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Predicting distracted driving: The role of individual differences in working memory

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ABSTRACT

The present study investigated the role of working memory capacity (WMC) in predicting distracted driving performance using a working memory distractor. Forty-nine participants completed four working memory complex spans prior to completing a distracted and non-distracted simulated driving trial. During the distracted driving trial, participants drove while simultaneously completing the Grocery List Task (GLT), a semi-naturalistic working memory task developed by the authors. Results showed that participants were significantly slower at braking when a yellow traffic light appeared and during sudden braking events when distracted. Furthermore, the impairing effect of distraction on braking response time was partially mediated by WMC. There was also a trend towards a moderating effect of WMC, where the impairing effect of distraction was more pronounced for individuals with low WMC than high WMC. Theoretical and practical implications for the role of individual differences in cognition and driving, in-vehicle devices use and traffic safety, as well as semi-autonomous vehicle design are also discussed.

Practitioner Summary

This study was conducted to evaluate the relationship between Working Memory Capacity and distracted driving in a simulated driving environment. WMC partially mediated the effect of distraction on driving as measured by braking response time, and showed a trend towards moderating the effect of distraction on driving. Practical implications are that drivers with low WMC are more susceptible to the effects of driver distraction. Consequently, drivers with low WMC may be at risk for traffic-related crashes due distracted driving.

1. Introduction

According to the National Highway Traffic and Safety Administration (NHTSA, 2016), there are approximately 35,000 fatal driving accidents a year in the United States, incurring $242 billion in economic and $836 billion in societal costs. A dangerous factor associated with such driving fatalities is driver distraction (NHTSA, 2014). In fact, driver inattention was implicated in the deaths of over 3000 individuals and the injuries of over 400,000 individuals (NHTSA, 2014; Ranney et al., 2000). Also, research by Dingus et al. (2006) reported that driver inattention was responsible for 78 percent of all crashes and 65 percent of near crashes.

Traditionally, driver distraction has been attributed to the detrimental effect of physical distractors such as calling, texting, or using a GPS navigation device (NHTSA, 2016). However, an individual may still experience driving impairments even when the distraction is purely cognitive in nature (i.e., involving no physical manipulation of a device). In fact, while only 14% of distracted driving accidents were due to cell phone, *simply being "lost in thought"* was responsible for 61% of all distracted driving accidents between the years of 2012 and 2016 (Erie Insurance, 2018).

An important factor which may affect an individual's ability to remain resilient to the deleterious effect of cognitive distraction while driving may be WMC, or the ability to maintain and manipulate large amounts of information for an extended time. The present study was designed to empirically examine the role of WMC as a mediator and moderator of distracted driving performance. Previous research has not directly examined the role of WMC in the context of distracted driving, especially for those tasks not involving a physical distraction. Thus, it is important to understand the relationship between WMC and distracted driving because of its implications on driving-related accidents.

1.1. Working memory and driving

Working memory is termed as the memory storage system

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associated with holding and manipulating information for a temporary period (Jarrold and Towse, 2006; Baddeley, 2009). The theoretical framework used in this study is Kane and Engle's (2001) domain-general theory, which suggests that working memory consists primarily of a domain-general executive attention system, and secondarily of a domain-specific memory storage system. The domain-general theory is supported by an extensive body of literature which suggests that working memory is related to executive attention (McCabe et al., 2010); Kane and Engle, 2001; Conway et al., 2001; Kane et al., 2007; Engle, 2012).

Previous research shows that increasing working memory load can lead to poorer driving performance. Specifically, engaging in a secondary task can result in poorer situational awareness, more lane deviations on a lane-change task, and slower braking response time (Alm and Nilsson, 1995; Engstrom et al., 2010; Heenan et al., 2014). These studies manipulated working memory load by using a secondary task. However, it is not well understood whether an individual's working memory ability (WMC) predicts driving performance.

Studies on the relationship between WMC and driving performance have shown mixed findings. On one hand, some studies have shown that WMC was related to distracted driving performance. For example, WMC was associated with driving performance on a lane-changing task (Ross et al., 2014). Reductions in WMC was also related to delayed left-turns, slower brake reaction time, increased following distance, and slower speed (e.g., Guerrier et al., 1999; Lambert et al., 2010). In these studies, the distractor used was a working memory span, which is a valid but artificial measure of working memory. However, other studies have used a more naturalistic distractor task such as conversations or riddles. Their findings showed that, working memory capacity was *not* related to distracted driving.

