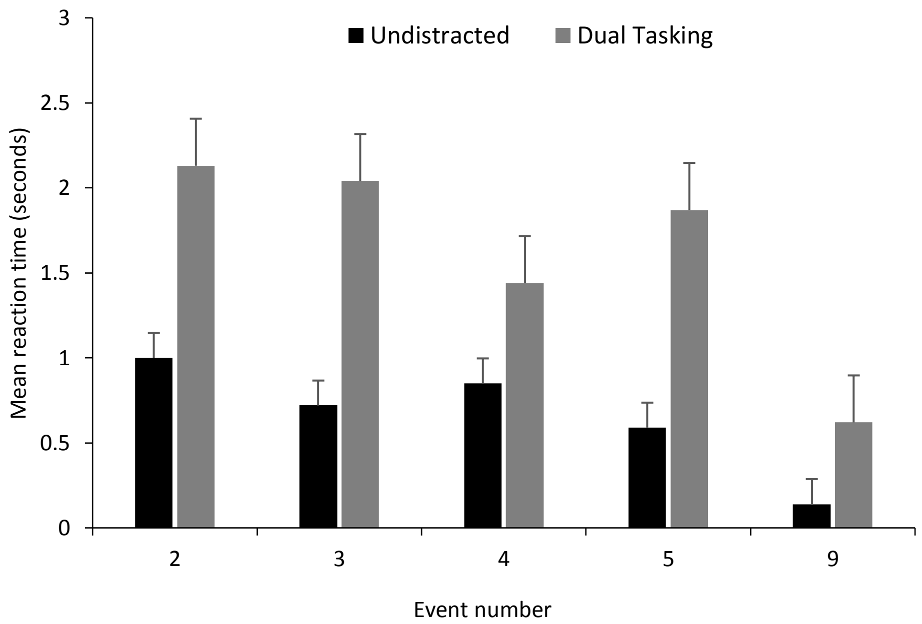


Figure 4: Mean reaction times for unexpected events across 'driving' conditions. Error bars show standard error.

The finding that all but one of the unexpected events, which gained enough responses to allow analysis, appeared in the centre of the scene suggests that dual tasking drivers were most likely focussing their visual attention directly ahead of them. The one peripheral event which was more reliably reacted to involved a halt in the flow of traffic to allow a vehicle to enter the carriageway, while the other peripheral events which were missed were largely unaccompanied by a change in the participant's course of action.

7. Conclusions

These findings demonstrate that dual tasking participants may show an overreliance on their expectations for 'normal' driving situations, as they detected fewer unexpected driving related events, and took significantly longer to react to events they did detect than undistracted participants. Dual tasking participants were more likely to notice and react to unexpected events presented at the centre of the scene; even so, they still took significantly longer to react to such events than did the undistracted participants. Failure to detect peripheral events when dual tasking is a common finding in research of this type, adding weight to the suggestion that dual tasking contributes to cognitive and visual tunnelling (Recarte and Nunes, 2000; Briggs et al., 2016).

8. General discussion

The combined results of the current investigation support the notion of drivers employing schemas and attentional sets when completing a driving task, which differentially affect their situation awareness (SA). All drivers noticed more driving-congruent (schema-congruent) events than incongruent events. However, when a secondary task was introduced, it appears that the attentional set of drivers altered further, to the extent that very few incongruent events were identified, particularly when they were in the peripheral areas of the scene. When unexpected events were relevant to the primary task, but ran contrary to expectations of 'normal' driving, dual tasking participants demonstrated decreased detection of events and again took longer to react to those events they did detect. These findings suggest that the attentional set applied by dual tasking 'drivers' is either different from that employed by undistracted participants, or that the added distraction of the secondary task negatively affected the application of the attentional set. Thus, dual tasking drivers may demonstrate an over-reliance on their expectations and, despite decreased awareness of aspects of the driving scene, continue to apply their original attentional set even when attentional resources are shared between two concurrent tasks.

