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Working Memory Capacity and Executive Attention as Predictors of Distracted Driving

Jennifer Louie
University of Central Florida

WORKING MEMORY CAPACITY AND EXECUTIVE ATTENTION AS PREDICTORS OF DISTRACTED DRIVING

by

JENNIFER F. LOUIE
B.A. The College of New Jersey, 2011
M.S. Villanova University, 2013

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Major Professor: Mustapha Mouloua

ABSTRACT

The present study empirically examined the effects of working memory capacity (WMC) and executive attention on distracted driving. Study 1 examined whether a Grocery List Task (GLT) distractor would load onto WMC. Forty-three participants completed a series of WMC tasks followed by the GLT. They then completed two driving trials: driving without the GLT and driving while completing the GLT. It was hypothesized that WMC would positively correlate with GLT performance. A bivariate correlation indicated that WMC was positively associated with performance on the GLT.

Study 2 tested a series of distractor tasks (GLT, Tone Monitoring, and Stop Signal) to examine whether these three distractor tasks were also related to WMC, and if each of the distractor tasks would result in poor driving performance. Eighty-four participants were randomly assigned to the distractor conditions. Results indicated that GLT was related to WMC, but Tone Monitoring was not related to WMC. Also, engaging in each of the three distractor tasks led to significantly poorer driving performance.

Study 3 evaluated whether rainy or clear weather conditions would affect the relationship between WMC and distracted driving using the same three distractor tasks (GLT, Tone Monitoring, and Stop Signal) as used in Study 2. Ninety-six participants were randomly assigned to the distractor conditions. Results showed that engaging in GLT while driving led to slower braking response times compared to not engaging in GLT driving while driving. Furthermore, WMC moderated the degree to which distraction impaired performance.

The present findings clearly indicate that all three distractor tasks had a deleterious effect on driving performance. Furthermore, this effect of distraction on driving depends on many factors, including the type of distraction, the driving performance measure, and the individual's cognitive capabilities. Both theoretical and practical implications are discussed and directions for future research are presented.

Keywords: Working memory capacity, Executive attention, Individual Differences, Driver behavior, Distracted driving

Dedication

I would like to dedicate this dissertation to my mother Sui, my father Benson, and my sister Jessica.

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CHAPTER 1: INTRODUCTION

Problem Statement

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 costs and $836 billion in societal costs. A dangerous factor associated with driving fatalities is distracted driving (NHTSA, 2014). Common sources of distractions are talking on the phone or texting, using a navigation device, and adjusting the radio or CD player (NHTSA, 2016). However, can an individual's cognitive abilities increase the likelihood of getting into an accident? It is important to identify what these cognitive risk factors are to reduce the chances of vehicle-related injuries and fatalities.

Certain studies have suggested that working memory capacity (WMC) is associated with driving performance. For instance, individuals with higher Operation Span (OSPAN) scores generally made fewer driving errors than those with lower OSPAN scores (Watson & Strayer, 2010; Ross, Yongen, Wang, Brijes, Brijes, Ruiter, & Wets, 2014). Such studies have often included artificial measures of working memory as distractions such as complex spans or n-back tests. However, not all findings have been as conclusive. Some studies, such as Louie and Mouloua (2015), Heenan, Herdman, Brown, and Robert (2014), and Scribner (2013) did *not* find a relationship between WMC and driving outcome. In this paper, it is suggested that the relationship between WMC and driving outcome may depend on the type of distraction.

Previous studies on WMC and driving may have found a relationship because they used similar working memory measures to measure WMC *and* to act as a distractor while driving.

Although the studies do underscore a possible relationship between WMC and driving, these findings limit a particular set of distraction types to those which are already well-established measures of WMC. Furthermore, the generalizability of such findings are limited to artificial environments, since it is not likely that individuals would complete complex spans such as the OSPAN while driving in real life. Before drawing any firm conclusions between WMC and driving, it is necessary to examine the wide range of distractions individuals would normally experience while driving.

Purpose of the Present Study

The purpose of the present study was to empirically examine the role of WMC and executive attention in distracted driving. Although a number of studies have previously been conducted on working memory, attention, and driving, there have been some few conflicting results as well as a gap in the literature. Possible reasons for conflicting results include using working memory capacity measures which may not have actually measured working memory and distraction task types which may not have tapped into working memory. Other studies which did not find a relationship between WMC and driving may have also used limited indices of driving performance indices. Lastly, the study addresses a gap in the literature, which is that many studies on WMC and distracted driving have used well-established, but artificial, distraction tasks involving working memory. Our study will evaluate whether previous findings can also be generalized to real-world settings using a more naturalistic distraction task that taps into working memory.

To address the mixed findings in the literature, the present study suggests using a naturalistic distractor task called a "Grocery List Task" which is based off a well-established working memory measure, the auditory Reading Span. Because it resembles the auditory

Reading Span, it meets the criteria for measuring working memory as indicated by Kane, Conway, Hambrick, and Engle (2007) and also resembles a task one might normally engage in while driving. In Study 1, participants will complete two driving trials: driving only and driving while completing the Grocery List task. In Study 2, participants will complete the same trials under high demand conditions, to evaluate the effect of task difficulty on WMC and distracted driving outcome.

It was generally hypothesized that WMC and executive attention would be related to driving outcome, especially under distraction. However, before studying the relationship between working memory capacity and distracted driving, one must provide a general overview on the working memory, attention, and driving literature.

CHAPTER 2. LITERATURE REVIEW

Attention

One well-known cognitive ability known to predict driving outcome is attention. Dividing attention using electronic devices such as cellular phones, navigation devices, and other in-vehicle entertainment systems while driving impairs behaviors critical to safe driving. For instance, engaging in distractions while driving on a driving simulator leads to significantly slower braking onset, increased following distance, more lane deviations, and higher crash rates. Rakauskas, Gugerty, and Ward (2004) also found that driving while carrying a cell phone conversation led to more variation in speed and acceleration regardless of conversation difficulty.

In another study using texting, Drews, Yazdani, Godfrey, Cooper, and Strayer (2009) required participants to drive in a driving simulator under three conditions: texting only, driving only, and texting while driving. The authors found that participants were slower to brake to avoid colliding with the pace car when they were in the texting while driving condition, compared to while they were driving only.

A similar study involving electroencephalogram (EEG) measures also found that when participants texted while driving, they were more likely to show more collisions and higher levels of distractibility as indicated by elevated EEG theta frequency (4-7 Hz) (Mouloua, Ahern, Rinalducci, Alberti, Brill, & Quevedo, 2010). The difficulty of the distraction task also appeared to affect driving performance, with participants making more brake presses when they had to answer more difficult compared to less difficult riddles (Emfield, Leavens, Mouloua, & Neider, 2013).

The effects of attention on driving were also found using on-road driving tasks. For instance, found that Caird, Willness, Steel, and Scialfa (2008) found that when individuals engaged in conversation using handheld phones, participants showed slower response times while driving. In addition, the driving impairments caused by cellular phones persisted even when the distractor was used with hands-free devices, suggesting that impairment could not simply have been attributed to the physical manipulation of the device (e.g., Caird et al., 2008; Reimer, Mehler, D'Ambrosio, & Fried, 2010; Mouloua, Rinalducci, & Hancock, 2001).

Similarly, *individual variation in attention* may be related to driving ability. For example, individuals with attentional deficit hyperactivity disorder (ADHD) were more likely to report a history of traffic violations, collisions, and license suspensions compared to non-ADHD controls (Barkley, Murphy, Dupaul, & Bush, 2002). When individuals with ADHD completed a secondary task while driving, they were also more likely to speed, engage in risky driving behavior, miss traffic signals and highway exits compared to normal controls (Reimer et al., 2010). Simulator studies found that individuals with ADHD are more likely to show variable acceleration and slower responses to speed changes compared to individuals without ADHD (Laberge, Ward, Manser, Karatekin, & Yonas, 2005). Even healthy control drivers who showed more errors on selective attention tasks as measured by the useful field of view (UFOV) test had higher individual crash rates (Barkley et al., 2002). These studies strongly suggest that attention might be a critical process in driving (Avolio, Kroeck, & Panek, 1985; United States Department of Transportation [USDOT], 2015; Wood, Chaparro, Lacherez, and Hickson (2012). Although there is a strong support for a relationship between attention and driving, there is little research in directly examining the interactive effects of attention and memory on driving behavior. Working memory is a cognitive process known to be related to attentional performance, and therefore, one would expect that this may also affect driving behavior.

Working Memory

More recently, research has reported that working memory is related to driving ability (Guerrier, Manivannan, & Nair, 1999; Lambert, Watson, Cooper, & Strayer, 2010). Working memory is the cognitive system that allows one to mentally hold and manipulate information. It is often used to complete goals, such as performing mental operations in one's head (i.e., without using pen and paper). Mental math requires maintaining memory for a series of numbers, while arranging them in visual space. To multiply 27 x 3, one must first multiply the 7 by 3 (which is 21), and then position the 1 in the tens column while positioning the 2 in the hundreds column, above the 2 in 27. Working memory is also used in more practical settings, such as recalling a series of navigational directions while driving or remembering a phone number. Although working memory predicts a wide range of abilities such as fluid intelligence, verbal and mathematical reasoning (Engle, 2000), less is known about how working memory abilities predict driving outcomes. Previous studies have often manipulated working memory – however, few studies have measured an individual's *inherent* working memory abilities to see how they relate to performance.

Increasing working memory load by adding a secondary task also appears to impair driving performance. Studies using simulated driving paradigms found that when working memory load was high, participants braked more slowly in predictable braking situations (Alm & Nilsson, 1995), as well as in emergency braking situations (Engstrom, Aust, & Vistrom, 2010). Working memory load also appeared to impair situational awareness of cars located behind and in front of the driver (Heenan, Herdman, Brown, & Robert, 2014).

Similarly, individual differences in working memory may also be related to poor driving performance. Although there were fewer studies conducted in this area, WMC appeared to be associated with lane-changing task performance (Ross et al., 2014). Studies on aging and driving also suggest that reduced WMC may be related to delayed left-turns, slower brake reaction time, increased following distance, and slower speed (e.g., Guerrier et al., 1999; Lambert, Watson, Cooper, & Strayer, 2010). A review of the research that has already conducted in WMC and distracted driving will be discussed in Chapter 4.

Relationship between Working Memory and Executive Attention

Previous research strongly suggested that working memory is related to executive attention (the ability to only attend to relevant information while ignoring irrelevant information). Individuals with high working memory spans were better able to name the color of a word that corresponds to the name of an incongruent color (e.g., the word "red" printed in blue ink) on Stroop tasks, compared to those with low working memory spans (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010; MacLeod, 1991; Kane & Engle, 2001). Other studies similarly showed that participants with low working memory capacity experienced difficulty ignoring irrelevant information compared to those with high working memory capacity (Conway, Cowan, & Bunting, 2001; Kane, Bleckley, Conway, & Engle, 2001). Even in cognitively healthy individuals, individuals given a large working memory load showed delayed response times when irrelevant information was presented on a modified version of the Stroop task (de Fockert, Rees, Frith, and Lavie, 2001).

Lastly, performance on the Stroop task which measured inhibition was significantly related to distracted driving performance when the distractor was a verbal working memory task. These studies point to a relationship between working memory capacity and executive attention during driving (Guinosso, Johnson, Schultheis, Graefe, & Bishai, 2016).

In this paper, the author will discuss how individual differences in working memory and executive attention may relate to distracted driving. Prior to this discussion however, it is important to discuss theories of working memory and, based on these theories, develop an operational definition of working memory as will be used in the present study.

Theories of working memory

There are several theories of working memory capacity, which is an individual's working memory ability. In this section, the traditional "modal" model of working memory will be described, as well as newer theories of working memory which emphasize its role as a combined attentional and memory system. Then based on these theories, I will discuss the criteria used to operationalize WMC as will be used in the present study.

Modal Model

One of the earliest and most popular models of working memory was conceived by Baddeley and Hitch (1974), who referred to working memory as a "mental workbench" associated with holding and manipulating information for a temporary period of time (Jarrold & Towse, 2006; Baddeley, 2009). While holding information in working memory, an individual can carry out complex activities such as language comprehension or following a set of instructions. Baddeley's working memory consists of four components: the phonological loop, visuospatial sketchpad, central executive, and episodic buffer.

The four components of the modal model maintain storage of perceptually relevant information. Perceptual information first enters working memory via two storage systems: the phonological loop or visuospatial sketchpad. Speech-based or auditory information such as someone's phone number enters the phonological loop. Visual, spatial, and possibly haptic information such as the layout of a house enters the visuospatial sketchpad. The information is then maintained in these storage systems via rehearsal processes. To remember a phone number for instance, silently repeating the number (known as subvocal rehearsal) would maintain the information in the phonological loop. To remember the layout of a house, visually rehearsing its form, color, and spatial orientation would maintain the information in the sketchpad.

The central executive coordinates attention between the phonological loop and visuospatial sketchpad. Unlike the storage systems which involve simple maintenance, the central executive focuses attention, divides attention between two targets, and switches attention between tasks (Baddeley, 1996). For instance, in the stop-signal task, participants must press a button on a screen according to the type of tone presented (e.g., low or high tone), except in instances where a vibration is presented. In this task, responding to the type of tone presented primarily requires the phonological loop, while attending to a vibration (i.e., the "stop" signal) requires the central executive (Baddeley et al., 2011). Lastly, the episodic buffer integrates incoming perceptual information with long-term memory. The episodic buffer handles multidimensional representations, such as phonological codes and semantic codes when comprehending a sentence. Together, the four components interact to carry out goal-oriented behavior (see Figure 1).

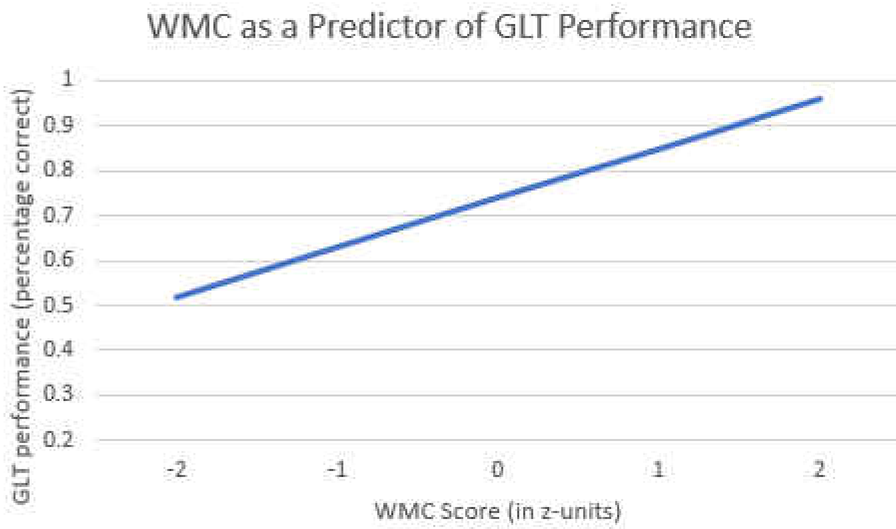


Figure 1. Time to brake at a yellow light as a function of WMC in the GLT distracted condition in Study 3. The regression equation can be expressed as GLT = 0.69 + 0.11(WMC) + 0.05. For every one-unit z-score increase in WMC, performance on the GLT task increased by 85 percentage points.

According to the modal model, distractions impair working memory storage. Subvocally rehearsing a series of to-be-remembered words typically aids in memory recall. However, if an individual repeats a single word continuously (e.g., "the") while reading the to-be-remembered words, then he or she is much less likely to recall the items afterward (Baddeley et al., 1975b). The secondary task of repeating an irrelevant word supposedly prevents the to-be-remembered information from entering the phonological store. Similarly, some tasks are typically aided by visualization, such as performing mental math by visualizing an abacus. However, if the individual simultaneously engages in an unrelated visuospatial task such as tapping a series of spatial locations, then the mental calculations would be impaired. It is assumed that the secondary task disrupts relevant information from being stored in the sketchpad. These studies strongly support the idea that distractions occupying the same storage systems as a primary task will lead to impaired performance in the primary task.

The modal model differs from more recent theories of working memory in several ways. Unlike other models, it has a very elaborate and detailed structure. Proponents of the modal model emphasize theory productivity by continuing to identify the various structures of working memory. For instance, current questions in the modal model literature concern whether sight, smell, syntactic and semantic information should be added as new components, and how rehearsal occurs for these modalities (Baddeley, 2012; Haarmaan, Davelaar, & Usher, 2003). However, there is no standard individual differences measure of working memory (i.e., "working memory capacity") used to predict outcomes (Kane et al., 2007). Studies that do investigate working memory capacity using the modal model reveal different predictions depending on the perceptual domain involved (Kane et al., 2007). So, an individual with "large working memory capacity" as determined by a visuospatial working memory span may have a "small working memory capacity" as determined by a phonological working memory span (Kane et al., 2004). In contrast, a more recent class of theories, which this study will broadly refer to as the "domain-general" theory, focuses less on identifying the structural makeup of working memory capacity and more on its general predictive abilities (e.g., in predicting intelligence).

Domain General Theory

More recently, some researchers have described working memory as a system primarily composed of attentional control and secondarily of memory storage (Kane, Conway, Hambrick, and Engle, 2007, p. 26-27; Engle & Kane, 2004). This theory was influenced by working memory's ability to predict individual differences in cognition and behavior (Kane et al., 2007; Underwood, 1975).

Attentional control is primarily domain-general, which means it operates independently of perceptual domains such as visuospatial or auditory information. Unlike short-term memory, executive attention uniquely predicts performance on criteria such as fluid intelligence, verbal and mathematical reasoning (Kane et al., 2004). Individuals with high working memory spans also show better performance on executive attention tasks. (Executive attention is the ability to attend to one task while ignoring or inhibiting one's response to another task). For instance, Stroop tasks show that individuals with higher working memory spans are better at inhibiting responses when the name of the color did not match its ink color (i.e., incongruent trials). Antisaccade tasks show that individuals with higher spans were better at inhibiting eye movements toward a distractor. Lastly in proactive interference tasks, individuals with higher spans were better at remembering earlier items even as they were presented with more lists. These tasks strongly support the role of executive attention in working memory capacity (Kane, 2002).

Secondarily, working memory involves domain-specific memory storage. "Domain-specific" means there are specialized memory systems: visuospatial, verbal, motoric, auditory, etc. Unlike Baddeley, Kane et al. (2007) do not focus much on the different types of memory systems. This is because, although the specialized memory systems predict performance on a range of cognitive abilities (for instance, visuospatial short-term memory predicts visuospatial reasoning, and verbal short-term memory predicts verbal reasoning), when they are regressed with executive attention as a moderator, they no longer significantly predict performance (Kane et al., 2007). This makes memory storage a secondary, lower-order factor in predicting cognitive abilities. Nonetheless, memory is still an integral component of working memory capacity. Memory is required to maintain task-relevant goals while switching attention from one task to another, for instance. In an antisaccade task, the words "look away from the flashing cross" must be maintained in active memory (Kane et al., 2007). Successfully performing the task requires actively holding this verbal information in memory to perform the looking-away behavior. When following a complex set of instructions, an individual must remember each step. Memory is the second important component of working memory.

