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Detrimental effects of carryover of eye movement behaviour on hazard perception accuracy: Effects of driver experience, difficulty of task, and hazardousness of road

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ABSTRACT

Novice drivers are more likely to be involved in road accidents than experienced drivers and this relates to their lower performance in hazard perception tasks. Hazard perception performed under dual task conditions is also affected differentially due to driver experience. In this study, we explore the detrimental effect of vertical eye-movement carryover from one task to a second task in drivers of different levels of experience, whilst accounting for road conditions. Participants searched letters presented horizontally, vertically, or in a random array. Following this, they identified a hazard in a driving scene. Carryover of eye movements from the letter search to the driving scene was observed and participants were quicker and more accurate when responding to a hazard following horizontal scanning, compared to following vertical and random scanning. Furthermore, while carryover of eye movements was equivalent for all participants, the negative effect it had on hazard identification accuracy was less prominent in experienced drivers, especially when viewing the most hazardous of images. These results indicate that carryover of eye movements is another potentially distracting effect that can impact on the ability and safety of novice drivers.

1. Introduction

Novice drivers are more than twice as likely to be involved in a road-traffic accident than more experienced drivers (Cooper, Pinili, & Chen, 1995). The rate of involvement in accidents decreases quickly over the first two years of driving (Fisher, Pollatsek, & Pradhan, 2006). The most reliable behavioural correlate of crash involvement is hazard perception (Drummond, 2000; Hull & Christie, 1992; McKenna & Horswill, 1999; Pelz & Krupat, 1974; Quimby, Maycock, Carter, Dixon, & Wall, 1986; Transport and Road Research Laboratory, 1979). Hazard perception occurs when a driver detects, evaluates, and reacts to driving situations that have a high likelihood of causing a collision (Crundall et al., 2012) and it tends to improve with driver experience. Novice drivers have lower hazard perception accuracy (Crundall, Underwood, & Chapman, 1999; McKenna & Crick, 1991; Renge, 1998; Sagberg & Bjørnskau, 2006) and slower reaction times than experienced drivers (Deery, 2000; Hosking, Liu, & Bayly, 2010; McKenna & Crick, 1991; Quimby & Watts, 1981; Sexton, 2000). These effects hold

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even when age is controlled for (Maycock & Lockwood, 1993; McKenna & Crick, 1991; Quimby et al., 1986). Though this might depend on the quality of the hazard perception test given failures to find group differences in hazard perception (Chapman & Underwood, 1998). One of the key reasons why novice drivers show poorer hazard perception (and are involved in more accidents) is due to their visual search strategies (McKnight & McKnight, 2003; Pradhan, Hammel, & DeRamus, 2005). Experienced drivers show more horizontal spread of search than novice drivers, therefore allocating attention to more relevant areas of space (Crundall, Chapman, Phelps, & Underwood, 2003; Crundall & Underwood, 1998; Falkmer, & Gregersen, 2005; Konstantopoulos, Chapman, & Crundall, 2010; Mourant & Rockwell, 1972; Underwood, Crundall, & Chapman, 2002; Underwood, Chapman, Brocklehurst, Underwood, & Crundall, 2003; Wallis & Horswill, 2007). Conversely, novice drivers tend to show more spread of search in the vertical plane relative to experienced drivers (Chapman & Underwood, 1998; Crundall & Underwood, 1998; Evans, 1991; Mourant & Rockwell, 1972). These eye-movement differences are more pronounced when viewing more hazardous driving scenes: Experienced drivers adapt their eye-movement pattern to suit the hazardousness of the road, whereas novice drivers do not (Chapman, Underwood, & Roberts, 2002; Crundall & Underwood, 1998; Garay-Vega, Fisher, & Pollatsek, 2009; Lee et al., 2008; Underwood, 2007). These results indicate that with experience, drivers learn to anticipate the location of potential road hazards. This experience tends to develop within three years of driving (Crundall et al., 2003).