The decreased performance in detection and reaction times for events can be explained in relation to both the SPIDER model (Fisher and Strayer, 2014) and SA (Endsley, 1995; Smith and Hancock, 1995). The reduced ability of dual tasking participants to notice and react to events (particularly in the peripheral areas) suggests failures in effective *scanning* of the scene and *identification* of items requiring a reaction. The decreased tendency to notice events meant that either a response was not made or, if it was, took significantly longer to be employed, supporting Fisher and Strayer's (2014) suggestion that failure in one aspect of the model can cascade throughout the other processes. Together, these findings suggest flaws in the *perception* and *comprehension* stages of a complete SA mental model. In Experiment 2, issues of perception and comprehension are also apparent for dual tasking participants, where an overreliance on expectations, based on past experiences, meant that unexpected yet driving relevant events were not *identified,* preventing informed d*ecision making* and the *execution* of an appropriate reaction to the event. Explanations for these findings can also be couched in terms of schema-driven processing (Neisser, 1976; Norman and Shallice, 1986) leading to a reduced awareness of the situation (Smith and Hancock, 1995) which can in turn contribute to decreased dual tasking performance (Bergen et al., 2013).

The results are also consistent with previous research on inattentional blindness (Mack and Rock, 1998), demonstrating further that when attention is divided or shifted between tasks, detection of unexpected items decreases, even when they should be personally salient to participants (e.g. smiley faces). Most and Astur's (2007) feature-based attentional set suggestion is supported by the findings of Experiment 1, where more driving-relevant items (road signs) were detected than driving-incongruent items. The suggestion that attentional sets can be semantic, rather than just feature-based (Pammer and Blink, 2012) is also supported by this investigation. The finding that dual tasking participants, in Experiment 2, failed to notice unexpected yet driving-relevant events supports the notion of an attentional set based on an understanding of what 'normally' occurs in these situations, rather than simple failure to detect specific objects (e.g. a green traffic light). Thus, whilst all drivers may employ an attentional set whist driving, which can be both semantic and feature-based, the introduction of a secondary task may lead to a schema-driven attentional strategy which is unreceptive to unexpected events in the driving scene (Parkes and Hooijmeijer, 2001; Fracker, 1988). This finding is relatively surprising given that participants were informed that there might be unexpected events in the 'driving' task, and were therefore primed to look out for such events, suggesting that their attentional set should have incorporated this information (Jones and Endsley, 1996). Regardless, in line with Most and Astur's (2007) investigation, dual tasking participants were more likely to miss critical events in the driving scene, suggesting perhaps that decreases in SA, brought about by dual tasking, automatically occur with the adoption of schema-driven processing, and only with consciously applied effort and allocation of attentional resources will SA improve (as proposed by Young and Stanton, 2002, and supported by Hockey, 1997).

As mentioned in the introduction, the behavioural consequences of using a mobile phone whilst driving are well-documented, but the processes underpinning these 'symptoms' remain to be elucidated (Young, Salmon and Cornelissen, 2013). An analysis of dual-tasking in terms of SA can explain a number of phenomena. Firstly, it helps to explain why so many drivers believe that they are capable of using a mobile phone while driving (Lesch and Hancock, 2004). Surveys suggest that whilst drivers notice that other drivers are impaired when using a phone, they consider their own driving to be unaffected. This may be partly due to the pervasive existence of ‘self-serving bias’, an inflated assessment of one's own abilities compared to other peoples’, yet if drivers have reduced SA while dual-tasking, they may well remain unaware of their own impairment. They simply fail to notice unexpected hazards and hence receive no feedback about their poor driving except when an accident actually occurs. This false self-assessment will be reinforced by the fact that most of the time, using a mobile phone whilst driving will have no obvious detrimental consequences: driving is fairly predictable, and so compensating for reduced SA by falling back on well-established schemata will often suffice. Another explanation may lie in Stanton et al's (2006) concept of ‘Distributed Situation Awareness’. We have considered SA from the viewpoint of the individual driver, but if one considers SA at the level of the entire road system, we can think of it being shared amongst the drivers in a given locale at any time. This makes for a forgiving system: if one driver has reduced SA because they are distracted, then other drivers with fuller SA can compensate for the distracted drivers' impairment, so that there are no adverse consequences. In short, other drivers can make allowances for the distracted drivers' poor driving, by giving them a wider berth if their lane-keeping is erratic, assessing which way the non-signalling distracted driver is likely to turn, based on that driver's road positioning, and so on. Accidents will only occur when the distributed SA cannot cope with the situation - for example, when someone steps off the pavement unexpectedly, or a driver stops at a green filter light instead of proceeding through it. Here, everything depends on the SA of the individual driver nearest the event. Normal driving consists of ‘long periods of sub-critical demand interspersed with moments of crucial response, or hours of boredom and moments of terror’ (Hancock, Lesch & Simmons, 2002, p. 503): thus a mobile phone-using driver with reduced SA can probably manage quite well on the basis of schema-driven behaviour until something unexpected happens - in which case an accident is likely to ensue.