The domain-general model differs from the modal model in that it describes working memory capacity as more of a process-based than a structural-based system. It is less focused on defining the structures associated with each perceptual domain (e.g., visuospatial, phonological). Instead, it suggests that the dissociation between visuospatial and phonological performance merely reflect differences in perceptual processes. For instance, visuospatial processing will be different from phonological processing which will be different from tactile, kinesthetic, gustatory processing, etc.). The domain-general model also addresses the modal model's limitations in predicting other criteria. One issue posed by the structural-based, modal model is that it is not clear how adding more structural systems would add any explanatory power to theories of working memory capacity. For instance, the Baddeley (1992) addition of the episodic buffer to the modal model adds nothing to the predictive power of the working memory span. Instead, the attentional component of the domain-general model predicts outcomes across a range of domains such as fluid intelligence, verbal, spatial, and mathematical reasoning (Kane et al., 2004).

Executive Functioning Theory

Executive function is a term used to describe the set of "general-purpose control mechanisms that modulate" complex cognitive functions. Miyake et al. (2000) identify three separable, but related executive functions: inhibiting, updating, and shifting. Updating is the process that involves storage and maintenance of items in working memory representation; inhibition is the process of suppressing dominant or prepotent responses; and shifting is the process of switching from one mental set or task to another. The authors found that working memory spans (Daneman & Carpenter, 1980) loaded onto the updating construct. On the other hand, tasks involving the suppression of prepotent responses such as the Stroop task, Antisaccade Task, and Stop-Signal task loaded onto the inhibition construct. Tasks that involved shifting mental sets such as Wisconsin Card Sorting Task (WCST) loaded onto the shifting construct.

Distractions affect executive functioning by affecting the inhibiting, updating, or shifting processes. When engaging in a driving-related distraction such as following a complex set of directions, an individual must inhibit responding to distractions while driving, such as billboards, landmarks, and other cars. He or she must also update the series of directions, which requires maintaining the step-by-step directions in memory, and identifying which tasks have already been completed or need to be completed, as he or she completes each step. Lastly, the individual must shift from one step in the list of directions to the other, and switching between the secondary, navigational task and the primary, driving task. The author note that the updating process involves memorial abilities, while the shifting and inhibiting involves more attentional abilities. Executive functioning differs from the two previous theories in that it is a theory of general higher-order processes, of which working memory is simply one aspect. Working memory is primarily an updating process that requires individuals to maintain and update a list in their heads. Like the domain-general model, it suggests that working memory tasks load onto both attentional factors (i.e., shifting and inhibiting) and memorial factors (i.e., updating). However, unlike the domain-general model, working memory tasks load most strongly onto updating, suggesting that working memory may rely more on memory storage than on attentional storage.

A two-factor definition of working memory

Based on the models described above, one can make several predictions as to how working memory predicts driving. According to the modal model, distractions occupy working memory via four components, the central executive, phonological loop, visuospatial sketchpad, and the episodic buffer. According to the domain-general theory, distractions may occupy attentional processes and memory storage processes. Lastly according to the executive functioning theory, distractions may occupy the inhibiting, updating, and shifting processes. The domain-general and executive function theories stress the importance of working memory as a domain-general process, while the modal model emphasizes a domain-specific, structural system. Also compared to the modal model, the domain-general and executive function theories more accurately predict individual differences in performance such as intelligence.

Our study does not seek to challenge the theories. In fact, Baddeley (2012) suggests that the differences between the modal model and more recent theories of working memory simply reflect a difference in terminology. The theories may be mutually supportive in that they share a set of common ideas: they emphasize working memory as a combined system of attention and memory storage. So, any working memory tasks would be expected to involve both executive attention and memory storage. Similarly, a distractor involves working memory only if it includes these two criteria (executive attention and memory storage).

Operational definition of working memory as used in present paper

The present paper operationalizes working memory using the two-factor model: i.e., as involving both executive attention and memory storage (Kane, Conway, Hambrick, & Engle, p. 22, 2007; also, Engle & Kane, 2004; Engle, Kane, & Tuholski, 1999; Kane & Engle, 2002; Kane, Hambrick, & Conway, 2005). The synergy of these two processes allow an individual to maintain and recover access to relevant task information, while blocking access to task-irrelevant information especially under conditions of distraction (Kane et al., p. 23, 2007). Any tasks that purportedly measure working memory span, and any distractions that occupy working memory, must include these two criteria.

Working memory consists of two primary components: executive attention and memory storage/updating. Executive attention is the process which sustains the activation of information, retrieves no-longer active information back into conscious focus, and inhibits goal-irrelevant information. Executive attention is particularly useful when the to-be-remembered information is relatively novel or is within an unfamiliar context (Kane et al., p. 22, 2007). Storage and updating "compares incoming information for relevance to the task at hand and then appropriately revises the items held in memory by replacing old, no longer relevant information with newer more relevant information. This process may be mediated by 'temporal tagging,' which keeps track of which information is old and no longer relevant." Unlike storage, "updating goes beyond simple maintenance of task-relevant information... and actively manipulates relevant information... rather than passively store information" (Miyake, p. 56-57, 2000; Jonides & Smith, 1997; Lehto, 1996).

The operational definition of working memory and executive attention was used to perform a literature search on WMC, executive attention, and distracted driving, as will be described below.

CHAPTER 3: PREVIOUS STUDIES ON INDIVIDUAL DIFFERENCES IN WORKING MEMORY AND EXECUTIVE ATTENTION AS PREDICTORS OF DISTRACTED DRIVING

To evaluate any mixed findings or gaps in the literature on WMC and distracted driving, a literature search was conducted.

Search strategy

A literature search was conducted on peer-reviewed journal articles published within the last ten years (i.e., 2007) using PsycINFO, PsycArticles, and GoogleScholar research databases. Older articles providing a framework for the present study rationale were also cited. To investigate the relationship between working memory capacity and distracted driving, the initial search terms were: working memory, working memory capacity; AND: driving, driving performance, and distracted driving. To include studies which may have evaluated working memory under a different name, broader terms such as “executive functioning,” “cognitive ability,” “cognitive traits, “Operation span,” and “OSPAN” were used.

The following operational definition of working memory was used to determine whether a study evaluated working memory: it must involve memory storage or updating and executive attention (as discussed earlier). Articles were also sorted according to working memory measure (e.g., Operation span, digit span) and distraction type (e.g., phone conversation, visuospatial distractor). A list of the working memory measures and distraction types can be found in Tables Y and Z. At the end of the literature review, a total of 73 studies were examined.

Overview of the literature

Previous studies have suggested that working memory affects the perceptual and cognitive processes required for safe driving. Endsley (1995) described three levels of situational awareness: perception of relevant information in the environment (Level 1; L1), comprehension of the current situation (Level 2; L2), and the strategic level of driving (Level 3; L3). Some research suggested that the levels of situational awareness corresponds to the three levels of driving behaviors (i.e., operational driving, tactical driving, and strategic driving, respectively); (Kaber, Jin, Zahabi, Pankok, 2016; Kass, Cole, & Stanney, 2007; Ma & Kaber, 2005; Ma & Kaber, 2006; Ma & Kaber, 2007).

Working memory likely affects one's ability to perceive hazards in the driving environment (L1 situational awareness). For instance, individuals engaging in a visuospatial working memory task were slower to orient to hazards and fixate on hazards for a shorter duration compared to those engaging in visuospatial, non-working memory task (Vossen, Ross, Jongen, Ruiter, & Smulders, 2016). Similar findings were reported in the individual differences literature, where low span individuals spent less time fixating on hazards compared to high span individuals (Kaber, Jin, Zahabi, & Pankok, 2016; Antsey, Horswill, Wood, & Hatherly, 2012; Wood, Hartley, Furley, & Wilson, 2016; Gugerty & Tirre, 2000). Another example of individual differences is individuals with autism-spectrum disorder (ASD), who identified fewer social hazards such as pedestrians and were slower to respond to the hazards compared to non-ASD individuals (Sheppard, Ropar, Underwood, and Loon, 2009).

Working memory ability also affects one's knowledge of where other vehicles are located relative to the driver (L2 situational awareness). For instance, completing phonological working memory tasks while driving led to poorer situational awareness for vehicles located behind one's car. Individuals were less accurate at judging the distance of surrounding vehicles and judging whether another vehicle is in the wrong lane (Johannsdottir & Herdman, 2010). Similar results were found when a naturalistic conversation task was used in place of formal working memory tasks (Heenan et al., 2014; Ma & Kaber, 2005). When situational awareness was shared with conversation partners who could see the driving environment and alert the drivers to upcoming exits or other vehicles, driving performance improved (Drews, Pasupathi, & Strayer, 2008; Gaspar, Street, Windsor, Carbonari, Kaczmarski, Kramer, & Mathewson, 2014).

Working memory ability may affect one's ability to predict the future status of other vehicles (L3 situational awareness). For instance, high span individuals showed better strategic driving compared to low span individuals, as demonstrated by a faster arrival time when stuck in slow, heavy traffic marked by no-pass boundaries (Kaber, Jin, Zahabi, & Pankok, 2016). Drivers may also compare their current driving situation with previously encountered situations in memory to evaluate potentially dangerous driving situations. For example, individuals may check the rearview mirror before braking at a yellow light, with braking at a yellow light cueing earlier incidents when an accident may have occurred (Groeger, 2000).

Lastly, working memory load can affect eye movements that occur while scanning the road. Individuals with better performance on a multiple-object tracking task showed a wider visual search during more complex (i.e., city and highway) routes, and greater saccade velocity and saccade size (Mackenzie & Harris, 2017). Additionally, working memory capacity was associated with longer visual fixation on hazards (Wood, Hartley, Furley, & Wilson, 2016). However, safe driving does not *require* more frequent or longer saccades – individuals may orient to cars in hazardous locations without making eye movements (Vossen et al., 2016).

Certain types of environmental factors may also affect working memory factors associated with driving. For instance, it is possible that certain environmental factors may increase the executive attention demands required to detect potential hazards. Visual clutter in the driving environment such as billboards and street signs increase the number of visual fixations required to detect a target (Ho, Scialfa, Caird, & Graw, 2001). The presence of a car crash would lead to more visual fixations away from the road, compared to when a physical barrier prevented the driver from viewing the crash (Colon, Rupp, & Mouloua, 2013). Time of day also affects working memory – brief, 18 minute exposure to simulated daytime light modulates responses in the frontal and parietal cortices implicated with working memory (Vandewalle, Gais, Schabus, Balteau, Carrier, Darsaud, Sterpenich, et al., 2007; Cajochen, Munch, Kobialka, Krauchi, Steiner, Oelhafen, Orgul, et al., 2005; Lockley, Evans, Scheer, Brainard, Czeisler, & Aeschbach, 2006). Rainy conditions, however, have shown mixed findings in terms of its effect of driving performance. For instance, suggested that rainy conditions would improve distractability while driving as indicated by increased theta activity (Kee, Tamrin, & Goh, 2010). However, it is also possible that rainy conditions would decrease visibility and as a result increase executive attention demands to detect potential hazards, leading to poorer driving performance.

A description of *working memory capacity measures* used in previous studies

There are different measures of working memory capacity requiring various levels of executive attention and memory storage. A task is considered a true measure of working memory capacity if it meets Kane et al. (2007) and Engle and Kane's (2004) criteria of involving both executive attention and memory storage. The different measures are enumerated below.

Complex spans are traditionally used measures of working memory capacity which involves memorizing a series of items while completing a secondary task. For example, in the operation span, auditory span, and visuospatial span, participants are presented with a series of items to be recalled which requires *memory storage*. After each item presentation, a secondary task such as an arithmetic task is presented. Participants must complete the secondary task while maintaining item storage, requiring *executive attention*. Greater recall of items indicates greater working memory capacity. For example, a complex verbal span used by Ross et al. (2014) which involved memorizing a list of letters while shifting attention from different visuospatial locations predicted distracted driving outcomes, when the n-back task was used as a distractor.

Simple spans closely resemble complex spans. However unlike complex spans, they do not involve the presentation of a secondary task and therefore requires less *executive attention*. For instance, in the Wechsler Adult Intelligence Scale (WAIS) simple span, participants recall a series of numbers in the same order they were presented (forward span), or in the reverse order they were presented (backwards span). However, neither forward nor backward digit span was predictive of driving performance (Alexandersen et al., 2009; Rizzo et al., 1997; Duchek et al., 1999; as cited by Asimakopulos). Similarly, for other variants of the simple span such as the Ross et al. (2014) visuospatial span, participants reproduce a random sequence of boxes in a 4-by-4 grid by clicking on the squares which had turned blue. Initially, only three boxes turned blue. A box was added to each sequence until participants were no able to reproduce sequences on two consecutive trials (Ross et al., 2014). Interestingly, unlike the other (complex) span used by Ross et al. (2014) the simple visuospatial span did *not* predict driving outcome.

Matrix monitoring tasks involve comparing the location of a dot before and after moving. For instance, a 4 x 4 matrix would first appear with a black dot in one of the squares. After the matrix and dot disappear, a sequence of three arrows would indicate the movement of the dot in the imaginary matrix, requiring *executive attention* to shift the original dot location. After the matrix reappears, participants indicate if the new position of the dot is *same* or *different* as the position indicated by the arrow, requiring a comparison in *memory storage* (Mantyla, Carelli, & Forman, 2007; Salthouse, Atkinson, & Berish, 2004).

The paper folding task involves indicating how an unfolded sheet of paper would look like after it has a hole punched in it, requiring *executive attention* to shift from various unfolded stages and *memory storage* to compare the original folded and final unfolded configuration. Participants select from two alternative solutions (De Raedt & Ponjaert-Kristoffersen, 2000; Mathias & Lucas, 2009). The paper folding task was moderately correlated with the OSpan (r = .38); (Salthouse, Mitchell, Skovronek, & Babcock, 1989).

The WAIS Letter-Number Sequencing task involves recalling a series of numbers in ascending order and letters in alphabetical order. For instance, if the participant is auditorally presented with a sequence of numbers and letters such as 2, R, M, 1, I, L, 9, 3, he or she must recall "1, 2, 3, 9, I, L, M, R" after the entire list has been presented. The task requires *memory storage* of all the items previously presented, as well as *executive attention* to re-order the sequence of items into their proper numerical/alphabetical order. This task is a subtest of the Wechsler Adult Intelligence (WAIS; Wechsler, 1955) Verbal IQ scale, and it appears to be related simple forward and backward spans, but not to the visuospatial complex span (Crowe, 2000).

The N-back involves identifying when an item is presented again relative to a previous presentation. The procedure typically involves a series of items (e.g., words) presented continuously on a screen. Participants must click on the item each time its presentation is repeated relative to the item presented "n" items prior (e.g., 1 item for 1-back, 2 items for 2-back, and 3 items for 3-back); (e.g., Mantyla et al., 2007). Successful performance on the N-back requires *memory storage* of the last n-items, as well as *executive attention* to compare the n-back item with the current item.

A description of *distraction task types* used in previous studies

Although there are many different types of distractions that one may engage in while driving, not all distractions may involve the same level of working memory as others. Below the authors will list several types of distraction task types used in the driving literature.

Complex spans are frequently used as distraction tasks in studies of distracted driving. For example, in the auditory OSPAN, participants are auditorally presented with a series of items to be recalled. After each item presentation, an arithmetic task is presented. Participants must complete the secondary task while maintaining item storage. Reading spans, in which participants must remember a series of items while completing a semantic judgment task (e.g., judging whether a sentence makes meaningful sense) are also used. Some studies suggest a relationship between WMC and distracted driving when using complex spans as distractors (Strayer & Johnston, 2001). However, the relationship between naturalistic distractions and WMC are less clear.

Guessing games are a type of distraction task used to simulate natural conversations. For instance, in the 20-questions distraction task, participants must guess the experimenter's word from a pre-selected list using no more than 20 yes-or-no questions. (Heenan, Herdman, Brown, & Robert, 2014); (Ma & Kaber, 2005). A study by Leavens, Emfield, Mouloua, and Neider (2013) found that when a riddle task was used as a distractor, participants pressed the brake pedal more frequently. However, because working memory capacity was not measured beforehand, it is unclear whether working memory capacity would have predicted distracted driving performance.

Lastly, conversations can be used as naturalistic distraction tasks in studies of distracted driving. A conversation topic is typically chosen for the participant to engage in with an experimenter or another partner. Conversation topics can be categorized as “simple” (e.g., simple riddles) or “difficult” (e.g., difficult riddles). Naturalistic conversations may also be used (e.g., Briem & Hedman, 1995; Strayer & Johnston, 2001; Emfield, Leavens, Mouloua, & Neider, 2013). These studies using conversations as a distractor have found a relationship between WMC and distracted driving.

A gap in the WMC and driving literature

Previous studies have found that WMC predicted driving outcome when a working memory span (typically the OSPAN) was used as a distractor. For instance, field dependent individuals showed poorer driving outcomes when they had small working memory capacity than large working memory capacity (Lottridge & Chignell, 2007). They were also more likely to brake slowly when switching from automatic to manual transmissions in semi-autonomous vehicles (McCarty, Funkhouse, Zadra, & Drews, 2016). Some studies also found a relationship between working memory capacity and driving outcomes without any distractors. For instance, small WMC individuals showed slower braking response time, larger following distance, and decreased speed (Ross et al., 2014). However, not all findings have been as conclusive.

“WMC” measures did not truly measure WMC

To the author’s surprise, several studies have not found a relationship between WMC and driving outcome. For instance, the simple span, which is considered a measure of “working memory” in the Wechsler Adult Intelligence Scale (WAIS), was not related to driving outcome

(Duchek et al., 1999; Alexandersen et al., 2009). In Duchek et al. (1999), cognitively healthy individuals and individuals with “mild” or “very mild” Alzheimer’s disease completed the forward and backward simple span prior to driving on a 45-minute road test. However, there was no relationship between either simple spans with the number of driving errors made (e.g., basic maneuvers such as starting the car and more advanced maneuvers such as speed maintenance, obeying traffic signs, signaling, changing lanes, and negotiating intersections).

In another study by Alexandersen et al. (2009), individuals who received “inconclusive” neuropsychological evaluations completed WAIS forward and backward spans prior to completing a two-hour driving test in different driving scenarios such as in downtown traffic, a highway, and in a parking lot. Similar to Duchek et al. (1999), there was no relationship between the simple spans with driving performance on driving habits and skills, attention, position, speed, maneuvering and traffic behavior.

Finally Fried, Petty, Surman, Reimer, Aleardi, Coughlin, Martin, et al.’s (2005) study on driving performance in ADHD and non-ADHD individuals failed to find a relationship between the Digit Span (which is a version of the simple span using only digits) and history of self-reported driving performance using a 24-item driving demographic questionnaire. Indices of driving performance included a history of lapses in attention or memory failures while driving, number of driving errors (e.g., failure to achieve planned actions while driving), and deliberate deviations from safe driving practice.

