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Working Memory Capacity, Visual Attention and Hazard Perception in Driving☆

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In two experiments we explored the influence of individual differences in working memory capacity (WMC) on hazard perception performance in a simulated driving task. In Experiment 1, we examined the relationship between WMC and hazard perception performance under control and dual task conditions, and self-reported driving behavior. Results revealed significant relationships between WMC, hazard perception performance and self-reported driving behavior. Participants lower in WMC performed poorer in dual task conditions and reported more instances of inattention when driving. In Experiment 2, we explored the gaze behavior of low and high WMC individuals whilst completing the hazard perception test under control and dual task conditions. Results revealed that low-WMC individuals had poorer hazard perception performance under dual task conditions and these performance decrements were mirrored in reductions in mean fixation durations on the hazard. Interestingly, pupillary dilation appears to discriminate between low- and high-WMC individuals and might be a useful index of attention for future research.

Keywords: Controlled attention, Gaze, Eye-movements, Driver behavior, Pupillometry, Pupil dilation

Ninety-five percent of driving accidents have been attributed to human error (Rumar, 1985) and of these around 20–30% are thought to be a result of driver distraction (Talbot, Fagerlind, & Morris, 2013). Driver distraction has been defined as “the diversion of attention away from activities critical for safe driving toward a competing activity” (Lee, Young, & Regan, 2008, p. 34), and as such reflects the importance of maintaining goal-directed attentional control to task relevant information while resisting the interference of irrelevant and distracting information. Due to the development of in-car technologies that actively increase the likelihood of distraction, it is no surprise that researchers have been quick to test the implications of such technologies on driver safety and performance. Numerous studies have shown that telephone conversations (Strayer & Johnston, 2001), conversations with passengers (Drews, Pasupathi, & Strayer, 2008), the behavior of child occupants (Koppel, Charlton, Kopinathan, & Taranto, 2011), listening to music (Brodsky & Slor, 2013), and even cell phone notifications (Stothart, Mitchum, & Yehnert, 2015) can have a significant distracting effect, and can impair driver safety. What is clear from this research is that modern day driving environments are littered with potential distractions that need

Author Note

☆ Please note that this paper was handled by the former editorial team of JARMAC.

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to be resisted if a safe level of driving proficiency is to be maintained.

Studies on driving distraction often implicate limitations of working memory (WM) to explain these adverse driving behaviors, whereby cognitive load causes a distraction away from task-relevant information and the exhaustion of attentional capacity. Interestingly the ability to resist distraction and cognitive interference has been linked to individual differences in working memory capacity (WMC) in other applied settings like sport (Furley & Memmert, 2010, 2012) and pressurized performance contexts (Kleider, Parrott, & King, 2010; Wood, Vine, & Wilson, 2015). The results of these studies add support to the contention that high-WMC individuals are generally better able to maintain cognitive control and remain task focused (Engle & Kane, 2004) whereas low-WMC individuals are likely to suffer periodic failures in goal maintenance due to their inability to inhibit distraction or interference (De Jong, Berendsen, & Cools, 1999). Surprisingly, while studies have shown that individual differences in constructs related to WMC such as cognitive failures (Allahyari et al., 2008) and mind-wandering (Galéra et al., 2012) do predict driving performance and self-reported aberrant driving behavior, there is a paucity of research that has explicitly explored the interaction between cognitive load and individual differences in WMC as a predictor of driving performance (Ross et al., 2014).

Two notable exceptions are Watson and Strayer's (2010), and Ross et al.'s (2014) exploration of braking and lane changing behavior respectively. Watson and Strayer (2010) explored the braking behavior of participants under control and dual-task (an auditory OSPAN task) conditions in a driving simulator. Their results showed that whereas the vast majority of participants showed significant performance decrements in dual-task conditions, a small percentage of participants with high-WMC (labeled as 'supertaskers' due to their exceptional multitasking abilities) suffered no decrements in braking performance. Ross et al. (2014) explored the influence of WMC on the lane changing behaviors of young novice drivers under differing cognitive load conditions. Results showed that high-WMC individuals were influenced less by a cognitive load task and performed better on the lane changing driving task.

However, while lane changing and braking behavior are important skills for effective driving, the ability of drivers to anticipate potentially dangerous situations on the road ahead (i.e., hazard perception) has been identified as one of the few measures of driving-specific skill that correlates with the risk of road traffic accidents (Horswill & McKenna, 2004). Hazard perception skills involve having a continuous and dynamic composite representation of current traffic situations (Isler, Starkey, & Williamson, 2009) and therefore this ability relies heavily of WM (Groeger, 2000). In fact, such is the importance of these perceptual abilities that these tests have been incorporated into licensing procedures in the UK and Australia (McKenna & Horswill, 1999). Given the importance of this task to driver proficiency and safety, and considering that modern-day driving environments are littered with the potential for distraction and interference, an explicit examination of the influence of individual differences in WMC and hazard perception performance is warranted.

Experiment 1

The aim of this first experiment was to investigate the relationship between individual differences in WMC, hazard perception performance and self-reported driving behavior. We hypothesized that there would be no significant relationship between WMC and hazard perception performance in the control condition with no load on WM. However, under conditions of high cognitive load we predicted a positive relationship between WMC and hazard perception performance. Specifically, we predicted that lower WMC scores would be related to poorer hazard perception performance. Due to this proposed relationship we further predicted that low-WMC scores would be related to more self-reported instances of driver error, aggressive behaviors, traffic violations and lapses in concentration in participants' driving history.

Methods

Participants

Forty-six drivers (mean age = 24.67, *SD* = 7.41 years) volunteered to take part in the study. All participants held a valid UK driving license and had experience of driving on UK roads (mean experience = 5.41, *SD* = 5.48 years). All participants gave written informed consent prior to commencing the testing procedures and these were approved by a local ethics committee.

Measures

Operation span task. An automated version of the operation span task (OSPAN; Unsworth, Heitz, Schrock, & Engle, 2005) was used to measure WMC. This was presented on a Dell Optiplex desktop PC connected to a 19″ LED monitor running E-Prime (v.2) software. In this task participants are required to solve a series of math problems (e.g., (8/2) − 1 = 1? true/false?) that are each followed by an unrelated letter that needed to be remembered. The task included 15 trials (3 trials each with 3, 4, 5, 6, and 7 letters to remember) and after each trial participants had to recall as many letters as possible. The primary measure of WM capacity was the OSPAN score calculated as the total number of letters recalled across all error-free trials (Unsworth et al., 2005).

Hazard perception performance. The UK Driver and Vehicle Standards Agency (DVSA) hazard perception test is a standard requirement of the UK driving license application process. The test consists of a series of 14 video clips lasting 1 min in duration. The clips feature everyday road scenes containing at least one 'developing hazard' – but one randomized clip features two 'developing hazards'. A developing hazard is described as something that may result in the driver having to take some action, such as changing speed or direction. When the participant perceives a developing hazard they are required to press the mouse button to illustrate it has been detected. The hazard perception score is calculated by the speed at which the participant detects a developing hazard and makes a response. The faster