8.1. Methodological limitations

The use of a video-based approach to investigate the attentional set employed by participants is open to criticism in terms of the degree to which participants consider the task of detecting unexpected events as personally important or critical. For this reason, the results need to be treated with caution and it would be beneficial to replicate these investigations using a more realistic and actively controlled driving simulator, or an on-road task. Whilst our approach allows for a focused investigation into detection of unexpected events, it does not necessarily adequately represent all of the processes required, and associated workload experienced in real driving situations. Our approach cannot, for example, simulate the full deployment of a schema as this would involve some kind of action component. However, in principle many of the properties of schemata can still be investigated even if the schema does not run its full course. For example, event nine in Experiment two showed a car stopping at an empty zebra crossing. In terms of the SPIDER model, this clip initially activates an ‘actions to take at a pedestrian crossing’ schema, based on previous experience. The schema begins with *Scanning* the video for driving-relevant features such as pedestrian crossings. It involves *Predicting*, in the sense that pedestrian crossings often have pedestrians nearby, waiting to cross: if there are pedestrians, then the car in front may stop to let them cross; if there are not, the car in front will probably carry on at its present speed. The next process is *Identifying:* if there are no pedestrians, the car ahead is unlikely to decelerate or brake; however, if there *are* pedestrians waiting to cross, the car in front is likely to stop. In normal driving, *Decision making* should then follow. In Norman and Shallice's (1986) model, this part of the schema could be handled fairly automatically by the contention scheduling system, on the basis of environmental triggers and two fairly simple IF-THEN rules: IF pedestrians are present THEN prepare to stop the car, versus IF there are no pedestrians THEN continue to drive. Only the very last part of the schema, *Executing a Response*, is not simulated in our study. In real driving, this would involve using the vehicle controls to either maintain progress or halt the car, depending on the presence or absence of pedestrians. Our participants did execute a response (pressing a button) but of course this is not the usual response that would be made by a driver in a real car. For our purposes, this is not a crucial problem; both distracted and undistracted participants have, in effect, been asked to substitute a button press for the normal chain of events that are executed as part of the schema. If there are no differences between the two groups, they should be similarly affected by this response-substitution (and should produce similar hazard detection and hazard response times). The fact that the distracted participants were significantly poorer at this task is consistent with a prediction of schema theory, at least as outlined in Norman and Shallice's (1986) model. One interpretation is as follows: both groups of participants initially rely on the contention scheduling system to 'choose' between the two competing responses ordinarily activated as part of this schema. When it suddenly becomes apparent that this schema is not progressing in its normal way, the Central Executive has to step in and assume control, abandoning the schema as a means to execute behaviour. This takes time, but is much quicker for the undistracted participants because they are less heavily reliant on the schema in the first place.

Further improvement could be made by increasing the sample sizes for each experiment in this investigation. This would be of particular advantage when analysing the reaction time data for the unexpected events in Experiment 2 where only half of the events had enough responses from dual tasking participants to enable meaningful analyses. In all cases of items excluded from analysis, the majority of dual tasking participants failed to react *at all* to the event. Whilst it could be claimed that this is purely due to the experimental manipulation being highly effective, the limited number of experimental trials call this conclusion into question. Furthermore, as there were relatively few events which could be analysed for reaction time differences between conditions their results cannot necessarily be considered representative of typical behaviour.

When looking at the specific events contained in those clips which did return enough responses to allow analysis, it appears that most of them were more relevant to affecting the continuing progress of the driver (e.g. giving way when driver has priority, stopping flow of traffic to allow a car to pull out, stopping at an empty zebra crossing). Conversely, dual tasking participants did not all reliably react to events which may have increased the time available to them to effectively dual task, temporarily reducing overall cognitive workload (e.g. failing to move when traffic light turns green, and giving way on a roundabout when driver has priority). Whilst it is possible that the types of event presented may have differentially allowed dual taskers to switch attention between tasks, this was not controlled for in the original design and therefore cannot be assumed. Another possibility is differences in the positioning and salience of the unexpected events, which could affect reaction rates; these were combined into a single factor for Experiment 1 and it may be informative to replicate the experiment with stimuli that allow them to be treated as separate variables. Future investigations could also benefit from questioning participants after completion of the procedure as a measure of the importance they place on safety in specific driving situations (e.g. speed of approach, lane discipline, etc.), as well as taking additional measures of SA. An alternative method to investigate participants' reliance on schemas might be to use Jackson, Chapman and Crundall's (2009) 'what happens next?' procedure, where video clips are stopped before a hazard fully unfolds and participants have to say what was likely to happen, based on what had happened so far. One might expect distracted participants to produce predictions that were much more schema-based than those of undistracted participants.