The lack of a relationship between WMC and driving outcome in the previous three studies may be a consequence of the “WMC measures” not truly measuring WMC. Using Kane et al.’s (2001) and Kane et al.’s (2007) criteria for working memory, a measure involves working memory if it includes both memorial storage *and* executive attention. The present paper argues that the WAIS simple spans and digit spans used in previous studies may not have been sufficient indicators of WMC, as they primarily involved memorial storage and little executive attention. Further, any study evaluating the relationship between WMC and distracted driving should use a WMC measure involving *both* memorial storage and executive attention.

Distractors did not load onto working memory

Second, another possible reason is that the distractors used did not load (or loaded weakly) onto working memory. For example, two studies used a 20-questions task as a distractor which the authors presumed would load onto working memory. The first study by Heenan et al. (2014) evaluated the effect of driving while completing the 20-questions task on situational awareness and driving performance. Situational awareness is generally defined as the ability to "track and locate surrounding vehicles" (Heenan et al., 2014, p. 1078). At the end of each trial, the simulator screens were blanked and participants were asked to estimate the positions of other vehicles. The study found that driving while completing the 20-questions task led to impaired situational awareness of other vehicles. However, completing the 20-questions task was not associated with any other driving errors such as lane deviations and collisions. Also, because the study did not evaluate WMC prior to the driving trials, it was uncertain whether WMC predicted driving performance.

In another study, Louie and Mouloua (2015) evaluated individuals' WMC prior to completing driving trials using complex spans, and then had participants drive while completing three trials: pre-distracted (no distractions), distracted (i.e., while completing the 20-questions task), and post-distracted. Although the study did find that executive attention moderated driving performance while completing the 20-questions distracting task, there was no moderating relationship between WMC and driving while distracted. Furthermore, there was no relationship between performance on complex spans which measured WMC and performance on the 20-questions task. According to the study, WMC did not predict distracted driving performance.

It is possible that the failure of WMC to predict distracted driving performance in the previous two studies was attributed to a distraction task that was inappropriate for measuring working memory. A distraction task that does not measure working memory precludes the possibility of finding any relationship between WMC and distracted driving. To test these potential limitations, the author proposes a study using different distraction tasks which may or may not load onto WMC. As discussed previously, working memory appears to be composed of primarily two factors: executive attention and memory storage. Any distraction task loading onto either executive attention or memory storage but not both would not be considered an appropriate measure of WMC.

Limited Indices of driving performance

Third, some studies failing to find a relationship between WMC and driving outcomes may have not used appropriate measures of driving performance. For instance, Scribner (2013) proposed a model of WMC, stress coping style, and driving performance. The OSPAN was used to evaluate individuals' WMC, followed by a demographic questionnaire and the Dundee Stress State Questionnaire (DSSQ; Matthews, Joyner, Gilliland, Campbell, Falconer, & Huggins, 1999). Participants completed three randomized dual task driving scenarios under low, moderate, or high demand driving scenarios using an auditory version of the OSPAN as distractor. Although the authors found a mediating relationship between WMC with coping style and secondary task error, they did *not* find a relationship between WMC and driving performance. The lack of a significant finding may have been attributed to using only one index of driving performance – lane deviations. Previous studies on WMC and driving performance have typically used more indices of driving performance, including response-time sensitive measures such as braking response time or accelerator response time. To increase the likelihood of finding a relationship between WMC and driving performance, it is important to use a wider range of driving performance indices.

Lack of a naturalistic working memory distractor

Lastly, since most individuals would likely not engage in working memory spans while driving in real life, it is important to see how naturalistic tasks would affect driving outcome. The author proposes employing distraction tasks resembling well-established, but artificial measures used in previous studies as well as more naturalistic tasks. For example, as a traditional measure of working memory, one can use the tone monitoring task which loads onto working memory storage (Miyake, 2000). As a naturalistic distractor, one can use a "grocery list" task, a self-designed task which the author believes employs the same processes as those found in complex span tasks and tone monitoring tasks. A comparison of traditional working memory tasks with naturalistic distractors will help generalize previous findings to more realistic situations.

A summary of gaps in the literature

In summary, although some research has found that working memory capacity predicts distracted driving, not all studies have been conclusive. For instance, certain studies may not have been true measures of WMC, resulting in a lack of a relationship between WMC and driving outcome. Second, some distractors may not have loaded onto working memory, such as the 20-questions task. Third, some studies only used a few indices of driving performance, which may have limited the possibility of finding a significant result. Lastly, previous studies finding a relationship between WMC and distracted driving used traditional, but artificial, measures of WMC such as complex spans and n-back tasks.

CHAPTER 4: THEORETICAL FRAMEWORK AND RATIONALE FOR PROPOSED STUDIES

To address the aforementioned mixed findings and gaps in the literature, this study was designed to employ a WMC measure and a distraction task which both fulfill the criteria for working memory as outlined by Kane et al. (2001) and Kane et al. (2007). Driving performance would be measured using a range of driving performance indices such as braking and accelerating response time, number of lane deviations, and number of collisions. The naturalistic distraction task will be an in-lab designed "Grocery List Task" based on the auditory operation span. The authors predict that this task, like the complex span tasks, will moderate working memory capacity and driving outcome. By broadening the scope of distraction task types and ensuring that they load onto working memory, one can better understand the relationship between working memory capacity and distracted driving.

For the distractors used in the present study, the author presents several tasks which presumably load or do not load onto WMC. One artificial measure of WMC is the tone monitoring task, where participants must report whenever a tone is played for the fourth time (Miyake, 2000). A naturalistic measure of WMC is a Grocery List task which requires participants to remember a list of ingredients while completing a series of "real life" mathematical operations. The stop-signal task is primarily a measure of executive attention (and not storage) that involves inhibiting a button-press response when a tone is preceded by a vibration (Miyake, 2000).

If the present hypothesis is correct, the author predicts that the naturalistic grocery store task will be positively associated with tone monitoring, because they primarily rely on memory storage in addition to executive attention. In addition, working memory capacity would be related to distracted driving outcome when tone monitoring or grocery lists is used as a distractor. In contrast, the stop-signal task will *not* be related to WMC, because they primarily rely on executive attention and rely less on memory storage.

A variety of distractor tasks have been used in studies intended to tax working memory capacity. However, it is not clear whether these tasks load onto working memory capacity. To clarify the association between working memory capacity and distraction, the author proposes a study where participants complete a series of distraction tasks: grocery list, tone monitoring, and stop-signal tasks. Performance data on these tasks are then entered into a bivariate correlation to see if they are related to working memory capacity.

Secondly, it is possible that environmental conditions may affect the relationship between working memory capacity and distracted driving. For instance, rain may reduce the visibility required to detect hazards, resulting in increased attentional shifting to avoid potential accidents. Because rain increases the number of potential hazards that needs to be attended to, it is predicted that it would be more demanding on working memory than clear weather conditions. To evaluate whether the effect of distractions on driving magnify under rainy conditions, the author proposes a study where participants drive either under clear or rainy conditions.

Lastly, research on distracted driving has either looked at executive attention alone or WMC alone. This study is the first to employ both executive attention and complex spans to evaluate the domain-general account of WMC as a predictor of distracted driving performance. If the domain-general account of WMC is accurate, then executive attention must be a necessary (but not sufficient) condition of WMC. In other words, any significant relationship between

WMC as measured by the complex spans and distracted driving performance requires executive attention as a significant predictor. However, there can be a significant relationship between executive attention and distracted driving performance without a significant relationship between WMC as measured by the complex spans and distracted driving performance.

The rationale for Study 1 is to evaluate the validity of the Grocery List Task as a measure of WMC. Since it is based off the auditory Operation Span, it is predicted that it would be positively correlated with the Operation Span. It is also predicted that it would be positively associated with Operation Span, Symmetry Span, and Rotation Span individually and also as measured by their composite score.

The rationale for Study 2 is twofold: the first is to determine what types of distractor tasks are associated with working memory capacity (WMC), using executive attention and memory storage as criteria. The author will identify any relationships between an individual's working memory capacity and four distractor tasks which potentially tap into working memory.

Second, it appears that not all types of distractions affect driving outcome equally. For instance, driving impairments were less severe when an individual conversed with an in-car passenger than with someone on a cell phone or while alone (Rueda-Domingo et al., 2004; Drews, Pasupathi, & Strayer, 2008; as cited by Gaspar, Street, Windsor, Carbonari, Kaczmarski, Kramer, & Mathewson, 2014). The differences in distraction types may account for the mixed findings on WMC as a predictor of distracted driving outcomes. Although certain studies using complex spans or n-backs as distractor tasks found that WMC predicted driving outcome (e.g., Ross et al., 2014; Watson & Strayer, 2010), other studies using more naturalistic tasks such as Louie and Mouloua (2015) did *not* find a relationship between WMC and driving outcome. It is possible these results were attributed to an inappropriate distraction task which did *not* load sufficiently onto both executive attention and memory storage.

In Study 2, the author will determine whether WMC is related to distracted driving outcome using two simulated driving trials: non-distracted (i.e., no distraction) and distracted (i.e., participants complete a distraction task). The author predicts that when appropriate distractors are used, WMC would be related to distracted driving. Specifically, it would moderate the impairing effect of distraction on driving performance.

Study 3 will be conducted to determine whether the relationship between WMC and distraction is affected by weather conditions (i.e., clear versus rainy weather) using the same three distractor conditions as in Study 2. It is possible that the *driving scenario* may not load sufficiently onto working memory, making it difficult to find a relationship between working memory capacity and distracted driving. Because rain increases the number of potential hazards that drivers must attend to while driving, it is predicted that it would be more demanding on working memory than in a clear scenario.

CHAPTER 5: STUDY 1

Method

Participants

Forty-three undergraduate students from the University of Central Florida were recruited from SONA, the university's online recruitment system. Sixteen participants completed the first version of the GLT, while 27 participants completed the second version of GLT. Data from one participant was missing due to technical difficulties.

Participants' ages ranged from 18 to 29 years old, with a mean age of 21 years old. Twenty-five of the participants were female (56.8%), with one participant's gender unreported. Finally, the sample was primarily white (45.5%), with the remaining race/ethnicities being black (15.9%), Hispanic/Latino (13.6%), Asian (11.4%), and Mixed/Other (9.1%). The required sample size of 19 participants needed for a power size of .80 and a large effect size of .80 was estimated using a G*Power version 3.1 statistical power calculator. The input parameters were an alpha statistical criterion of .05 using a two-tailed test and 6 predictors (WMC, executive attention, TMT A, TMT B, distraction condition [distracted versus non-distracted]).

Participants were all 18 years of age or older, had 20-20 or corrected-to-normal vision, and no color blindness. Participants also reported no history of neurological disorders or seizures. All participants received extra course credits for their participation and were treated according to the APA research and ethical guidelines.

Measures

Apparatus

E-Prime 2.0 (Psychology Software Tools, Inc., 2012). E-Prime (Psychology Software Tools, Inc., 2012) was the software used to display the stimuli for the Operation span, Rotation span, Symmetry span, and Reading Span. Individual performance data on each task was generated into separate data files.

Materials

Working memory complex spans

Working memory capacity was calculated as the mean z-score using four measures of working memory: the operation span, rotation span, spatial symmetry, and reading span. For each span, participants recalled a sequence of items (i.e., letters or arrows) presented in a specific order. Before and after each item presentation, a secondary task was also given. The nature of the secondary task depended on the span – for instance in the operation span, participants decided whether a given math statement (e.g., “5 + 7 = 11”) was true or false.

Shortened versions of working memory capacity tasks, which previous studies have found to be reliable and valid, were used for this study (Foster, Shipstead, Harrison, Hicks, Redick, & Engle, 2015). Each span consisted of one block of seven trials, with each trial presenting sequences of two to seven letters. The length of the letter sequence was randomized across trials for each participant. Next, the author describes the method used to calculate working memory capacity in described in further detail below (Conway et al., 2005).

In order to calculate working memory capacity, scores were first calculated for each individual (we will refer to them as “individual scores”). Individual scores were calculated as partial scan scores, or the number of items recalled in the correct order across all trials. For instance, if a person recalled 4 out of 7 letters in a trial, his or her partial score for that trial would be *4*. The other type of score was the absolute span score, in which participants would only receive credit for scoring 100% accuracy within that trial. For instance, if a person recalled 4 out of 7 letters in a trial, his or her absolute score for that trial would be *0*. Only partial scores were used in this study because they allowed for more variance among scores. Scores with larger variance were preferred because they are better at discriminating between participants with lower and higher working memory abilities (Conway et al., 2005). The individual scores were then used to compute the sample mean for each working memory measure. The sample mean was used to compute the participant's z-score for each working memory measure, by subtracting the span mean from the participant's score, and then dividing the difference by the span standard deviation. Finally, the z-scores were averaged across the three working memory measures to form the latent, working memory capacity construct. Negative z-scores indicated smaller than average working memory capacity, while positive z-scores indicated larger than average working memory capacity. This method of using several measures to form a latent variable has been suggested to minimize Type II error and increase power in measuring working memory capacity (Kane et al., 2001).

Operation span. Participants recalled a sequence of letters which had been presented while completing a series of arithmetic tasks (e.g., True or false: "5 + 7 = 11"?)

Rotation span. Participants recalled the spatial location of a series of arrows which had been presented while completing a series of letter rotation tasks (e.g., can "И" become "N" after it is rotated counter-clockwise?)

Symmetry span. Participants recalled a sequence of letters which had been presented while completing a series of symmetry judgments (e.g., is the following image symmetrical?).

Reading span. Participants recalled a sequence of letters which had been presented while completing a series of reading judgments (e.g., does the following sentence make sense: “She was very tired after spaghetti all day?”).

Distractor tasks.

Grocery List Task version 1. Participants recalled a list of grocery store items auditorily presented by the experimenter. The experimenter began by naming a set of ingredients. After each set of ingredients (e.g., turkey, radish, and tomatoes), the participant completed a secondary chore task. The chore task involved responding to an experimenter’s question regarding a chore (e.g., what are the steps needed to wash the laundry?). At the end of each trial, the participant was instructed to recall all the ingredients (e.g., bacon, lettuce, tomatoes, etc.). The participant’s span score was calculated as the proportion of food items correctly recalled across all trials. A greater proportion of items correctly recalled indicated larger WMC. To ensure that participants were devoting sufficient attention to the chore task, they were asked to spend at least 10 seconds describing how they would perform each chore. Participants’ mean number of utterances and steps enumerated (e.g., set machine settings to large load, turn on water, pour in laundry detergent, put in clothes) would also be coded and entered as a covariate in regression analyses.

All food items were screened beforehand to ensure they are not within the top 10% of the 5,000 most frequently used English words to reduce the likelihood of random guessing, and not too infrequent (the bottom 10% of 5,000 frequently used English words) to reduce the “pop-out” salience effect (http://www.wordfrequency.info). A total of fifteen list-chores was used in this study. Six were related to housework (e.g., name the steps you take to clean your room thoroughly), six were related to academics (e.g., name the steps you take to write a research paper), and three were related to social life (e.g., name the steps you take to get ready for a date). The measures were piloted beforehand to assess perceived difficulty.

The grocery list task was modeled after the auditory reading span (Oswald, McAbee, Redick, & Hambrick, 2015), which involved memory storage (i.e., recalling a series of letters) and executive attention (i.e., alternating to the secondary task of making true-false semantic judgments). Similar to the auditory reading span, the grocery list involved memory storage (i.e., recalling a series of food items) and executive attention (i.e., alternating to the secondary task of describing how one would perform a chore). The task was intended to be a more naturalistic measure of WMC, resembling the kinds of working memory tasks one might actually perform while driving. The task presumably does not overlap with the visual or physical demands of driving.

Grocery List Task version 2. Participants recalled a list of grocery store items auditorily presented by the experimenter. The experimenter began by naming a set of ingredients. Each ingredient was described as costing a certain amount of dollars in a certain number of boxes (e.g., 2 boxes of $3 turkey). After each food-price pair was presented, the experimenter named a price (e.g., $6?) and the participant decided whether the indicated priced was accurate by verbally reporting “yes” or “no” within four seconds after the price was listed. After four seconds, the next ingredient-pricing pair was presented (e.g., “3 box of $7 bacon. $28?).

Each trial consisted of a three to eight food-price pairs. At the end of each trial, the participant recalled all the ingredients (e.g., turkey, bacon, lettuce, tomatoes, etc.). The participant’s span score was the proportion of food items correctly recalled across all trials. A greater proportion of items correctly recalled indicated greater WMC. To ensure that participants were devoting sufficient attention to the secondary price-judgment task, only participants performing at 70% accuracy on the secondary, price-judgment task were considered for data analysis.

As before, the food items were screened beforehand to ensure they were not within the top 10% of the 5,000 most frequently used English words to reduce the likelihood of random guessing, and not too infrequent (the bottom 10% of 5,000 frequently used English words) to reduce the "pop-out" salience effect (http://www.wordfrequency.info). A total of nineteen trials were used in this study.

Like Grocery List Task version 1, version 2 was modeled after the auditory operation span (Oswald, McAbee, Redick, & Hambrick, 2015), which involves memory storage (i.e., recalling a series of letters) and executive attention (i.e., alternating to the secondary task of making true-false mathematical judgments). Similar to the auditory operation span, the grocery list involves memory storage (i.e., storing a list of food items) and executive attention (i.e., alternating to the secondary task of calculating the cost of each food item).

Design and Procedures

Two types of designs were used for Study 1. First, a correlational design was used to evaluate whether Grocery List Task versions 1 and 2 related to WMC. They were also used to evaluate whether GLT and WMC were related to demographics, simulated driving performance, and self-reported driving behavior. The second was a one-way within-subjects experimental design used to measure task performance under non-distracted (i.e., either GLT or driving) and distracted (i.e., combined GLT and driving) conditions.

For Study 1, participants were first provided informed consent. They then completed a demographics questionnaire, Trailmaking Tasks A and B, and the WMC tasks: operation span, rotation span, symmetry span, and reading span. Afterward, they completed the Grocery List Task distraction alone, the driving task alone, and the Grocery List Task distraction and driving simultaneously. The NASA-TLX and DSSQ short-version were administered after each distraction and driving task to assess subjective engagement, distress, worry, mental demand, physical demand, temporal demand, frustration, and perceived performance. At the end of the study, the participants were debriefed and were awarded credit for their participation.

Two types of Grocery List Task versions were initially used for this study. The first one involved storing a list of food items while describing how one would complete a certain chore. The second one involved storing a list of food items while performing a set of embedded arithmetic operations (see APPENDIX: DISTRACTOR TASKS). Data from the two versions were then analyzed to select the more appropriate working memory distraction. Afterward, performance involving the Grocery List Task was evaluated using only the more appropriate version ($N = 27$ participants). However, where the Grocery List Task is not being considered, data were analyzed using all 43 participants.