The pattern of eye movements in experienced drivers indicates that visual search is driven by skill, experience, and familiarity (Ranney, 1994). When viewing natural scenes, in general, observers tend to show highly stereotypical eye movements, focusing on the most informative part of a visual scene (Loftus & Mackworth, 1978; Mackworth & Morandi, 1967) and extracting the most diagnostic information for encoding (Hills & Pake, 2013). Eye movements are also affected by salient objects in the visual scene capturing attention (Buschman & Miller, 2007; Connor, Egeth, & Yantis, 2004). For drivers, these can include hazards generally (Chapman & Underwood, 1998) and specifically their location in the visual field and whether they are moving (Underwood, Chapman, Berger, & Crundall, 2003). In Itti and Koch's (2000) model of attention, top-down and bottom-up factors such as those described can interact to affect attention and eye movements. Indeed, two parallel pathways – focusing on local feature saliency and global contextual features – have been proposed for the control of eye movements and attention (Torralba, Oliva, Castelhano, & Henderson, 2006).

There is another factor that influences eye movements during hazard perception when viewing road scenes. Using relatively realistic driving images and videos, Thompson and Crundall (2011) demonstrated that eye movements from a previous task can carry over to a second task even when the tasks are unrelated. Their participants performed a letter-search task with strings of letters that were arranged horizontally, vertically, or randomly across the screen. Immediately following this, participants saw a road scene (or video clip) and were asked to memorise it (Experiment 1), rate it for hazardousness (Experiment 2), or respond to the onset of the hazard (Experiment 3). Even though the time spent completing the letter search was minimal, the orientation of letters in this task influenced the allocation of attention and eye movements when viewing the road scene, with increased vertical search following the vertically orientated letter-search task (see also Hills et al., 2016; Thompson, Howting, & Hills, 2015). In addition, responses to the hazards in Experiment 3 were made significantly quicker following letters presented horizontally compared to letters presented randomly or vertically.

This finding may have some important implications for real world driving scenarios. As the driving task is characterised by a predominantly horizontal spread of search (as described above) secondary displays (in-car and road-side) which induce a more vertical search could influence subsequent (primary) search, and may even be detrimental to the detection of hazards. Potentially, the presentation of a secondary task may be adding to the demands of the driving task. It is well known that distraction is the major contributory factor in crashes (Lestina & Miller, 1994). In an extensive prospective study on distraction, Klauer, Dingus, Neale, Sudweeks, and Ramsey (2006) found that approximately 78% of crashes and 65% of near-crashes reported were caused by some form of inattention. Distraction is commonly caused by mobile phones or other in-car displays that involve searching (conceptually similar to the letter-search task employed by Thompson & Crundall, 2011). Furthermore, novice drivers are more susceptible to distraction-related accidents (Stutts, Reinfurt, Staplin, & Rodgman, 2001).

Given the role of distraction in crashes, it is important to understand how carryover of eye movements affects drivers with different levels of experience. Secondary tasks that add to the mental workload of the driver tend to decrease the driver's scanning (Recarte & Nunes, 2003). The perceptual load theory (Lavie, 2010; Lavie, Hirst, De Fockert, & Viding, 2004) would suggest that this is due to the attentional spotlight narrowing to allow focus on the more central features of the task. This restricts the potential to be distracted by external information. Experienced drivers have a more proficient search strategy and deploy their attentional resources more effectively than novice drivers (Crundall et al., 2003). While we might assume that this leads them to be less affected by dual tasks, McKenna and Farrand (1999) have shown that experienced drivers actually suffer greater interference in hazard perception under dual task conditions than novice drivers. This might be because novice driver's performance might be too low to be affected by such additional pressures, whereas there is more potential for performance detriment in experienced drivers. The letter string task of Thompson and Crundall (2007) intermixed with a driving task can be considered a dual task procedure, therefore we might expect that experienced drivers will be more affected by carryover than less experienced drivers. This effect should be enlarged when the primary task is more difficult than when it is easier as this further adds to the mental workload.

While considering the role of hazard perception, it is important to consider the nature of the hazards. We have noted that experienced drivers are able to deploy more horizontal scanning to more hazardous driving scenes than novice drivers. This is based on their attentional capacity. Indeed, when viewing undemanding driving scenes, experienced drivers can devote