8.2. Future investigations

The current investigation has revealed that drivers may routinely adopt an attentional set for processing aspects of the driving scene. When dual tasking, the reliance on this schema-driven attentional set may be increased to the extent that the driver's situation awareness is diminished, which could impair task performance. Further investigation is, however, required to ascertain the effects of different types and positioning of unexpected events. Given the assumption of reduced scanning capabilities of dual tasking participants, a measurement of eye movements would provide useful confirmation. This would also allow for investigation of overall variance in eye movements of participants, which could add further understanding as to why some unexpected yet driving relevant events went undetected. Further, as the current investigation had clear goals set for participants (i.e. detection of images/events), more natural driving activities should be investigated where goals may change during the course of the trial (e.g. changing route, imposing time limits, etc.). Such an approach may allow for a more rounded measure of SA than simply event detection and reaction time data. Additionally, as the assumption is made that attentional set can differentially affect SA, especially whilst dual tasking, investigation into individual differences in capability of maintaining an up-to-date mental model of a situation may be beneficial, with measures of working memory capacity being a logical starting point.

If the attentional set employed by a driver can be affected by the introduction of a secondary task, interventions aimed at increasing driver education regarding dual tasking should be considered. Many drivers may be surprised to learn that they routinely employ shortcuts in their attention allocation strategies when they are driving without distraction. However, the introduction of a secondary task, which may demand resources already allocated to the driving task, can further significantly impair performance in detection of and reaction to critical driving events. Changes to the hazard perception test, currently completed by all learner drivers, could address some of these issues. The inclusion of hazards which run contrary to expectations, along with information on how attention is allocated whilst driving, could contribute to improved safety awareness. Application of these findings to current use of information signs for drivers could also prove interesting. Many digital overhead road signs are routinely used for varying purposes (e.g. warning of forthcoming congestion as well as general safety messages, e.g. 'seatbelts save lives'). Future research which assesses driver attentional set and the effectiveness of such multi-use signs may be beneficial, with particular focus on whether the changing use of signs alters a driver's expectations and attentional set.

References

Atchley, P., Tran, A.V. & Salehinejad, M.A. (2017). Constructing a publically available distracted driving database and research tool. *Accident Analysis and Prevention, 99*, 306-311.

Bacon, W. F., & Egeth, H. E. (1994). Overriding stimulus-driven attentional capture. *Perception and Psychophysics, 55*, 485-496.

Bergen, B., Wheeler, K., Medeiros-Ward, N., Drews, F. & Strayer, D. (2013). The Crosstalk Hypothesis: why language interferes with driving. *Journal of Experimental Psychology: General*, *142*(1), 119–130.

Borowsky, A., Oron-Gilad, T., Meir, A., & Parmet, Y. (2012). Driver's perception of vulnerable road users: a hazard perception approach. *Accident Analysis and Prevention, 15*, 1-10.

Borowsky, A., Shinar, D., & Parmet, Y. (2008). The relation between driving experience and recognition of road signs relative to their locations. *Human Factors, 50*, 173-182.

Briggs, G.F. Hole, G.J. & Land, M.F. (2016). Imagery-inducing distraction leads to cognitive tunnelling and deteriorated driving performance. *Transportation Research Part F - Traffic Psychology and Behaviour, 38*, 106-117.

Cartwright-Finch, U., & Lavie, N. (2007). The role of attentional load in inattentional blindness. *Cognition, 102*, 321-340.

Dingus, T.A., Guo, F., Lee, S., Antin, J.F., Perez, M., Buchanan-King, M, & Hankey, J. (2016). Driver crash risk factors and prevalence evaluation using naturalistic driving data. *Proceedings of the National Academy of Sciences of the United States of America, 113*(10), 2636-2641.

Endsley, M.R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors 37 (1),* 32–64.

Endsley, M. R. (2000). Theoretical underpinnings of situation awareness: A critical review. In M. R. Endsley & D. J. Garland (Eds.) (2000). *Situation awareness analysis and measurement.* Mahwah, NJ, Lawrence Erlbaum Associates.