A bivariate correlation was used to evaluate the relationship between the Grocery List Tasks and WMC. Paired samples t-tests were also used to evaluate the performance on the driving tasks and the Grocery List Tasks when completed separately or as a combined task. Finally, a series of bivariate correlations were used to evaluate the relationship between the Grocery List Task, driving performance, WMC, and demographics and self-reported driving behavior.

Hypotheses

H1: WMC as measured by performance on the complex spans would positively correlate with the percentage of items correctly recalled on the Grocery List Task.

H1a: *Driving performance* would be more impaired on the combined Grocery List and driving task than compared to driving alone.

H1b: *Grocery List Task performance* would be more impaired on the combined Grocery List and driving task than compared to the Grocery List Task alone.

Results

Selecting a Grocery List Task as a working memory distractor

The Grocery List Task (version 2) was positively associated with WMC, with low span individuals performing more poorly on the task than high span individuals. Specifically, WMC was related to performance on the math portion of the task when the participants were completing the Grocery List Task alone ($r(24) = .41$, $p < .05$) and as a combined Grocery List Task and driving task ($r(24) = .45$, $p < .05$). However, it was not related to performance on the word recall portion of the task ($r(24) = -.08$; $p > .05$); ($r(24) = .03$, $p > .05$).

In contrast, Grocery List Task version 1 was *not* associated with WMC ($p > .05$; see Table 1). Because only GLT version 2 loaded onto WMC, it was selected as the working memory distractor used for further data collection and analysis. Unless otherwise stated, all analyses listed below involve GLT version 2.

Table 1. GLT performance indicators as measures of WMC

		r
GLT v.1	Word recall, GLT alone	.357
	Word recall, GLT and Driving	.344
	Arithmetic judgment, GLT alone	.357
	Arithmetic judgment, GLT and Driving	.344
GLT v. 2	Word recall, GLT alone	-.075
	Word recall, GLT and Driving	.032
	Arithmetic judgment, GLT alone	.411*
	Arithmetic judgment, GLT and Driving	.451*
GLT v. 3	Word recall, GLT alone	.132
	Word recall, GLT and Driving	.186
	Arithmetic judgment, GLT alone	.022
	Arithmetic judgment, GLT and Driving	.025

** Correlation is significant at the 0.05 level (2-tailed).*

In the following analyses, we evaluate two conditions: one is the control condition and the other is the experimental condition. The control condition consisted of driving a series of scenarios without taking the GLT. However in the experimental condition, participants drove the same driving scenario while responding to a secondary GLT. There was a significant difference between driving alone and driving while responding to the secondary task. Those who drove and responded to the secondary task had significantly lower GLT scores, as well as poorer driving performance.

Grocery List Task performance

Participants recalled significantly fewer words when completing the combined Grocery List and driving task ($M = 0.61$, $SD = 0.18$) than when driving alone ($M = 0.68$, $SD = 0.13$); ($t(26) = 3.95$, $p < .05$). They also were less accurate on the arithmetic judgment task when completing the combined task ($M = 0.75$, $SD = 0.24$) than when driving alone ($M = 0.85$, $SD = 0.19$); ($t(26) = 3.44$, $p < .05$).

Driving performance

Participants made fewer lane deviations while completing the combined driving and GLT distraction task than when driving alone ($p < .05$; see Table 2). There was also no difference in the number of collisions, the number of times the braking pedal was pressed, or the average duration of each brake press between the combined task and the driving alone task ($p > .05$).

There was no significant difference in braking response time while completing the combined driving and GLT distraction task ($M = 1.76$, $SD = 0.87$) than while driving alone ($M = 2.57$, $SD = 1.08$); ($t(3) = 1.31$; $p = .28$).

There was no significant difference in accelerating response time while completing the combined driving and GLT distraction task ($M = 3.60$, $SD = 2.21$) than while driving alone ($M = 4.36$, $SD = 1.29$); ($t(24) = 1.83$; $p = .08$).

Table 2. GLT performance during non-distracted and distracted conditions

	Condition	*M*	*SD*
Word recall performance	GLT alone	0.68	0.13
	GLT and driving	0.61	0.18
Arithmetic Judgment Performance	GLT alone	0.85	0.19
	GLT and driving	0.75	0.24

** Correlation is significant at the 0.05 level (2-tailed).*

Subjective stress

DSSQ. Participants were more worried while simultaneously driving and completing the GLT (M = 17.77, SD = 6.13) than while driving alone (M = 15.32, SD = 5.64); ($t(21) = 2.28$, $p < .05$). However, they were not any more distressed or engaged while simultaneously completing the GLT than while driving alone ($p > .05$; see Table 3).

NASA TLX. Participants perceived that the combined distraction and driving task was more mentally demanding ($t(21) = 5.39$, $p < .05$), more temporally demanding, ($t(21) = 3.09$, $p < .05$), and more frustrating ($t(21) = 2.38$, $p < .05$) than driving alone. Participants also believed that their performance was worse in the combined distraction and driving task than driving alone. However, the combined task was not perceived as any more physically demanding or involving more effort ($p > .05$).

Table 3. Study 1 DSSQ pre-task and task scores

	M	*SD*	*N*	*t*	*p*
Engagement Pre-task	23.62	5.039	29	4.17	$p < .05$
Engagement GLT	20.67	4.592	36	-	-
Distress Pre-task	6.79	5.294	29	-12.2	$p < .05$
Distress GLT	20.89	7.749	36	-	-
Worry Pre-task	9.34	5.544	29	-6.17	$p < .05$
Worry GLT	16.08	7.758	36	-	-

Self-reported driving behavior.

Related to Grocery List Task. Participants who reported frequently losing track of the time and losing track of where they are while driving were more likely to perform worse on the *math portion* of the Grocery List Task alone ($r(24) = -.44$, $p < .05$; $r(24) = -.51$, $p < .05$). They also performed worse while completing the combined task, however this was significant only for those who frequently lost track of time ($r(24) = -.48$, $p < .05$).

Also, individuals who drove more frequently during the week performed more poorly on the word recall portion of the Grocery List Task when completing it alone ($r(24) = -.40$, $p < .05$). They also performed more poorly when completing it as a combined task, but this correlation was not significant ($r(24) = -.30$, $p > .05$).

Related to simulated driving behavior. Participants who reported typically driving faster than the average flow of traffic were more likely to get into collisions while driving with and without the GLT distraction ($r(24) = .51$, $p < .05$; $r(24) = .56$, $p < .05$). Participants who frequently lost track of the time and where they were while driving showed fewer lane deviations ($r(24) = -.42$, $p < .05$; $r(24) = -.50$, $p < .05$). However, they were *more* likely to collide with another vehicle (losing track of time: $r(24) = .53$, $p < .05$; losing track of location: $r(24) = .39$, $p < .05$).

Related to WMC

Participants with larger WMC typically drove slower than the average flow of traffic ($r(23) = -.40$, $p < .05$).

Related to Executive Attention

Participants with higher ANT accuracy were more likely to have been in a minor accident within the past 5 years ($r(23) = .41$, $p < .05$)

Missing data

A few items in the Driving Behavior Questionnaire were not included in the dataset because the participant had responded incorrectly. For example, for the question "Please state the year you obtained your driver's license," a participant responded "Florida."

Discussion

The findings of Study 1 suggest that GLT version 2 was a more suitable measure of distraction of working memory. Unlike GLT version 1, GLT version 2 was positively correlated with WMC as measured by the complex spans. One reason why version 2 may have been positively correlated is that demanded more memory storage than version 1. While version 1 may have only required the storage of the X number of food items listed while retrieving information from long-term memory to complete the chore task, version 2 required active storage of the X number of food items while actively storing and manipulating information for the math task. Another reason why version 2 may have been positively correlated was due to the increased effort it demanded compared to GLT version 1.

Also, only the math portion of GLT version 2 loaded onto WMC. Although it is not entirely clear why the other word recall task did not load onto WMC, the present findings suggest two possibilities. First, there may have been *domain-specific differences* in working memory storage. For instance, math tasks may be more sensitive to differences in WMC than word tasks. This would support Baddeley's (2009) model that WMC differs across different domains such as arithmetic versus verbal domains. Second, the mathematics portion of version 2 may have simply required more storage than the word recall portion, *regardless of domain* (i.e., numbers versus non-numbers). For instance, the math task may have involved the storage and manipulation of more units of math information than reading information. Each item involved an embedded word and operation task – for instance, "Two boxes of $3 Jell-O – $6?" Each item always included the same four units of math information required to complete the math task (e.g., *two*, *multiply, three*, and *six*). In contrast, the item only required one unit of information required to complete the word task (e.g., *Jell-O*). So, in a trial involving four items: "Two boxes of $3 Jell-O – $6? Six boxes of $4 pasta – $24? Six boxes of $7 berries – $36? Seven boxes of $1 mango - $7?" There are 16 units of math information and only 4 units of word information.

The asymmetrical relationship between the Grocery List sub-tasks and WMC provides an opportunity to further examine if the Grocery List Task supports a domain-specific or domain-general theory of WMC. It would be interesting to investigate this relationship by creating a new (third) version of the Grocery List task that would either support or fail to support a domain-specific account of WMC. In the third GLT, there would be more units of word information than the math information required. If the GLT finds that the word portion of the task still does not load onto WMC, then we would have more evidence to support a domain-specific account of

WMC – specifically that semantic information may be less sensitive to differences in WMC than numerical information. However, if the GLT finds that the word portion of the task *does* load onto WMC, then this would support a domain-general account of WMC.

Another interesting finding was that individuals who self-reported typically driving faster than the general flow of traffic were more likely to collide with another vehicle during their simulated drive. This finding supports previous studies suggesting that individuals with ADHD are more likely to speed while driving (Reimer et al., 2010). Because executive attention and working memory are closely and positively related (Conway et al., 2001; Kane et al., 2001), it is likely that individuals with low WMC are also likely to show driving impairments as seen in individuals with deficits in executive attention.

Interestingly, individuals showed *fewer* lane deviations during the distracted trial (with GLT) than during the non-distracted trial (without the GLT). Numerous studies have also found that the higher cognitive workload associated with distraction *decreases* lateral position variability (Atchley & Chan, 2011; Beede & Kass, 2006; Brookhuis, De Vries, & De Waard, 1991; He & McCarley, 2011; Jamson & Merat, 2005; Knappe, Keinath, Bengler, & Meinecke, 2007; Östlund et al., 2004; Reimer, 2009; Cooper, Medeiros-Ward, & Strayer, 2013). Some have suggested that a higher cognitive workload would decrease eye movements, consequently decreasing steering wheel movement. However, Cooper et al. (2013) suggest that the effect of cognitive workload on lateral position is separable from eye movements

Overall, the Study 1 results were partially supported. As expected, driving while completing the GLT resulted in poorer driving performance and poorer GLT performance. GLT version 2 was related to WMC. Because the math portion of the task was particularly sensitive to differences in WMC, the author used the math performance as an index of WMC in the following studies.

CHAPTER 6: STUDY 2 PILOT

The purpose of the Study 2 pilot was to identify whether a third version of GLT would be more strongly associated with WMC compared to the second version of GLT.

Method

Participants

Forty-four undergraduate students from the University of Central Florida were recruited from SONA, the university's online recruitment system. Twenty-one participants completed the second version of GLT, while 23 participants completed the third version of GLT. The required sample size of 20 participants needed for a power size of .80 and a large effect size of .80 was estimated using a G*Power version 3.1 statistical power calculator. The input parameters were an alpha statistical criterion of .05 using a two-tailed test and 8 predictors (WMC, executive attention, TMT A, TMT B, GLT (version 2 or version 3), and distraction condition [distracted versus non-distracted]).

Participants were 18 years of age or older, had 20-20 or corrected-to-normal vision, and no color blindness. Participants were also screened to ensure they did not have any history of neurological disorders or history of seizures, to reduce the possibility of adverse effects while using the driving simulator. All participants received class credit for their participation.

Measures

Apparatus

E-Prime 2.0 (Psychology Software Tools, Inc., 2012). E-Prime (Psychology Software Tools, Inc., 2012) was the software used to display the stimuli for the Operation span, Rotation span, Symmetry span, Reading Span, and Attention Network Task. Data on an individual's performance was generated into a data file after each task was completed.

GE I-SIM. A medium-fidelity driving simulator was used to simulate driving. The simulator included a three-panel display displaying 150 degrees of the visual field. The vehicle emulated a Ford Taurus with similar accelerating and braking feedback. The driving conditions were clear, daytime driving on dry pavement.

Materials

Demographics questionnaire. The demographics questionnaire is a brief survey consisting of questions regarding the participants' age, class year, number of years driving, as well as their frequency of driving, whether they use secondary devices such as cell phones or navigation devices while driving, and history of traffic violations and accidents. Data from the survey were submitted and stored in a spreadsheet via Google spreadsheets.

TMT A and TMT B. TMT A is a popular measure of processing speed used in neuropsychological tests. Participants simply drew lines to connect numbers in ascending order without lifting the pen or pencil from the paper (e.g., 1, 2, 3, 4…). Faster completion times indicated faster processing speed. TMT B is a measure of processing speed and *shifting* used in neuropsychological tasks. Participants will make a path from an alternating series of numbers in ascending order and letters in alphabetical order (i.e., 1, A, 2, B, 3, C…). Faster completion times indicated faster processing speed and more efficient shifting ability (Reitan, 1958; Alexandersen, Dalen & Bronnick, 2009; Marcotte, Wolfson, Rosenthal, Heaton, Gonzalez, Ellis, et al., 2004; Soderstrom, Pettersson, & Leppert, 2006; Stolwyk, Charlton, Triggs, Iansek, & Bradshaw, 2006).

Working memory complex spans

The same working memory complex spans were used as in Study 1.

Operation span. Participants recalled a sequence of letters which had been presented while completing a series of arithmetic tasks (e.g., True or false: “5 + 7 = 11”?)

Rotation span. Participants recalled the spatial location of a series of arrows which had been presented while completing a set of letter rotation tasks (e.g., can “И” become “N” after it is rotated counter-clockwise?).

Symmetry span. Participants recalled a sequence of letters which had been presented while completing a series of symmetry judgments (e.g., is the following image symmetrical?).

Reading span. Participants recalled a sequence of letters which had been presented while completing a series of reading judgments (e.g., does the following sentence make sense: “She was very tired after spaghetti all day”?).

Attention Network Task (ANT); (Fan, McCandliss, Sommer, Raz, & Posner, 2002). The ANT is a task created by Fan et al. (2002) which combines two paradigms for measuring three attentional networks. The first is Posner’s cued reaction time (RT) task, in which participants responded to a target as soon as it appears on a screen following the presentation of a cue. The second is Eriksen and Eriksen’s (1974) flanker task, in which participants identified a target (e.g., a leftward or rightward arrow) flanked by congruent stimuli (i.e., same direction), incongruent stimuli (i.e., opposite direction), or neutral stimuli. In this study, participants identified the leftward or rightward orientation of a target stimuli following a cue, while it was surrounded by congruent, neutral, or incongruent flanker stimuli. Three blocks of 96 trials and a practice block of 24 trials were administered. Self-paced breaks were given after each block, resulting in a total session time of 30 minutes.

The efficiency of the executive attention network was measured by performing cognitive subtractions. Specifically, executive attention was measured as the *difference in the amount of time it takes to* identifying the orientation of a target stimulus when presented with *incongruent* stimuli, compared to when it was presented with *congruent* stimuli (in ms); (referred to in this document as "ANT Reaction Time"). It was also measured as the difference in the *number of errors* between incongruent stimuli compared to congruent stimuli ("ANT Number of Errors"). Greater mean differences in times or errors indicated weaker executive attention (Fan et al., 2002).

Distractor tasks.

Grocery List Task version 2. Participants recalled a list of grocery store items auditorily presented by the experimenter. The experimenter began by naming a set of ingredients. Each ingredient was described as costing a certain amount of dollars in a certain number of boxes (e.g., 2 boxes of $3 turkey). After each food-price pair was presented, the experimenter named a price (e.g., $6?) and the participant decided whether the indicated priced was accurate by verbally reporting "yes" or "no" within four seconds after the price is listed. After four seconds, the next ingredient-pricing pair was presented (e.g., "3 box of $7 bacon. $28?).

Each trial consisted of three to eight food-price pairs. At the end of each trial, the participant recalled all the ingredients (e.g., turkey, bacon, lettuce, tomatoes, etc.). The participant's span score was the proportion of food items correctly recalled across all trials. A greater proportion of items correctly recalled indicated greater WMC. To ensure that participants were devoting sufficient attention to the secondary price-judgment task, only participants performing at 70% accuracy on the secondary, price-judgment task were considered for data analysis.

Grocery List Task version 3. Participants were presented with a list of allergies (e.g., salmon, milk, and celery) and a list of categories (e.g., fish, dairy, fruit). They were instructed to identify if the food items presented matched the category *and* was not on the allergy list. If the food item matched the category *and* was not an allergy, the participant would respond "yes" (i.e., he/she can buy the item). If the food item either *did not* match the category *or* was on the allergy list, the participant would respond "no" (i.e., he/she *cannot* buy the item).

For instance, the allergy list might be: salmon, paprika, carrots, and watermelon. The experimenter would then tell the participant that they need to buy four boxes of fish. Would we be able to buy salmon? The answer would be no, because even though salmon is a type of fish, it is on the allergy list. Next, the experimenter may tell the participant that they need to buy ten boxes of vegetables. Would we be able to buy celery? The answer would be yes, because celery is a type of vegetable and is not on the allergy list. Finally, the experimenter may tell the participant they need to buy two boxes of dessert. Would we be able to buy salt? The answer would be no, because salt is not considered a type of dessert.

Participants were given three seconds for each response before the next food item was presented. At the end of each trial, participants were asked to state how many kinds of food he/she is getting. In this example, she would get one kind of food (celery). The experimenter's dialogue was pre-recorded into an audio file with each phrase spoken at 40 beats per minute and a three-second (silent) period for the participant to respond after each item.

There were two to eight items in each trial, for a total of 19 trials in the task. All food items were randomized and were taken from the same list of words used in Grocery List Task versions 1 and 2. Additionally, the number of items in each trial was randomized using http://www.random.org to ensure that there were no effects of trial size on performance. The participant's span score was the proportion of food items correctly recalled across all trials. A greater proportion of items correctly recalled indicated greater WMC.

Like Grocery List Task versions 1 and 2, version 3 was modeled after the auditory operation span (Oswald, McAbee, Redick, & Hambrick, 2015), which involves memory storage (i.e., recalling a series of letters) and executive attention (i.e., alternating to the secondary task of making true-false mathematical judgments). Similar to the auditory operation span, the grocery list involves memory storage (i.e., storing the number of kinds of food items one can buy) and executive attention (i.e., comparing the food item to the category and list of allergies).

Design and Procedures

For the Study 2 pilot, a series of zero-order correlations were used to evaluate the relationship between WMC and the four distractor tasks. Additionally, a moderated regression using the general linear model (GLM) was used to evaluate the relationship between distraction trial, WMC and driving outcome.

Session one.