A fundamental question that merits further consideration is why did WMC fail to predict distracted driving performance when naturalistic distractions (i.e., distractions one may typically engage in during everyday driving) were used in the above-mentioned studies? Also, is it possible that the naturalistic distractions used in those studies did not load onto working memory? To address these questions, the present study developed and used a Grocery List Task (GLT) distractor task as a semi-naturalistic adaptation of a complex working memory span, the Auditory Operation Span, and was used as a distractor in the distracted driving trial.

1.2. Gaps in the literature

The present study was conducted to further address the conflicting findings reported with naturalistic distractors used in previous studies of WMC and distracted driving. For example, studies reporting that larger WMC predicted better driving performance often used working memory tasks as distractors such as the operation span, n-back, or digit span (Lambert et al., 2010; Watson and Strayer, 2010). This was a useful paradigm considering that the tasks were already valid measures of working memory. Also, by making the distractor task a working memory task, it also increased the likelihood that WMC would predict driving performance during distraction. However, one may argue that using the operation span as a distractor may have been limiting as it bore little to no resemblance to real-life driving distractions.

Additionally, only a few studies which examined naturalistic distractions used distractors such as conversations or riddles (Heenan et al., 2014; Emfield et al., 2013; Louie and Mouloua, 2015). Using naturalistic distractions in empirical research is valuable and necessary because it potentially extends the findings obtained from controlled laboratory settings to more realistic driving environments. However, such studies have failed to find a significant relationship between working memory and distracted driving. Although it is not certain, it is possible that using naturalistic distractor tasks may have yielded non-significant results because the tasks themselves did not load onto working memory. For instance, although conversations may potentially tap into working memory, there was no evidence to suggest that the conversations as used in the study did load onto working memory.

Furthermore, other studies which failed to find a relationship between WMC and distracted driving used measures such as the simple digit span (Fried et al., 2006; Alexandersen et al., 2009; Marcotte et al., 1999), which is a measure popularly used to measure working memory in neuropsychological tests such as the WAIS (multiple versions; Wechsler, 1955). However, it is also possible that this was a more appropriate measure of short-term memory than working memory (Foster et al., 2015). Similarly, another study which did not find a significant relationship used a Plus-Minus task, which is a task that involves shifting between adding and subtracting a series of randomly selected numbers (Mantyla et al., 2009). This task may have loaded onto executive attention instead of working memory. Studies using such distraction tasks may not have found significant effects because such tasks did not load onto working memory.

The gap in the literature suggests two limitations in prior research: first, studies involving naturalistic distractors such as conversations may have failed to find significant relationships because the distractors may not have loaded onto working memory. Second, studies which did load onto working memory may have been artificial and lacking in generalizability to real-life distracted driving situations. To address this gap, our study employed a semi-naturalistic distractor task which has been shown to load onto working memory based on the domain-general model of working memory (Louie, 2018). If a significant relationship is obtained, then our study would be the first to suggest that WMC predicts distracted driving performance even when the participant is engaged in a semi-naturalistic distraction task. Hence, the findings would provide a step towards better understanding how WMC could affect individuals' driving performance when using different types of distraction tasks with differing levels of working memory.

1.3. Specific aims

The goal of this study was to empirically examine the role of WMC in predicting distracted driving behavior in a simulated driving environment. This research is the first to use a semi-naturalistic distractor task which loads onto working memory according to the domain-general theory of working memory (Louie, 2018; Foster et al., 2015). In this study, the synthesis of the literature was carried out in order to review past research and identify any gaps in the literature. As a result, this research aimed to develop a semi-naturalistic (GLT) distractor task which loaded onto working memory, and was used as the basis to empirically examine the effects of working memory on distracted driving. It was hypothesized that an individual's WMC would predict driving performance, especially under distracted driving conditions. Specifically, it was predicted that participant's WMC would mediate and moderate the relationship between distraction and driving.

2. Method

2.1. Participants

A sample of 49 participants consisting of 18 male and 38 female participants (1 unreported) from a large Southeastern University. They were randomly selected using the university's online participant (SONA) recruitment system. All participants were required to hold a valid driver's license and reported a 20/20 or near 20/20 corrected vision. The ages of participants within the sample was generally representative of the undergraduate population ($M = 19.51$, $SD = 4.24$). There was one adult who was significantly older than the other participants (57 years old). However, her working memory and driving performance scores were all within 1 standard deviation of the mean. As a result, her data was included as part of the analyses.

All participants received extra course credit as part of their participation, and all were treated according to the American Psychological