Endsley, M. R. (2015). Situation awareness misconceptions and misunderstandings. *Journal of Cognitive Engineering and Decision Making, 9*, 4-32.

Fisher, D. L., & Strayer, D. L. (2014). Modelling situation awareness and crash risk. *Annals of Advances in Automotive Medicine, 5*, 33-39.

Fracker, M. L. (1988). A theory of situation assessment: Implications for measuring situation awareness. In *Proceedings of the Human Factors Society 32nd Annual Meeting* (pp. 102-106). Santa Monica, CA.

Gugerty, L. & Falzetta, M. (2005). Using an event-detection measure to assess drivers' attention and situation awareness. *Proceedings of the 49th Annual Meeting of the Human Factors and Ergonomics Society*. Santa Monica: Human Factors & Ergonomics Society.

Gugerty, L., Rakauskas, M. & Brooks, J. (2004). Effects of remote and in-person verbal interactions on verbalization rates and attention to dynamic spatial scenes. *Accident Analysis and Prevention, 36*(6), 1029-1043.

Hancock, P.A., Lesch, M. & Simmons, L. (2003). The distraction effects of phone use during a critical driving maneuver. *Accident Analysis and Prevention, 35*(4), 501-514.

Heenan, A., Herdman, C. M., Brown, M.S. & Robert, N. (2014). Effects of conversation on Situation Awareness and Working Memory in simulated driving. *Human Factors, 56*(6), 1077–1092.

Hockey, G. R. J. (1997). Compensatory control in the regulation of human performance under stress and high workload: A cognitive-energetical framework. *Biological Psychology 45*, 73-93.

Hole, G. & Tyrell, L. (1995). The influence of perceptual "set" on the detection of motorcyclists using daytime headlights. *Ergonomics, 38* (7), 1326-1341.

Hyman, I. E., Boss, S. M., Wise, B., M., McKenzie, K. E., & Caggiano, J. M. (2009). Did you see the unicycling clown? Inattentional blindness while walking and talking on a cell phone. *Applied Cognitive Psychology, 24*, 597-607.

Jackson, L., Chapman, P., & Crundall, D. (2009). What happens next? Predicting other road users' behavior as a function of driving experience and processing time. *Ergonomics, 52*(2), 154–164.

Jones, D. G. & Endsley, M. R. (1996). Sources of situation awareness errors in aviation. *Aviation, Space and Environmental Medicine, 67 (6),* 507-512.

Kovivisto, M., & Revonsuo, A. (2008). The role of unattended distractors in sustained inattentional blindness. *Psychological Research, 72*, 39-48.

Leber, A. B., & Egeth, H. E. (2006). Attention on autopilot: Past experience and attentional set. *Visual Cognition, 14*, 565-583.

Lesch, M.F. & Hancock, P. A. (2004). Driving performance during concurrent cell-phone use: are drivers aware of their performance decrements? *Accident Analysis and Prevention, 36* (3), 471-480.

Lee, J. D., Morgan, J., Wheeler, W.A., Hulse, M.C. & Dingus, T.A. (1997). *Development of human factors guidelines for advanced traveller information systems (ATIS) and commercial vehicle operations (CVO): description of ATIS/CVO functions* (FHWA-RD-95-201). Federal Highway Administration, Washington DC.

Ma, R. & Kaber, D. B. (2005). Situation awareness and workload in driving while using adaptive cruise control and a cell phone. International Journal of Industrial *Ergonomics, 35*, 939–953.

Mack, A. & Rock, I. (1998). *Inattentional Blindness*. California, MIT Press.

Most, S. B. & Astur, R. S. (2007) Feature-based attentional set as a cause of traffic accidents. *Visual Cognition 15 (2),* 125 – 132.

Most, S. B., Simons, D. J., Scholl, B. J. & Chabris, C. F. (2000). *Sustained Inattentional Blindness: The Role of Location in the Detection of Unexpected Dynamic Events.* Psyche, 6 (14).

Neisser, U. (1976). *Cognition and Reality: Principles and Implications of Cognitive Psychology.* San Francisco: Freeman.

Neisser, U. & Becklen, R. (1975). Selective looking: Attending to visually significant events. *Cognitive Psychology, 7*, 480-494.

Norman, D. A. & Shallice, T. (1986). Attention to action: Willed and automatic control of behaviour. In R. Davidson, G. Schwartz & D. Shapiro (Eds.), *Consciousness and self regulation: Advances in research and theory* (pp. 1-18). New York, Plenum.