After completing informed consent, participants completed a demographics questionnaire on their age, class year, number of years driving, as well as their history of traffic violations and accidents. Next, they completed the Trailmaking tasks A and B which assessed their processing speed. Then, they completed the working memory capacity and executive attention tasks: operation span, rotation span, symmetry span, reading span, and ANT. Lastly, they completed the distraction tasks: Grocery List Task, tone monitoring task, and stop-signal task. Participants were allowed a brief, 2-minute break in between each task. Session one took approximately seventy minutes. At the end of session one, participants were allowed a 10-minute break before starting session two.

Session two.

Participants completed one practice trial and two, 7-minute driving trials on a driving simulator. In each trial, they were instructed to drive as they normally would while navigating a highway route. During the non-distracted trials, participants drove without any distractions while navigating the highway route. During the distracted trials, participants drove while engaging in the Grocery List Task, tone monitoring task, or stop-signal task.

The driving scenario involved a highway route with high traffic density. Most of the cars were simulated to drive within 15 miles per hour (mph) of the speed limit of 65 mph. The cars would drive faster than its designated speed and switch to the left lane when the car in front was driving slower; they would also drive slower and brake when the car in front suddenly braked. Several trucks were also added that drove much more slowly than others (i.e., at 25 miles per hour and under), limiting the speed of surrounding vehicles and creating high traffic density. Because the same city route was used for non-distracted and distracted trials, the trials were counterbalanced to ensure any effects were not due to the order of route presentation.

Hypotheses

H1c: GLT version 2 and 3 would be positively associated with working memory capacity as measured by complex spans.

H1d: *Driving performance* would be more impaired on the combined Grocery List and driving task than compared to driving alone.

H1e: *Grocery List Task performance* would be more impaired on the combined Grocery List and driving task than compared to the Grocery List Task alone.

Results

Selecting a Grocery List Task as a working memory distractor

A bivariate correlation was conducted to evaluate whether Grocery List Task versions 2 and 3 were related to WMC. As before, GLT version 2 was related to WMC ($r(19) = .46$, $p < .05$), with low span individuals performing more poorly on the task than high span individuals. Specifically, WMC was related to performance on the word recall portion of the task when the participants were completing the GLT alone ($r(19) = .46$, $p < .05$). However, WMC was neither related to performance on the math performance of the task during non-distracted ($r(17) = .02$, $p > .05$) or distracted ($r(17) = .29$; $p > .05$) trials, nor performance on the word recall of the task when participants were completing the combined GLT and driving task ($p > .05$).

In contrast, none of the GLT version 3 performance indicators were related to WMC ($p > .05$). Because only GLT version 2 loaded onto WMC, it was selected as the working memory distractor used for further data collection and analysis. Unless otherwise stated, all analyses listed below involve GLT version 2.

GLT and executive attention

A bivariate correlation was conducted to evaluate the relationship between GLT and the executive attention. None of the GLT performance indicators were related to ANT accuracy ($p > .05$) or ANT response time ($p > .05$).

GLT performance under single and dual-task conditions

In general, participants recalled significantly *more* words when completing the combined Grocery List and driving task ($M = 0.93$, $SD = 0.77$) than when driving alone ($M = 0.57$, $SD = 0.12$); ($t(13) = 8.30$, $p < .05$). They were significantly less accurate on the arithmetic judgment task when completing the combined task ($M = 0.78$, $SD = 0.23$) than when driving alone ($M =$

0.50, *SD* = 0.25); ($t(17) = 2.75$, $p < .05$).

Driving performance under single and dual-task conditions

There was no significant effect of distraction on braking response time when GLT was used as a distractor ($p > .05$). However, there were significantly more lane deviations when the participants simultaneously completed the GLT and driving tasks (*M* = 4.21, *SD* = 2.27) than when they were driving alone (*M* = 2.89, *SD* = 1.20); ($t(18)=3.31$, $p < .05$).

GLT subjective stress

DSSQ. Participants were more distressed while completing the combined GLT 2 and driving task (*M* = 15.38, *SD* = 8.66) than while driving alone (*M* = 9.57, *SD* = 5.68; $t(20) = 3.04$, $p < .05$). However, they were not any more engaged or worried while completing either task ($p >$ .05).

NASA TLX. Participants found the combined GLT 2 and driving task to be more mentally and temporally demanding (*M* = 7.71, *SD* = 1.68); (*M* = 6.05, *SD* = 2.80) than driving alone (*M* = 6.10, *SD* = 2.07; *M* = 3.43, *SD* = 2.58, respectively; $t(20) = 4.48$, $p < .05$; $t(20) = 4.23$). They also found the combined GLT 2 and driving task to be more frustrating and involving more effort (*M* = 5.43, *SD* = 3.19; *M* = 8.00, *SD* = 1.61) than driving alone (*M* = 3.48, *SD* = 2.93; *M* = 6.62, *SD* = 1.88, respectively; $t(20) = 3.08$, $p < .05$; $t(20) = 6.18$). Finally, participants did not perceive their performance to be any worse in either combined or driving alone task ($p > .05$).

GLT and self-reported driving behavior.

Performance on the GLT was not related to self-reported driving behavior as measured by the Driving Behavior Questionnaire employed in this study ($p > .05$).

Discussion

The GLT loaded onto WMC, as predicted. The GLT was predicted to be related to WMC because it involved both memory storage and executive attention, which are the domain-general requirements for working memory. However, the Tone Monitoring Task was not related to WMC, which was not as predicted. The Tone Monitoring Task was predicted to be related to WMC because it appeared to also involve the memory storage and executive attention requirements for working memory. Neither GLT nor the Tone Monitoring Task was related to executive attention. It is possible that the GLT and Tone Monitoring tasks may have tapped into a different type of executive attention not measured by the ANT – for instance, the GLT and Tone Monitoring task may have tapped into *shifting* (between items of a category), compared to the ANT conflict function which taps into *inhibiting* (suppressing prepotent responses).

The lack of a distraction effect on braking response time also may be due to the lack of braking events occurring in a highway scenario with little stop-and-go traffic. Additionally, any "sudden braking events" (events where the participant *must* brake to avoid an imminent collision) would have been minimized when participants engaged in compensatory behaviors such as maintaining a larger following distance. With few braking events to sample from, the statistical power would have been too small to detect any significant relationships between distraction and driving. To address this concern, Studies 2 and 3 employ city routes where participants are instructed to brake whenever a yellow traffic light appears. Specifically, Study 3 evaluates the effect of rain on distracted driving performance using the city route.

Studies 2 and 3 employ a city route to increase the number of potential braking events.

CHAPTER 7: STUDY 2

Method

Participants

Eighty-four participants with the same criteria (i.e., at least 18 years old, 20-20 or corrected-to-normal vision, no color blindness, and no history of neurological disorders or seizures) were used for Study 2. 0. Twenty-eight participants completed each condition (GLT, Tone Monitoring, and Stop Signal).

A power analysis suggested a total sample size of 57 participants for Study 2. This required a sample size of 19 participants per distraction type (i.e., GLT, Tone Monitoring, and Stop Signal tasks) was calculated using a G*Power version 3.1 statistical power calculator. Input parameters included a power of .80 and a large effect size of .80 estimated using a G*Power version 3.1 statistical power calculator. An alpha statistical criterion of .05 using a two-tailed test and 6 predictors were also used (WMC, executive attention, TMT A, TMT B, distraction condition [distracted versus non-distracted]).

Measures

Apparatus

E-Prime 2.0 (Psychology Software Tools, Inc., 2012). E-Prime (Psychology Software Tools, Inc., 2012) was the software used to display the stimuli for the Operation span, Rotation span, Symmetry span, Reading Span, and Attention Network Task. Data on an individual's performance was generated into a data file after each task was completed.

GE I-SIM. A medium-fidelity driving simulator was used to simulate driving. The simulator included a three-panel display displaying 150 degrees of the visual field. The vehicle emulated a Ford Taurus with similar accelerating and braking feedback. The driving conditions were clear, daytime driving on dry pavement.

Materials

Demographics questionnaire. The demographics questionnaire is a brief survey consisting of questions regarding the participants' age, class year, number of years driving, as well as their frequency of driving, whether they use secondary devices such as cell phones or navigation devices while driving, and history of traffic violations and accidents. Data from the survey were submitted and stored in a spreadsheet via Google spreadsheets.

TMT A and TMT B. TMT A is a popular measure of processing speed used in neuropsychological tests. Participants simply drew lines to connect numbers in ascending order without lifting the pen or pencil from the paper (e.g., 1, 2, 3, 4…). Faster completion times indicated faster processing speed. TMT B is a measure of processing speed and *shifting* used in neuropsychological tasks. Participants will make a path from an alternating series of numbers in ascending order and letters in alphabetical order (i.e., 1, A, 2, B, 3, C…). Faster completion times indicated faster processing speed and more efficient shifting ability (Reitan, 1958; Alexandersen, Dalen & Bronnick, 2009; Marcotte, Wolfson, Rosenthal, Heaton, Gonzalez, Ellis, et al., 2004; Soderstrom, Pettersson, & Leppert, 2006; Stolwyk, Charlton, Triggs, Iansek, & Bradshaw, 2006).

Working memory complex spans

The same working memory complex spans were used as in Study 2.

Operation span. Participants recalled a sequence of letters which had been presented while completing a series of arithmetic tasks (e.g., True or false: "5 + 7 = 11"?)

Rotation span. Participants recalled the spatial location of a series of arrows which had been presented while completing a set of letter rotation tasks (e.g., can "И" become "N" after it is rotated counter-clockwise?)

Symmetry span. Participants recalled a sequence of letters which had been presented while completing a series of symmetry judgments (e.g., is the following image symmetrical?).

Reading span. Participants recalled a sequence of letters which had been presented while completing a series of reading judgments (e.g., does the following sentence make sense: "She was very tired after spaghetti all day"?).

Attention Network Task (ANT). The ANT used in Study 2 was the same as in Study 1. The efficiency of the executive attention network was measured by performing cognitive subtractions. Specifically, executive attention was measured as the *difference in time* between correctly identifying the orientation of a target stimulus when it was presented with *incongruent* stimuli and when it was presented with *congruent* stimuli (in ms); (referred to in this article as "ANT Reaction Time"). It was also measured as the difference in the *number of errors* between incongruent stimuli compared to congruent stimuli ("ANT Number of Errors"). Greater mean differences in times or errors indicated weaker executive attention (Fan et al., 2002).

Distractor tasks.

GLT version 2. Participants recalled a list of grocery store items auditorily presented by the experimenter. The experimenter began by naming a set of ingredients. Each ingredient was described as costing a certain amount of dollars in a certain number of boxes (e.g., 2 boxes of $3 turkey). After each food-price pair was presented, the experimenter named a price (e.g., $6?) and the participant decided whether the indicated priced was accurate by verbally reporting "yes" or "no" within four seconds after the price is listed. After four seconds, the next ingredient-pricing pair was presented (e.g., “3 box of $7 bacon. $28?).

Each trial consisted of three to eight food-price pairs. At the end of each trial, the participant recalled the ingredients (e.g., turkey, bacon, rice, pineapple, etc.). The participant’s span score was the proportion of food items correctly recalled across all trials. A greater proportion of items correctly recalled indicated greater WMC. To ensure that participants were devoting sufficient attention to the secondary price-judgment task, only participants performing at 70% accuracy on the secondary, price-judgment task were considered for data analysis.

Tone monitoring task. Participants heard a continuous series of three tones (i.e., 300 Hz, 800 Hz, and 1200 Hz) which were presented in a random sequence and separated by 1200 ms intervals. They were instructed to respond whenever each tone was played for the fourth time. For example, when a 1200 Hz tone was played for the fourth time, they needed to press the button indicating the 1200 Hz tone. Performance was measured as percent accuracy (i.e., 0 to 100% accurate), d’ (i.e., signal to noise detection ratio), and response time (in ms). The tone monitoring task involved executive attention to shift from one tone category to the next, and memory storage to keep track of the number of times a particular tone has been played. The task also presumably did not overlap with the visual demands of the driving task, although some physical skills may have been needed to press the buttons on the screen.

The tone monitoring task resembles other measures of working memory such as the counting task and the multi-sensory workload assessment protocol (M-SWAP; Jerison, 1955; Kennedy, 1971; Cholewiak, Brill, & Schwab, 2004; Brill, Mouloua, Hancock, Gilson, & Kennedy, 2003). Both measures involve the storage and maintenance of the number of times a type of stimulus is presented, and executive attention to shift between types of stimuli (e.g., tactile, auditory, or visual). Performance on the M-SWAP has been shown to be reliable and has been used as a tool to measure performance evaluation in extreme (e.g., highly stressful) environments (Brill, Mouloua, Hancock, & Kennedy, 2003).

Stop-signal task. Participants heard a series of low or high tones. They were instructed to simply press the left side of the screen when they heard a low tone, or the right side when they heard a high tone. The tone continued to play until they pressed a side or the trial times out. Participants needed to press the button as quickly and as accurately as they could before the tone ended.

Participants were first given an acclimation trial to listen to each tone. They could listen to each tone for as long as they wanted until they felt comfortable. They were then given a practice trial to practice the task. The practice trial continued until the participant completed 9 consecutive trials without any errors.

The experimental trial consisted of two blocks: no inhibition and inhibition. In the first no-inhibition block, participants simply pressed the left or right side of the screen when they heard or a low tone or high tone, respectively. In the second inhibition block, participants completed the same task – however, when the tone was preceded by a vibration, they needed to inhibit their responding. Faster response times and more accurate responding indicated better inhibition (and therefore, better executive attention) ability. The total duration of the task was approximately 7 minutes.

Design and Procedures

A repeated measures GLM was used to measure task performance under non-distracted (i.e., driving only) and distracted (i.e., combined GLT and driving) conditions. The covariates used in this study were WMC and ANT performance.

The procedures were similar to that of Study 2. Participants completed one of three distractor tasks: Stop Signal Task, Tone Monitoring Task, or GLT, while driving under non-distracted and distracted conditions. The driving task involved navigating a city scenario under moderate traffic conditions in clear, daytime conditions.

Session one.

Participants completed the informed consent, demographics questionnaire, and TMTs A and B. They also completed the working memory tasks and the executive attention task. Session one took approximately one hour.

Session two.

Participants completed a practice trial and two experimental driving trials on a driving simulator: one was a non-distracted trial and the other was a distracted trial (i.e., participants drove while completing the GLT). The order of trial administration was counterbalanced to reduce the possibility of sequence effects, with half the participants completing non-distracted trials first, and the remaining half completing the distracted trials first.

The scenario used for the practice and experimental trials was the same. The scenario involved following a series of arrows posted as street signs on the road. The participant was instructed to slow down as soon as the light turns yellow to accurately capture their response time to traffic signals. Aside from slowing down at yellow lights, the participants were instructed to drive as they normally would while navigating a city route.

Hypotheses

H2a: GLT and Tone Monitoring Tasks would be positively associated with working memory capacity as measured by complex spans.

H2b: *Driving performance* would be more impaired on the combined Grocery List and driving task than compared to driving alone.

H2c: *Grocery List Task performance* would be more impaired on the combined Grocery List and driving task than compared to the Grocery List Task alone.

H2d: Driving performance would be more impaired on the combined Tone Monitoring and driving task than compared to driving alone.

H2e: Tone Monitoring performance would be more impaired on the combined Tone Monitoring and driving task than compared to the Tone Monitoring alone.

H3a: The *Stop-Signal Task* would *not* be associated with WMC as measured by complex spans; however, it would be positively associated with executive attention as measured by the ANT.

H3b: Driving performance would be more impaired on the combined Stop Signal Task and driving task than compared to driving alone.

H3c: WMC would mediate the effect of GLT and tone monitoring distractors on driving performance, such that individuals with smaller WMC would show disproportionately more driving errors than those with larger WMC.*H25:*

H3d: Executive attention would mediate the effect of the Stop Signal task distractor on driving performance, such that participants with less efficient executive attention would show disproportionately more driving errors than those with more efficient executive attention.

Results

Performance on each distractor task was first compared across all distraction types, GLT, Stop Signal, and Tone Monitoring. There was a significant interaction between being distracted (i.e., non-distracted and distracted) and distraction type (i.e., GLT, Stop Signal, and Tone Monitoring), ($F(1, 37) = 5150.17$, $p < .05$). These results suggest that the effect of being distracted across distraction types leads to different performance outcomes.

These results also support previous findings showing that different types of distractions lead to difference performance outcomes. For instance, visuospatial working memory tasks may impair driver's situational awareness for *forward vehicles*, while phonological working memory tasks interfere with the driver's situational awareness for vehicles located *behind one's car* while driving (Johannsdottir & Herdman, 2010). Using riddles as a distractor appears to lead to more frequent braking, but there was no effect on lane deviations or speed maintenance as predicted (Leavens et al., 2013). In contrast, completing an n-back working memory task leads to slower lane changes and more lane change errors (Ross et al., 2014).

The author also evaluated if there were any differences in WMC scores across distractor tasks. If WMC did differ across distractor tasks, then one would have to consider if any differences in distracted driving performance across distractor tasks may have been accounted for by WMC. A univariate ANOVA was performed using distractor type as the independent variable and WMC as the outcome variable. Results showed that there were no statistically significant differences in WMC across distractor tasks ($p > .05$). As a consequence, one can rule out the possibility that any differences in distracted driving performance across distractor tasks would have been accounted for by WMC.

Because driving is a complex task involving sensory, perceptual, cognitive, and motor processes, the effects of distraction on driving can vary widely. The significant interactions found between being distracted and distraction types suggest that the different types of distraction can lead to different distracted performance outcomes. As a consequence, for the following analyses, the analysis of impact of distraction on driving performance was evaluated separately for each distraction type.

Relationship between Distractor Types, WMC, and Executive Attention

Correlation among GLT measures

A series of four bivariate correlations were conducted to evaluate the relationship between the GLT sub-tasks, primary verbal recall and secondary price-judgment task during non-distracted and distracted conditions.

There was a significant negative correlation between the primary verbal recall task and secondary price-judgment task during non-distracted conditions ($r(15) = -.50$, $p < .05$), but not during distracted conditions ($p > .05$). Performance on the GLT primary verbal recall task alone was also significantly correlated with performance on the GLT primary verbal recall task while driving ($r(15) = .90$, $p < .05$). Performance on the GLT secondary price-judgment task alone was also significantly correlated with performance on the GLT primary verbal recall task while driving ($r(15) = .97$, $p < .05$).

GLT and WMC

Overall GLT performance was positively associated with WMC as measured by the mean operation span, rotation span, symmetry span, and reading span score ($r(16) = .53$, $p < .05$). The GLT verbal and math sub-tasks were also positively associated with WMC ($r(16) = .51$, $p < .05$; $r(16) = .55$, $p < .05$).

GLT and Executive Attention

GLT was not associated with either executive attention response time or accuracy. None of the verbal and math sub-tasks were associated with executive attention response time or accuracy ($p < .05$ for all comparisons).

Correlation among Tone Monitoring Measures

A bivariate correlation was conducted to evaluate the relationship between the Tone

Monitoring performance measures – percent accuracy, during non-distracted and distracted conditions.

Percent accuracy was *not* correlated with Tone Monitoring when it was completed alone and when it was completed while simultaneously driving ($p > .05$).

Tone Monitoring and WMC

Performance on the tone monitoring task was not associated with WMC as measured by the mean operation span, rotation span, symmetry span, and reading span score ($p < .05$ for all comparisons).

Tone Monitoring and Executive Attention

Performance on the tone monitoring task was associated with executive attention accuracy ($r(23) = .52$, $p < .05$). Better performance on the tone monitoring task was associated with greater accuracy on the executive attention task. However, it was not associated with executive attention response time ($p > .05$).

Correlation among Stop Signal Measures

A series of four bivariate correlations were conducted to evaluate the relationship between Stop Signal performance measures – nonstop accuracy and stop accuracy during non-distracted and distracted conditions.

Nonstop accuracy and stop accuracy were not correlated either when the Stop Signal Task was completed alone or while driving. Nonstop accuracy during the Stop Signal task when completed alone was significantly correlated with the Stop Signal task when completed while driving ($r(20) = .43$, $p < .05$). However, stop accuracy during the Stop Signal task when completed alone was not correlated with the Stop Signal task when completed while driving.

Stop Signal and WMC

Nonstop accuracy on the Stop Signal task during the distracted condition was associated with WMC as measured by the mean operation span, rotation span, symmetry span, and reading span scores ($r(21) = .41, p < .05$). Stop accuracy on the Stop Signal task during the distracted condition, and the nonstop and stop accuracy during the non-distracted condition, were not associated with WMC ($p > .05$ for all conditions).

Stop Signal and Executive Attention

Stop accuracy on the Stop Signal task during the non-distracted condition was negatively associated with executive attention response time ($r(22) = -.42, p < .05$). So, in general those who resolved conflict between incongruent trials more quickly in the executive attention tasks were also better at an inhibition task during non-distracted conditions. Nonstop accuracy on the Stop Signal task during the non-distracted condition, and the nonstop and stop accuracy during the distracted conditions were not associated with executive attention response time or accuracy ($p > .05$ for all conditions).

Subjective Stress and Workload

To evaluate whether subjective stress or workload may have accounted for the relationship between WMC and distracted driving, a bivariate correlation was conducted using subjective stress, workload, and difference scores in driving performance. Difference scores in driving performance were first calculated by subtracted driving performance indices during non-distracted trials from distracted trials. For example, the braking response time values during the non-distracted trials were subtracted from the braking response time values during the distracted trials. NASA-TLX scores were included as measures of workload and DSSQ were included as measures of stress.

For Study 2, there was no relationship between difference scores in driving performance indices and DSSQ and NASA-TLX scores. This suggests that any of the following relationships could not have been due to subjective stress or workload.

To further investigate the effect of distracted driving on subjective workload and stress while driving, a series of univariate ANOVAs were conducted using the NASA-TLX and DSSQ scores. Subjective workload and stress scores were organized according to distractor task type, with Table 4 showing GLT results, Table 5 showing Tone Monitoring results, and Table 6 showing Stop Signal results. Results indicated significant differences in NASA-TLX and DSSQ scores across all distractor task types. The only measures which did not show any significant difference was the effort measure for the GLT distractor condition, the worry measure for the Tone Monitoring distractor condition, and the worry measure for the Stop Signal distractor condition.

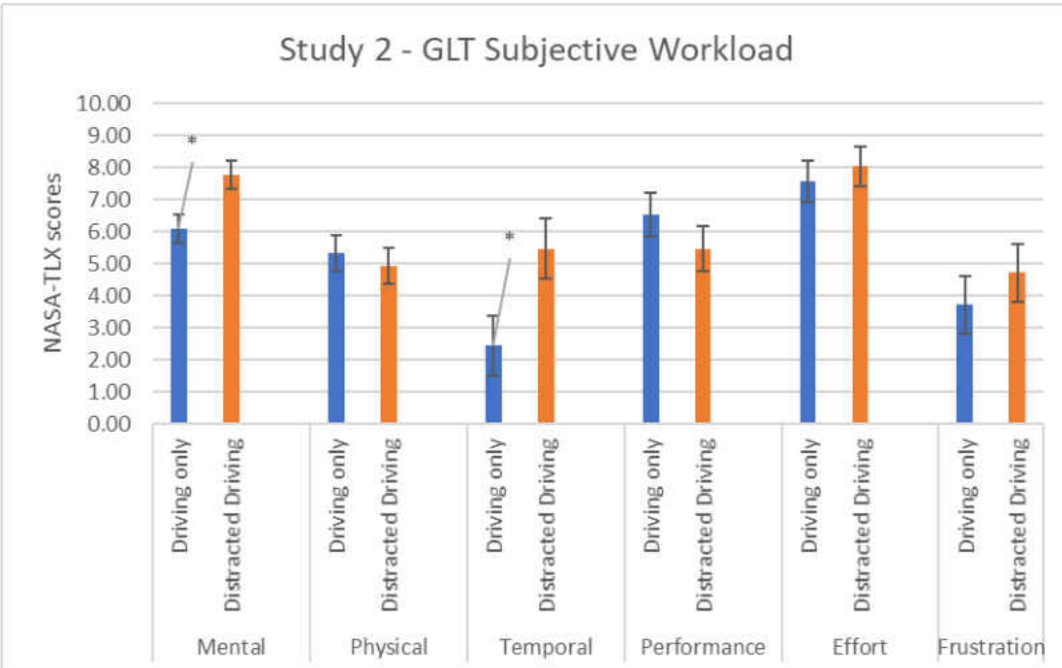
Post-hoc comparisons indicated that engaging in the GLT distractor task while driving led to significantly greater mental demand and greater temporal demand than driving without engaging in the GLT distractor task. Engaging in the Tone Monitoring task while driving led to significantly greater mental demand, greater physical demand, greater temporal demand, lower perceived performance, greater effort, greater frustration, less engagement, and greater distress than driving without engaging in the Tone Monitoring task. Finally, engaging in the Stop Signal task while driving led to significantly greater mental demand, greater physical demand, greater temporal demand, poorer perceived performance, and greater distress than without engaging in the Stop Signal task.

Table 4. Study 2 GLT subjective workload and stress

GLT - NASA TLX scores	*M*	*SD*	*N*	*F*	*p*
Mental Distractor	8.26	1.58	47	5.52	$p <$ .05
Mental Driving	6.07	2.71	48	-	-
Mental Distracted Driving	7.75	3.10	48	-	-
Physical Distractor	0.85	1.92	47	47.23	$p <$ .05
Physical Driving	5.32	2.54	48	-	-
Physical Distracted Driving	4.93	3.01	48	-	-
Temporal Distractor	7.00	2.77	47	19.85	$p <$ .05
Temporal Driving	2.43	3.06	48	-	-
Temporal Distracted Driving	5.46	3.75	48	-	-
Performance Distractor	4.48	2.10	47	6.18	$p <$ .05
Performance Driving	6.54	2.44	48	-	-
Performance Distracted Driving	5.46	2.43	48	-	-
Effort Distractor	8.11	1.55	47	0.67	*n.s.*
Effort Driving	7.57	2.08	48	-	-
Effort Distracted Driving	8.04	2.40	48	-	-
Frustration Distractor	6.81	2.35	47	8.54	$p <$ .05
Frustration Driving	3.71	3.02	48	-	-
Frustration Distracted Driving	4.71	3.32	48	-	-

GLT - DSSQ scores					
Engagement Distractor	20.00	4.07	47	9.11	$p < .05$
Engagement Driving	23.21	3.32	48	-	-
Engagement Distracted Driving	22.64	3.20	48	-	-
Distress Distractor	18.74	6.02	47	9.62	$p < .05$
Distress Driving	10.89	7.24	48	-	-
Distress Distracted Driving	14.82	6.82	48	-	-
Worry Distractor	9.56	4.89	47	8.88	$p < .05$
Worry Driving	6.32	4.16	48	-	-
Worry Distracted Driving	6.21	4.90	48	-	-

Figure 2. Study 2 - GLT subjective workload and stress



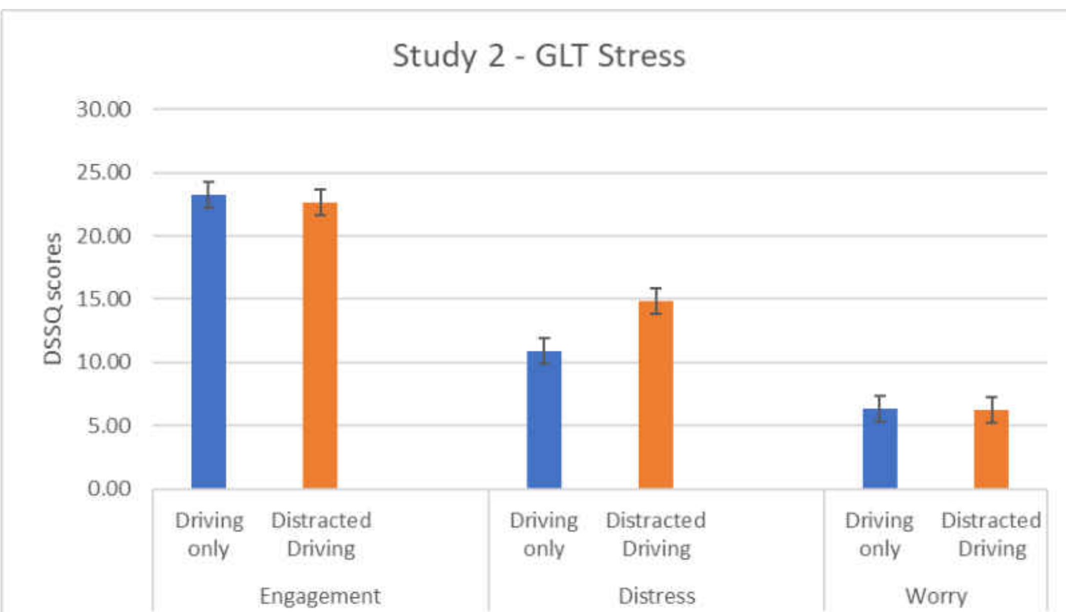
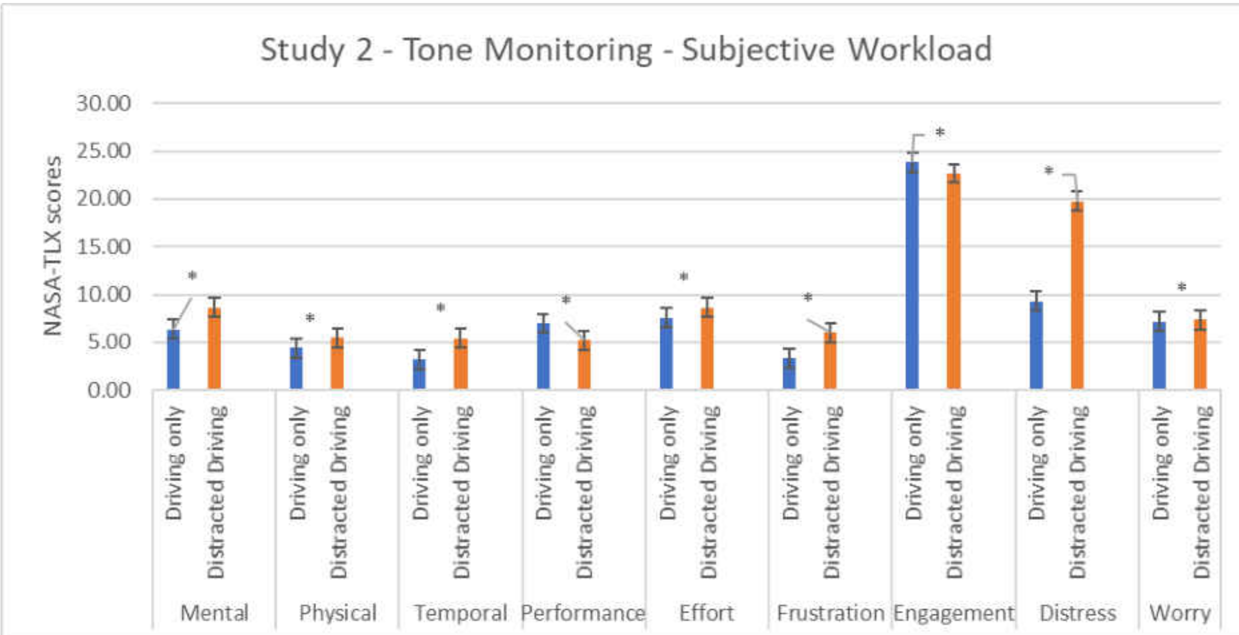


Table 5. Study 2 Tone Monitoring subjective workload and stress

Tone Monitoring - NASA TLX scores	*M*	*SD*	*N*	*F*	*p*
Mental Distractor	8.43	1.83	28	12.21	$p < .05$
Mental Driving	6.37	2.19	27	-	-
Mental Distracted Driving	8.63	2.32	27	-	-
Physical Distractor	2.29	2.34	28	19.43	$p < .05$
Physical Driving	4.44	3.40	27	-	-
Physical Distracted Driving	5.52	3.11	27	-	-
Temporal Distractor	6.00	3.09	28	9.02	$p < .05$
Temporal Driving	3.22	3.00	27	-	-
Temporal Distracted Driving	5.44	3.52	27	-	-
Performance Distractor	4.18	2.67	28	15.61	$p < .05$
Performance Driving	7.00	1.98	27	-	-
Performance Distracted Driving	5.22	3.07	27	-	-
Effort Distractor	7.71	1.82	28	4.73	$p < .05$
Effort Driving	7.56	2.22	27	-	-
Effort Distracted Driving	8.67	1.90	27	-	-
Frustration Distractor	7.04	2.60	28	22.32	$p < .05$
Frustration Driving	3.37	2.76	27	-	-
Frustration Distracted Driving	6.04	3.23	27	-	-

Tone Monitoring - DSSQ scores					
Engagement Distractor	21.11	5.76	28	10.85	*p* < .05
Engagement Driving	23.85	4.74	27	-	-
Engagement Distracted Driving	22.67	5.10	27	-	-
Distress Distractor	19.04	6.32	28	27.91	*p* < .05
Distress Driving	9.30	6.39	27	-	-
Distress Distracted Driving	19.78	7.42	27	-	-
Worry Distractor	8.29	5.16	28	1.26	*n.s.*
Worry Driving	7.19	5.86	27	-	-
Worry Distracted Driving	7.37	5.97	27	-	-

Figure 3. Study 2 - Tone Monitoring subjective workload and stress



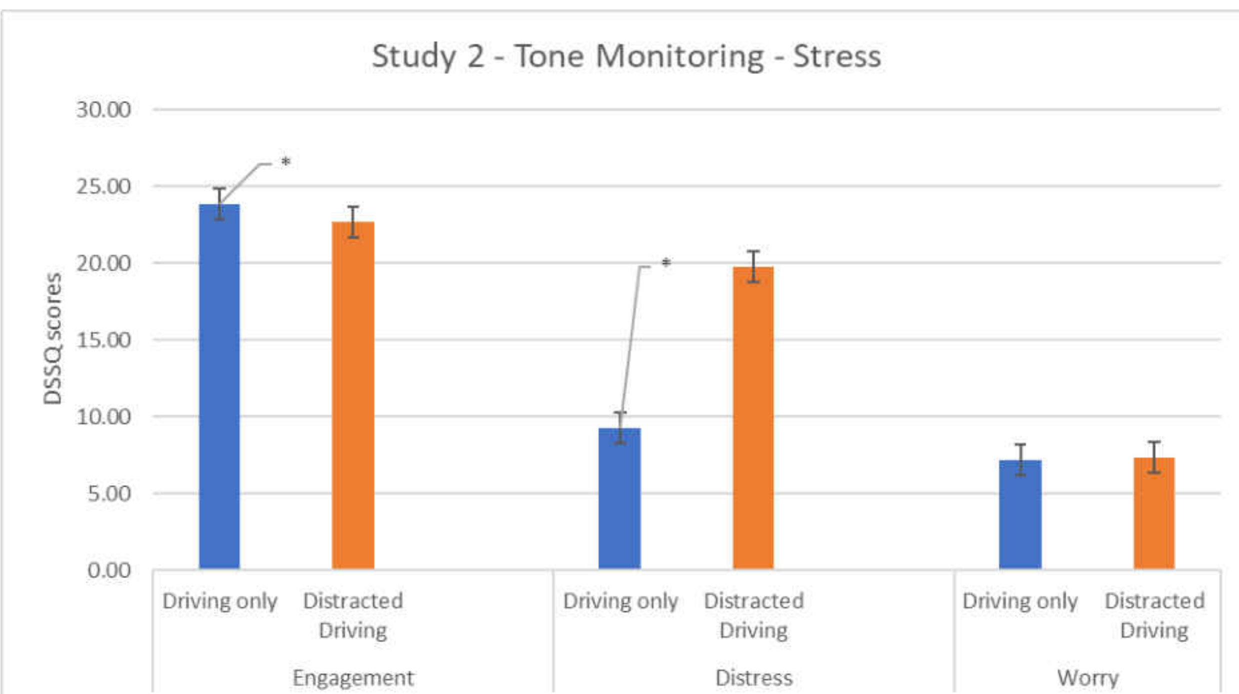
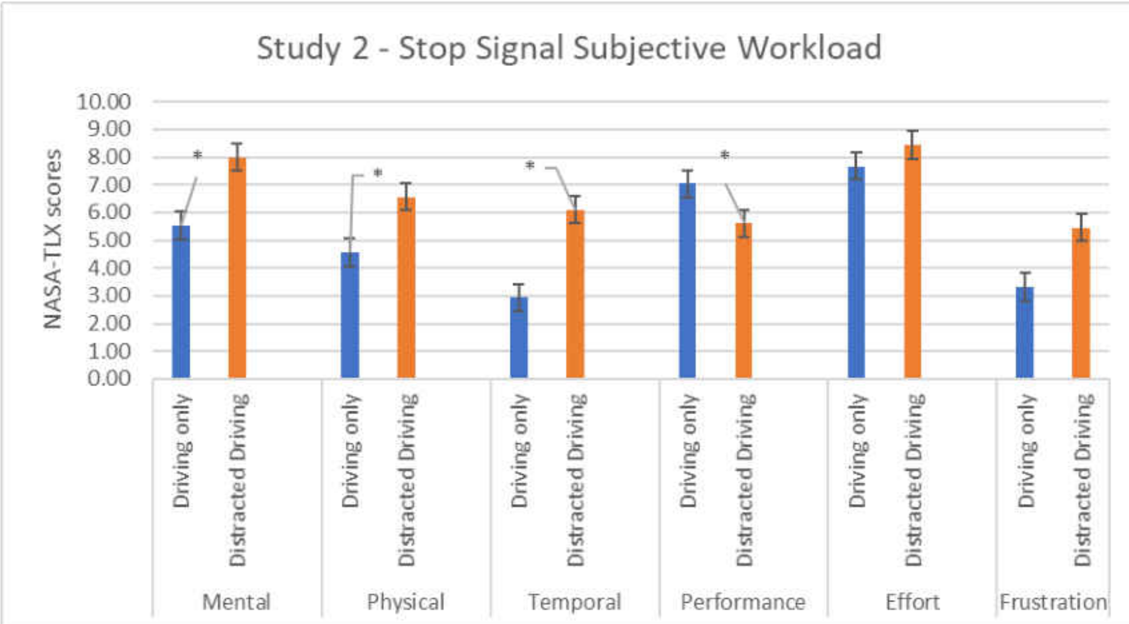