Pammer, K., & Blink, C. (2012). Attentional difference in driving judgments for country and city scenes: Semantic congruency in inattentional blindness. *Accident Analysis and Prevention, 50*, 955-963.

Parkes, A. M. & Hooijmeijer, V. (2001). Driver situation awareness and carphone use. In *Proceedings of the 1st Human-Centered Transportation Simulation Conference* (n.p.). Iowa City, University of Iowa.

Plant, K. L., & Stanton, N. A. (2016). The development of the Schema World Action Research Method (SWARM) for the elicitation of perceptual cycle data. *Theoretical Issues in Ergonomics Science, 17(4)*, 376-401.

Recarte, M. A. & Nunes, L. M. (2000). Effects of verbal and spatial-imagery tasks on eye fixations while driving. *Journal of Experimental Psychology: Applied, 6(1),* 31-43.

Redelmeier, D. A. & Tibshirani, R. J. (1997). Association between cellular-telephone calls and motor vehicle collisions. *The New England Journal of Medicine, 336,* 453-502.

Reed, N. & Robbins, R. (2008). *The effect of text messaging on driver behaviour: a simulator study.* TRL Project Report PPR 367. Transport Research Laboratory.

Rensink, R. A., O'Regan, J. K. & Clark, J. J. (1997). To see or not to see: the need for attention to perceive changes in scenes. *Psychological Science, 8(5),* 368- 373.

Salmon, P.M., Stanton, N.A., Walker, G.H., Baber, C., Jenkins, D.P., McMaster, R. & Young, M.S. (2008). What really is going on? Review of situation awareness models for individuals and teams. *Theoretical Issues in Ergonomics Science, 9* (4), 297–323.

Salmon, P. M., Stanton, N.A. & Young, K.L. (2012). Situation Awareness on the road: review, theoretical and methodological issues, and future directions. *Theoretical Issues in Ergonomics Science, 13* (4), 472–492.

Salmon, P. M., K. L. Young, K.L. & M. Cornelissen, M. (.2013). Compatible cognition amongst road users: The compatibility of driver, motorcyclist, and cyclist Situation Awareness. *Safety Science 56*, 6-17.

Shinar, D., Meir, M. & Ben-Shoham, I. (1998). How automatic is manual gear shifting? Human Factors, 40 (4), 647-654.

Smith, K. & Hancock, P.A. (1995). Situation Awareness is adaptive, externally directed consciousness. *Human Factors, 37*(1), 137-148.

Stanton , N. A., Stewart, R., Harris, D., Houghton, R. J., Baber, C., McMaster, R., Salmon, P., Hoyle, G., Walker, G., Young, M. S., Linsell, M., Dymott, R. & Green, D. (2006) Distributed situation awareness in dynamic systems: theoretical development and application of an ergonomics methodology, *Ergonomics, 49,12-13*, 1288-1311.

Strayer, D.L. & Drews, F.A. (2007). Cell-phone-induced driver distraction. *Current Directions in Psychological Science, 16*(3), 128-131.

Strayer, D. L., & Fisher, D. L. (2016). SPIDER: A framework for understanding driver distraction. *Human Factors, 58*, 5-12.

Strayer, D. L., Drews, F. A. & Johnston, W. A. (2003). Cell phone-induced failures of visual attention during simulated driving. *Journal of Experimental Psychology: Applied, 9 (1),* 23-32.

Underwood, G. (2002). Visual search while driving: skill and awareness during inspection of the scene. *Transportation Research Part F*, *5*, 87–97.

Victor, T.W., Harbluk, J.L., & Engstrom, J.A. (2005). Sensitivity of eye-movement measures to in-vehicle task difficulty. *Transportation Research Part F: Traffic Psychology and Behaviour, 8* (2), 167–190.

Walker, G. H., Stanton, N.A. & Salmon, P.M. (2011). Cognitive Compatibility of Motor-Cyclists and Car Drivers. *Accident Analysis & Prevention, 43* (3), 878–888.

Young, K. L., Salmon, P. M., & Cornelissen, M. (2013). Distraction-induced driving error: an on-road examination of the errors made by distracted and undistracted drivers. *Accident Analysis & Prevention, 58,* 218-225.

Young, M. S. & Stanton, N. A. (2002). Attention and automation: new perspectives on mental underload and performance. *Theoretical Issues in Ergonomics Science, 3(2),* 178-194.