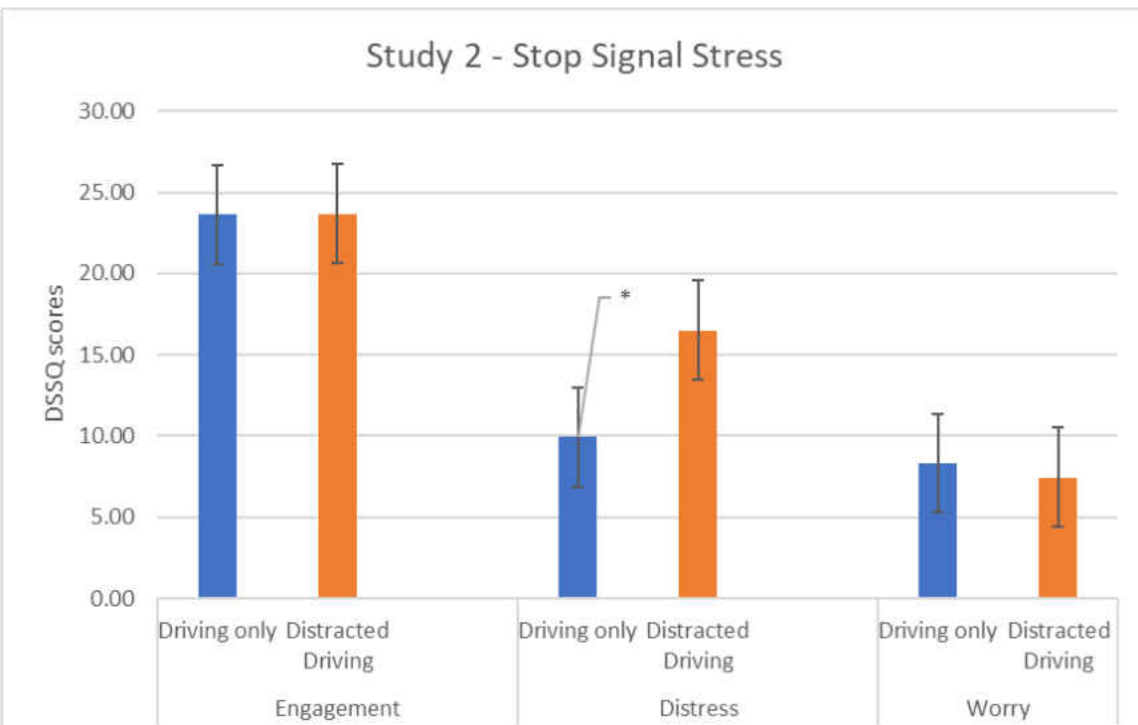
Table 6. Study 2 Stop Signal subjective workload and stress

Stop Signal - NASA TLX scores	*M*	*SD*	*N*	*F*	*p*
Mental Distractor	6.18	2.70	28	8.77	*p* < .05
Mental Driving	5.54	2.50	28	-	-
Mental Distracted Driving	8.00	2.83	28	-	-
Physical Distractor	3.14	2.55	27	18.14	*p* < .05
Physical Driving	4.57	2.52	28	-	-
Physical Distracted Driving	6.57	3.12	28	-	-
Temporal Distractor	5.07	2.77	28	12.54	*p* < .05
Temporal Driving	2.93	2.75	28	-	-
Temporal Distracted Driving	6.11	3.63	28	-	-
Performance Distractor	7.21	2.01	28	6.88	*p* < .05
Performance Driving	7.04	2.30	28	-	-
Performance Distracted Driving	5.61	2.06	28	-	-
Effort Distractor	7.11	2.77	28	4.1	*p* < .05
Effort Driving	7.68	2.23	28	-	-
Effort Distracted Driving	8.43	2.38	28	-	-
Frustration Distractor	4.54	3.07	28	7.3	*p* < .05
Frustration Driving	3.32	2.54	28	-	-
Frustration Distracted Driving	5.46	2.95	28	-	-

Stop Signal - DSSQ scores					
Engagement Distractor	18.18	6.06	28	21.39	*p* < .05
Engagement Driving	23.64	4.08	28	-	-
Engagement Distracted Driving	23.68	4.60	28	-	-
Distress Distractor	10.04	5.20	28	12.51	*p* < .05
Distress Driving	9.93	5.63	28	-	-
Distress Distracted Driving	16.50	6.84	28	-	-
Worry Distractor	8.86	6.88	28	1.2	*n.s.*
Worry Driving	8.32	6.55	28	-	-
Worry Distracted Driving	7.46	6.28	28	-	-

Figure 4. Stop Signal subjective workload and stress





Driving Performance under Single- and Dual-Task conditions

GLT distractor

There were significantly more lane deviations during the combined GLT and driving condition (M = 3.00, SD = 1.73) than the driving only condition (M = 1.55, SD = 1.21). There was no main effect of distraction (i.e., single- versus dual-task condition) on braking response time, braking duration, number of brake presses, or number of collisions when GLT was used as a distractor.

An ANCOVA was conducted to evaluate whether WMC or executive attention moderated the effect of distraction on driving performance. To conduct the analyses, WMC and executive attention were each entered separately as a covariate. The interaction term (e.g., Distraction X WMC) was then analyzed for significant effects. Results showed that the effect of distraction on driving performance was not moderated by WMC or executive attention ($p > .05$).

Tone Monitoring distractor

Participants pressed their brakes less frequently during the combined Tone Monitoring and driving condition (M = 7.40, SD = 4.01) than the driving only condition (M = 13.20, SD = 3.05). There was no main effect of distraction (i.e., single- versus dual-task condition) on braking response time, braking duration, number of lane deviations, or number of collisions when GLT was used as a distractor.

An ANCOVA was conducted to evaluate whether WMC or executive attention moderated the effect of distraction on driving performance. To conduct the analyses, WMC and executive attention were each entered separately as a covariate. The interaction term (e.g., Distraction X WMC) was then analyzed for significant effects. Results showed no moderating effects of WMC or executive attention ($p > .05$).

Stop Signal distractor

There were significantly more collisions during the combined Stop Signal and driving condition ($M = 0.31$, $SD = 0.48$) than the driving only condition ($M = 0.00$, $SD = 0.00$). There was no main effect of distraction (i.e., single- versus dual-task condition) on braking response time, braking duration, number of brake presses, or number of lane deviations when GLT was used as a distractor.

An ANCOVA was conducted to evaluate whether WMC or executive attention moderated the effect of distraction on driving performance. To conduct the analyses, WMC and executive attention were each entered separately as a covariate. The interaction term (e.g., Distraction X WMC) was then analyzed for significant effects. Results showed no moderating effects of WMC or executive attention ($p > .05$).

Distractor Task Performance under Single- and Dual-Task conditions

GLT Performance under Single and Dual-Task conditions

Participants performed significantly worse on the GLT verbal and math sub-tasks when they were distracted ($M_{verbal} = 0.45$, $SD_{verbal} = 0.18$; $M_{math} = 0.87$, $SD_{math} = 0.14$) than when they were not distracted ($M_{verbal} = 0.61$, $SD_{verbal} = 0.14$; $M_{math} = 0.90$, $SD_{math} = 0.15$); $p < .05$ for math and verbal sub-tasks.

Tone Monitoring performance under Single and Dual-Task conditions

Participants performed significantly worse on the Tone Monitoring task when they were distracted ($M = 22.50$, $SD = 11.30$) than when they were not distracted, ($M = 33.30$, $SD = 16.75$, $p < .05$).

Stop Signal performance under Single and Dual-Task conditions

Participants made significantly more errors during the non-stop trials while they were distracted (*M* = 59.42, *SD* = 22.28) than while they were not distracted (*M* = 86.93, *SD* = 8.65; $p < .05$). Participant also made more errors during the stop trials while they were distracted (*M* = 63.22, *SD* = 25.25) than while they were not distracted (*M* = 81.36, *SD* = 34.88); however, this difference was marginally significant ($p = .051$). Lastly, the intertrial delay time during the Stop Signal Task was significantly slower while the participants were distracted (*M* = 653.59, *SD* = 60.58) than while they were not distracted (*M* = 514.01, *SD* = 86.49, $p < .05$).

Effect of gaming experience on task performance

Gaming experience was measured as whether or not the participant played video games and the total number of hours played per week. Whether or not a participant played video games was neither related to performance on any of the distractor tasks (i.e., GLT, Stop Signal, or Tone Monitoring) nor on any of the driving performance indicators (i.e., number of lane deviations, number of collisions, braking response time, number of brake presses, and brake duration). The total number of hours played per week was also neither related to performance on any of the distractor tasks (i.e., GLT, Stop Signal, or Tone Monitoring) nor on any of the driving performance indicators (i.e., number of lane deviations, number of collisions, braking response time, number of brake presses, and brake duration).

Because there was no significant relationship between gaming experience and task performance, no further analyses involving adding gaming experience as a covariate were conducted.

Discussion

Study 2 was conducted to evaluate the effect of different types of distractors on driving performance. There were three different types of distractors: Tone Monitoring, Stop Signal, and GLT. Unlike the Study 2 pilot, a city scenario was used to increase the number of potential braking events. Interestingly, the effect of distraction on driving impairments differed depending on distraction type. For the GLT, a dual-tasking scenario led to more lane deviations. For the Tone Monitoring Task, dual-tasking led to fewer brake presses. For the Stop Signal Task, dual-tasking led to more collisions.

Although it is not clear why these results were obtained, it is certain that the *type* of distractor yields different effects on the type of driving impairment. It is possible that the Tone Monitoring task may have affected the memory processes required to decide when to brake. The Stop Signal Task may have affected inhibition processes required to brake to avoid imminent collisions. Finally, the GLT may have affected the memory storage and executive attention processes required to maintain lane positioning. In general, these findings suggest the importance of carefully selecting the type of distraction used when conducting a study on distracted driving, as the type of distraction may yield differential effects on driving performance.

For all distraction types, both working memory and executive attention partially mediated the effect of distraction on driving. These results are unprecedented, to our knowledge, in that it demonstrates that WMC and executive attention may be partly responsible for driving impairments even when a diverse range of distractors which have differing effects on driving impairment are used. A more detailed investigation on the impact each type of distractor (i.e., Tone Monitoring, Stop Signal, and GLT) on driving performance is suggested.

CHAPTER 8: STUDY 3

Method

Participants

Ninety-six participants with the same criteria (i.e., at least 18 years old, 20-20 or corrected-to-normal vision, no color blindness, and no history of neurological disorders or seizures) were used for Study 3. Forty-nine participants completed the GLT 2, 23 participants completed the Stop Signal Task, and 24 completed the Tone Monitoring Task. Forty-seven participants completed the clear condition, and 49 completed the rainy condition.

A power analysis suggested a total sample size of 60 participants for Study 3. The required sample size of 20 participants per distraction type (i.e., GLT, Tone Monitoring, and Stop Signal tasks) was calculated using a G*Power version 3.1 statistical power calculator. Input parameters included a power of .80 and a large effect size of .80 estimated using a G*Power version 3.1 statistical power calculator. An alpha statistical criterion of .05 using a two-tailed test and 8 predictors were also used (WMC, executive attention, TMT A, TMT B, distraction condition [distracted versus non-distracted], and raining condition [rainy versus clear]).

Measures

Apparatus

The same apparatuses, E-Prime (Psychology Software Tools, Inc., 2012) and GE I-SIM, were used to display the working memory and executive attention tasks and to simulate driving, respectively.

Materials

The materials used in Study 3 were identical to those used in Study 2.

Demographics questionnaire. The demographics questionnaire was a brief survey consisting of questions regarding the participants' age, class year, number of years driving, as well as their frequency of driving, whether they use secondary devices such as cell phones or navigation devices while driving, and history of traffic violations and accidents. Information was submitted and stored in a spreadsheet via Google spreadsheets.

TMT A and TMT B. TMT A is popular measure of processing speed used in neuropsychological tests. Participants simply drew lines to connect numbers in ascending order without lifting the pen or pencil from the paper (e.g., 1, 2, 3, 4…). Faster completion times indicated faster processing speed. TMT B is a measure of processing speed and *shifting* used in neuropsychological tasks. Participants made a path from an alternating series of numbers in ascending order and letters in alphabetical order (i.e., 1, A, 2, B, 3, C…). Faster completion times indicated faster processing speed and more efficient shifting ability (Reitan, 1958; Alexandersen, Dalen & Bronnick, 2009; Marcotte, Wolfson, Rosenthal, Heaton, Gonzalez, Ellis, et al., 2004; Soderstrom, Pettersson, & Leppert, 2006; Stolwyk, Charlton, Triggs, Iansek, & Bradshaw, 2006).

Working memory complex spans

The same working memory complex spans were used as in Study 2.

Operation span. Participants recalled a sequence of letters which had been presented while completing a series of arithmetic tasks (e.g., True or false: "5 + 7 = 11"?)

Rotation span. Participants recalled the spatial location of a series of arrows which had been presented while completing a series of letter rotation tasks (e.g., can "И" become

"N" after it is rotated counter-clockwise?)

Symmetry span. Participants recalled a sequence of letters which had been presented while completing a series of symmetry judgments (e.g., is the following image symmetrical?).

Reading span. Participants recalled a sequence of letters which had been presented while completing a series of reading judgments (e.g., does the following sentence make sense: "She was very tired after spaghetti all day?").

Attention Network Task (ANT). Participants identified the leftward or rightward orientation of a target stimuli following a cue, while it was surrounded by congruent, neutral, or incongruent flanker stimuli. The same procedures for ANT were used in Study 3 as in Study 2 (Fan et al., 2002).

Distractor tasks.

GLT version 2. Participants recalled a list of grocery store items auditorily presented by the experimenter. The experimenter began by naming a set of ingredients. Each ingredient was described as costing a certain amount of dollars in a certain number of boxes (e.g., 2 boxes of $3 turkey). After each food-price pair was presented, the experimenter named a price (e.g., $6?) and the participant decided whether the indicated priced was accurate by verbally reporting "yes" or "no" within four seconds after the price is listed. After four seconds, the next ingredient-pricing pair was presented (e.g., "3 box of $7 bacon. $28?).

Each trial consisted of three to eight food-price pairs. At the end of each trial, the participant recalled the ingredients (e.g., turkey, bacon, rice, pineapple, etc.). The participant's span score was the proportion of food items correctly recalled across all trials. A greater proportion of items correctly recalled indicated greater WMC. To ensure that participants were devoting sufficient attention to the secondary price-judgment task, only participants performing at 70% accuracy on the secondary, price-judgment task were considered for data analysis.

Tone monitoring task. Participants heard a continuous series of three tones (i.e., 300 Hz, 800 Hz, and 1200 Hz) which were presented in a random sequence and separated by 1200 ms intervals. They were instructed to respond whenever each tone was played for the fourth time. For example, when a 1200 Hz tone was played for the fourth time, they needed to press the button indicating the 1200 Hz tone. Performance was measured as percent accuracy (i.e., 0 to 100% accurate), d' (i.e., signal to noise detection ratio), and response time (in ms). The tone monitoring task involved executive attention to shift from one tone category to the next, and memory storage to keep track of the number of times a particular tone has been played. The task also presumably did not overlap with the visual demands of the driving task, although some physical skills may have been needed to press the buttons on the screen.

The tone monitoring task resembles other measures of working memory such as the counting task and the multi-sensory workload assessment protocol (M-SWAP; Jerison, 1955; Kennedy, 1971; Cholewiak, Brill, & Schwab, 2004; Brill, Mouloua, Hancock, Gilson, & Kennedy, 2003). Both measures involve the storage and maintenance of the number of times a type of stimulus is presented, and executive attention to shift between types of stimuli (e.g., tactile, auditory, or visual). Performance on the M-SWAP has been shown to be reliable and has been used as a tool to measure performance evaluation in extreme (e.g., highly stressful) environments (Brill, Mouloua, Hancock, & Kennedy, 2003).

Stop-signal task. Participants heard a series of low or high tones. They were instructed to simply press the left side of the screen when they heard a low tone, or the right side when they heard a high tone. The tone continued to play until they pressed a side or the trial times out.

Participants needed to press the button as quickly and as accurately as they could before the tone ended.

Participants were first given an acclimation trial to listen to each tone. They could listen to each tone for as long as they wanted until they felt comfortable. They were then given a practice trial to practice the task. The practice trial continued until the participant completed 9 consecutive trials without any errors.

The experimental trial consisted of two blocks: no inhibition and inhibition. In the first no-inhibition block, participants simply pressed the left or right side of the screen when they heard or a low tone or high tone, respectively. In the second inhibition block, participants completed the same task – however, when the tone was preceded by a vibration, they needed to inhibit their responding. Faster response times and more accurate responding indicated better inhibition (and therefore, better executive attention) ability. The total duration of the task was approximately 7 minutes.

Design and Procedures

A repeated measures GLM was used to measure task performance under non-distracted (i.e., driving only) and distracted (i.e., combined distraction task and driving) conditions. The covariates used in this study were weather condition (i.e., clear and rainy), WMC, and ANT performance.

The procedures were similar to that of Study 2. However, half the participants completed the driving tasks while under raining conditions while the remaining half completed the driving tasks under clear conditions. Data was collected from 96 participants.

Session one.

Participants completed the informed consent, demographics questionnaire, and TMTs A and B. They also completed the working memory tasks and the executive attention task. Session one took approximately one hour.

Session two.

Participants completed a practice trial and two experimental driving trials on a driving simulator: one was a non-distracted trial and the other was a distracted trial (i.e., participants drove while completing the distractor task). The order of trial administration was counterbalanced to reduce the possibility of sequence effects, with half the participants completing non-distracted trials first, and the remaining half completing the distracted trials first.

The scenario used for the practice and experimental trials was the same. The scenario involved following a series of arrows posted as street signs on the road. The participant was instructed to slow down as soon as the light turns yellow to accurately capture their response time to traffic signals. Aside from slowing down at yellow lights, the participants were instructed to drive as they normally would while navigating a city route.

Hypotheses

H4: For all three distractor conditions, there would be a main effect of distraction on driving performance, with poorer driving outcomes emerging during the distracted trial.

H5a: For GLT and Tone Monitoring, WMC would mediate distraction on driving performance.

H5b: For GLT, Tone Monitoring and Stop Signal tasks, executive attention would mediate distraction on driving performance.

H6: Additionally, environmental factors such as Raining conditions would moderate the relationship between distractions and driving performance.

Results

Performance on each distractor task was first compared across all distraction types, GLT, Stop Signal, and Tone Monitoring. There was a significant interaction between being distracted (i.e., non-distracted and distracted) and distraction type (i.e., GLT, Stop Signal, and Tone Monitoring), ($F(2, 86) = 34703.80$, $p < .05$). These results suggest that the effect of being distracted across distraction types leads to different performance outcomes.

These results also support previous findings showing that different types of distractions lead to difference performance outcomes. For instance, visuospatial working memory tasks may impair driver's situational awareness for *forward vehicles*, while phonological working memory tasks interfere with the driver's situational awareness for vehicles located *behind one's car* while driving (Johannsdottir & Herdman, 2010). Using riddles as a distractor appears to lead to more frequent braking, but there was no effect on lane deviations or speed maintenance as predicted (Leavens et al., 2013). In contrast, completing an n-back working memory task leads to slower lane changes and more lane change errors (Ross et al., 2014).

The author also evaluated if there were any differences in WMC scores across distractor tasks. If WMC did differ across distractor tasks, then one would have to consider if any differences in distracted driving performance across distractor tasks may have been accounted for by WMC. A univariate ANOVA was performed using distractor type as the independent variable and WMC as the outcome variable. Results showed that there were no statistically significant differences in WMC across distractor tasks ($p > .05$). As a consequence, one can rule out the possibility that any differences in distracted driving performance across distractor tasks would have been accounted for by WMC.

Because driving is a complex task involving sensory, perceptual, cognitive, and motor processes, the effects of distraction on driving can vary widely. The significant interactions found between being distracted and distraction types suggest that the different types of distraction can lead to different distracted performance outcomes. As a consequence, for the following analyses, the analysis of impact of distraction on driving performance was evaluated separately for each distraction type.

Subjective Stress and Workload

To evaluate whether subjective stress or workload may have accounted for the relationship between WMC and distracted driving, a bivariate correlation was conducted using subjective stress, workload, and difference scores in driving performance. Difference scores in driving performance were first calculated by subtracted driving performance indices during non-distracted trials from distracted trials. For example, the braking response time values during the non-distracted trials were subtracted from the braking response time values during the distracted trials. NASA-TLX scores were included as measures of workload and DSSQ were included as measures of stress.

To further investigate the effect of distracted driving on subjective workload and stress while driving, a series of univariate ANOVAs were conducted using the NASA-TLX and DSSQ scores. Subjective workload and stress scores were organized according to distractor task type, with Table 4 showing GLT results, Table 5 showing Tone Monitoring results, and Table 6 showing Stop Signal results. Results indicated significant differences in NASA-TLX and DSSQ scores across all distractor task types. The only measures which did not show any significant difference was the effort measure for the Tone Monitoring distractor condition, and the worry measure for the Stop Signal distractor condition.

Post-hoc comparisons indicated that engaging in the GLT distractor task while driving led to significantly greater mental demand, greater physical demand, greater temporal demand, poorer perceived performance, greater effort, greater frustration, less engagement, greater distress, and more worry than driving without engaging in the GLT distractor task. Engaging in the Tone Monitoring task while driving led to the same pattern of effects as engaging in GLT – however, there were no significant differences in worrying. Finally, engaging in the Stop Signal task while driving also led to the same pattern of effects as engaging in the GLT distractor task, except there were no significant differences in engagement or worrying.

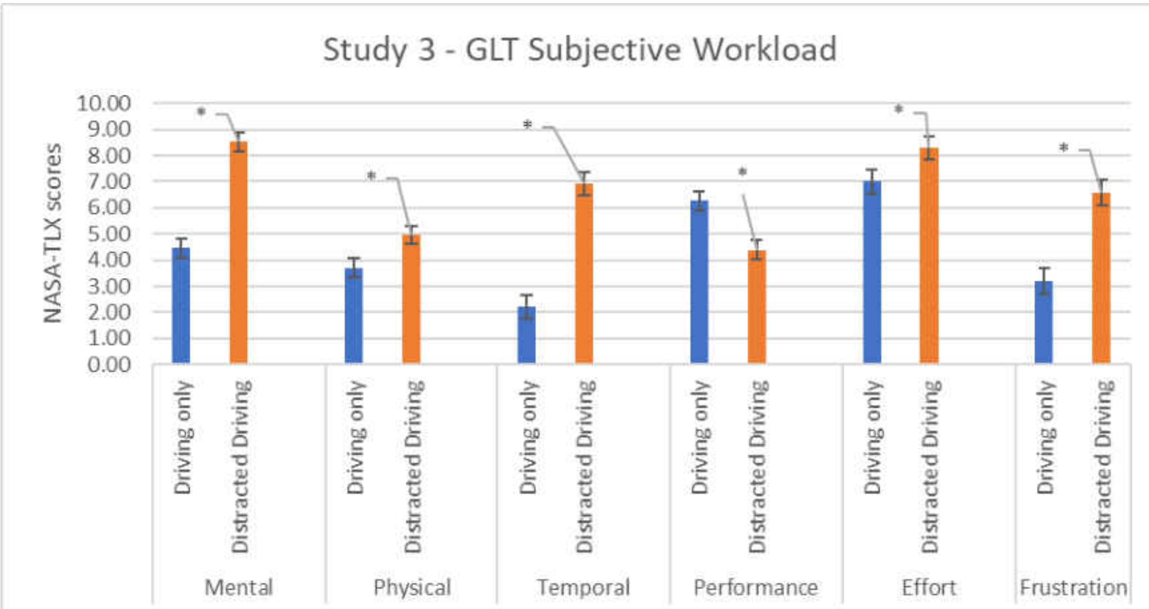
Table 7. Study 3 GLT subjective workload and stress

GLT - NASA TLX scores	*M*	*SD*	*N*	*F*	*p*
Mental Distractor	8.09	1.74	47	89.34	$p < .05$
Mental Driving	4.46	2.63	48		-
Mental Distracted Driving	8.54	2.41	48		-
Physical Distractor	0.98	1.57	47	45.69	$p < .05$
Physical Driving	3.71	2.82	48		-
Physical Distracted Driving	4.96	2.99	48		-
Temporal Distractor	7.38	2.53	47	89.64	$p < .05$
Temporal Driving	2.23	2.73	48		-
Temporal Distracted Driving	6.94	2.67	48		-
Performance Distractor	4.43	2.05	47	17.35	$p < .05$
Performance Driving	6.27	2.42	48		-
Performance Distracted Driving	4.40	2.21	48		-
Effort Distractor	8.43	1.39	47	8.46	$p < .05$
Effort Driving	7.00	2.87	48		-
Effort Distracted Driving	8.31	2.13	48		-
Frustration Distractor	6.43	2.57	47	34.1	$p < .05$
Frustration Driving	3.21	2.82	48		-
Frustration Distracted Driving	6.56	3.73	48		-

GLT - DSSQ scores

	M	*SD*	*N*	*F*	*p*
Engagement Distractor	24.34	4.09	47	4.46	$p < .05$
Engagement Driving	25.81	3.59	48		-
Engagement Distracted Driving	24.46	5.10	48		-
Distress Distractor	17.34	6.63	47	34.3	$p < .05$
Distress Driving	10.06	6.69	48		-
Distress Distracted Driving	17.79	7.18	48		-
Worry Distractor	9.66	4.90	47	14.05	$p < .05$
Worry Driving	6.94	4.92	48		-
Worry Distracted Driving	7.04	5.30	47		-

Figure 5. Study 3 – GLT subjective workload and stress



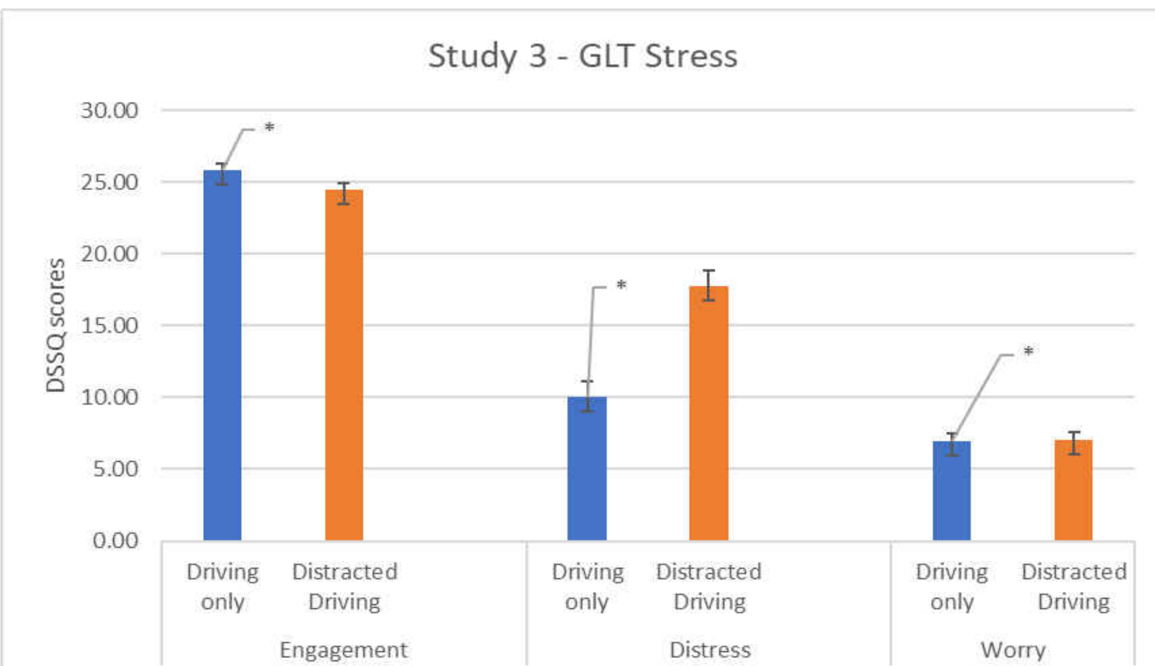


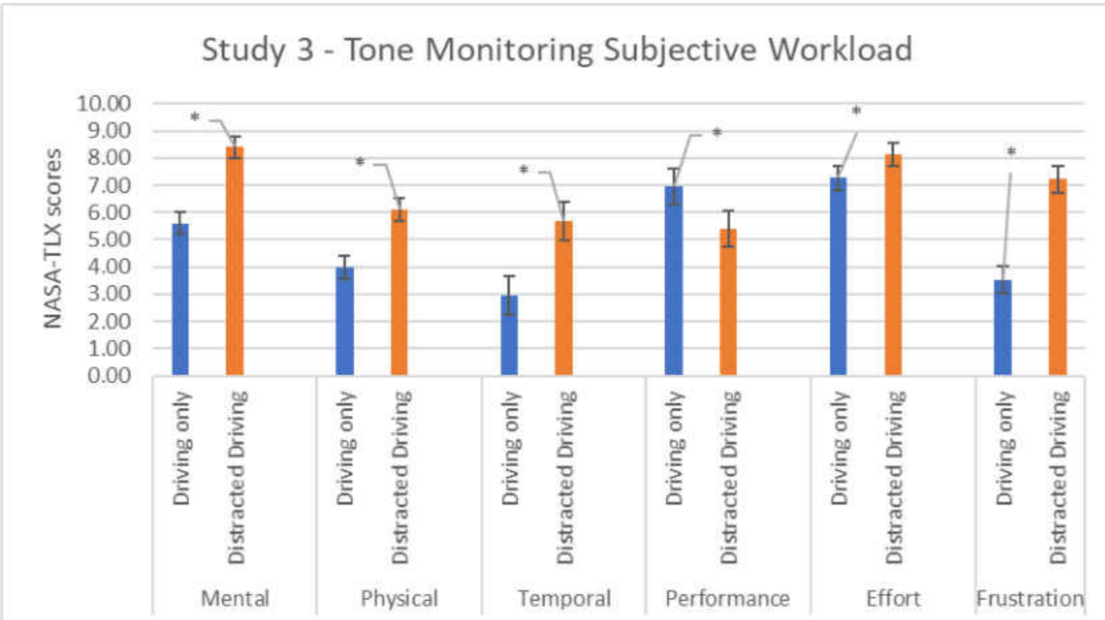
Table 8. Study 3 Tone Monitoring subjective workload and stress

Tone Monitoring - NASA TLX scores	*M*	*SD*	*N*	*F*	*p*
Mental Distractor	6.54	2.26	24	35.6	$p < .05$
Mental Driving	5.61	2.93	23		-
Mental Distracted Driving	8.39	1.75	23		-
Physical Distractor	2.33	2.28	24	45.73	$p < .05$
Physical Driving	4.00	2.61	23		-
Physical Distracted Driving	6.087	2.78	23		-
Temporal Distractor	4.912	2.69	24	9.91	$p < .05$
Temporal Driving	2.96	2.95	23		-
Temporal Distracted Driving	5.70	2.88	23		-
Performance Distractor	7.08	1.50	24	11.73	$p < .05$
Performance Driving	6.96	1.46	23		-
Performance Distracted Driving	5.39	2.48	23		-
Effort Distractor	7.21	2.36	24	7.4	*n.s.*
Effort Driving	7.26	2.73	23		-
Effort Distracted Driving	8.13	1.96	23		-
Frustration Distractor	4.75	3.19	24	15.07	$p < .05$
Frustration Driving	3.52	3.01	23		-
Frustration Distracted Driving	7.22	5.56	23		-

Tone Monitoring - DSSQ scores

	M	*SD*	*N*	*F*	*p*
Engagement Distractor	19.5	5.9124	24	4.71	$p < .05$
Engagement Driving	23.8696	4.03737	23		-
Engagement Distracted Driving	22.6522	6.14676	23		-
Distress Distractor	10.2083	7.02777	24	16.94	$p < .05$
Distress Driving	7.6957	6.75166	23		-
Distress Distracted Driving	15.4783	7.73933	23		-
Worry Distractor	6.5833	7.04592	24	0.21	$p < .05$
Worry Driving	5.087	5.96896	23		-
Worry Distracted Driving	3.7619	4.59244	21		-

Figure 6. Study 3 – Tone Monitoring subjective workload and stress



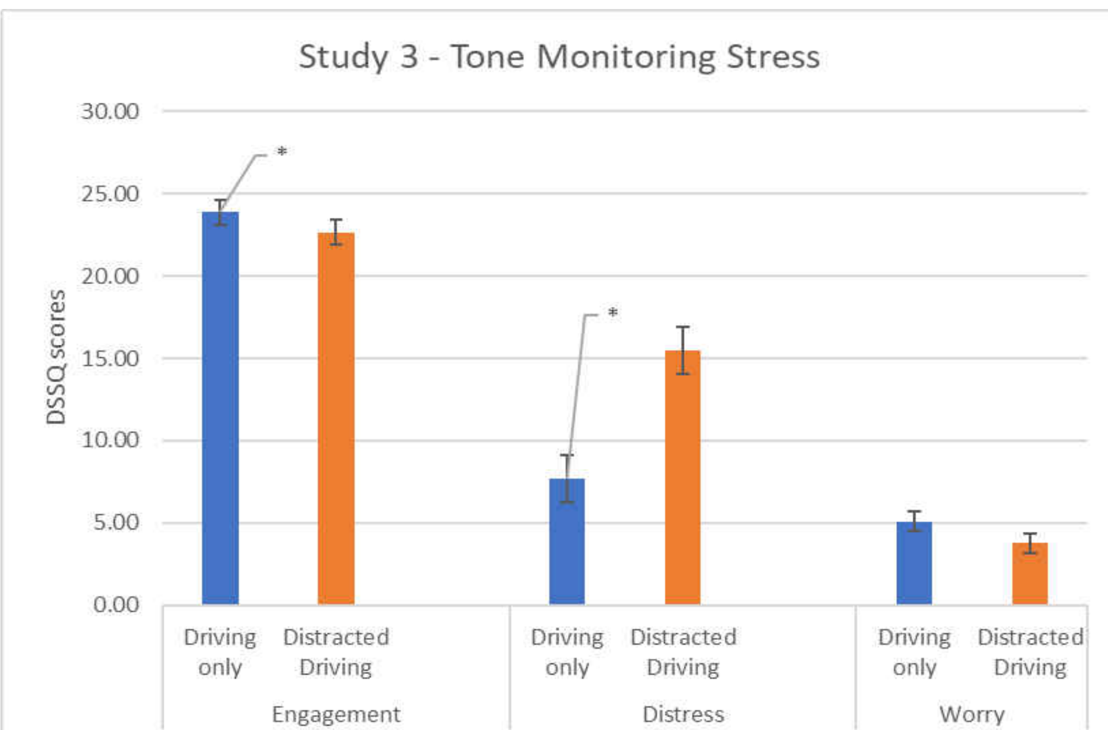
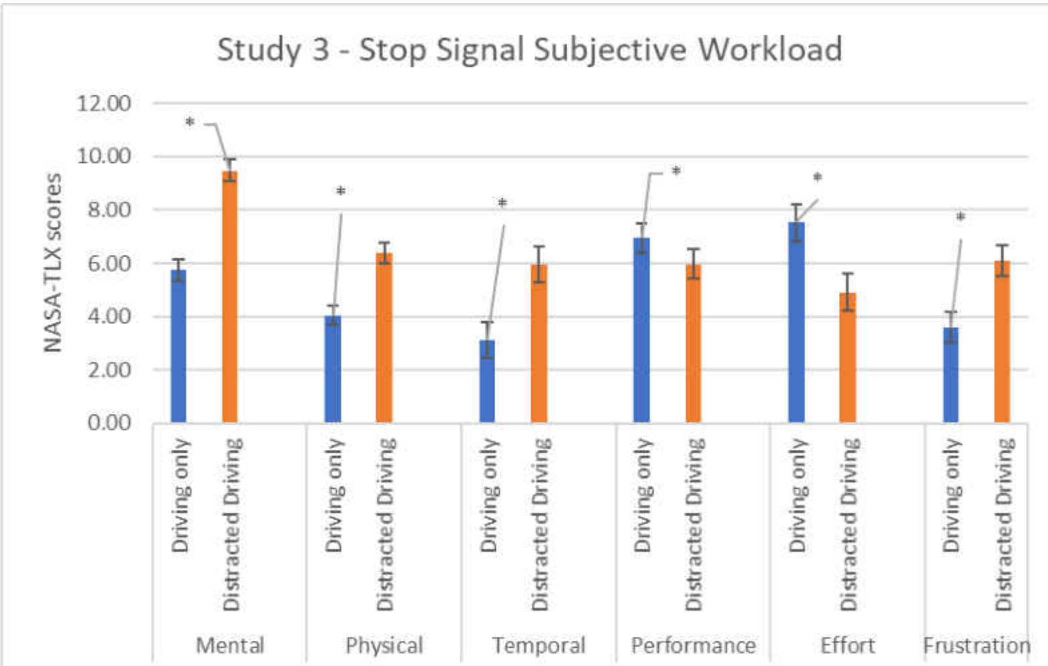


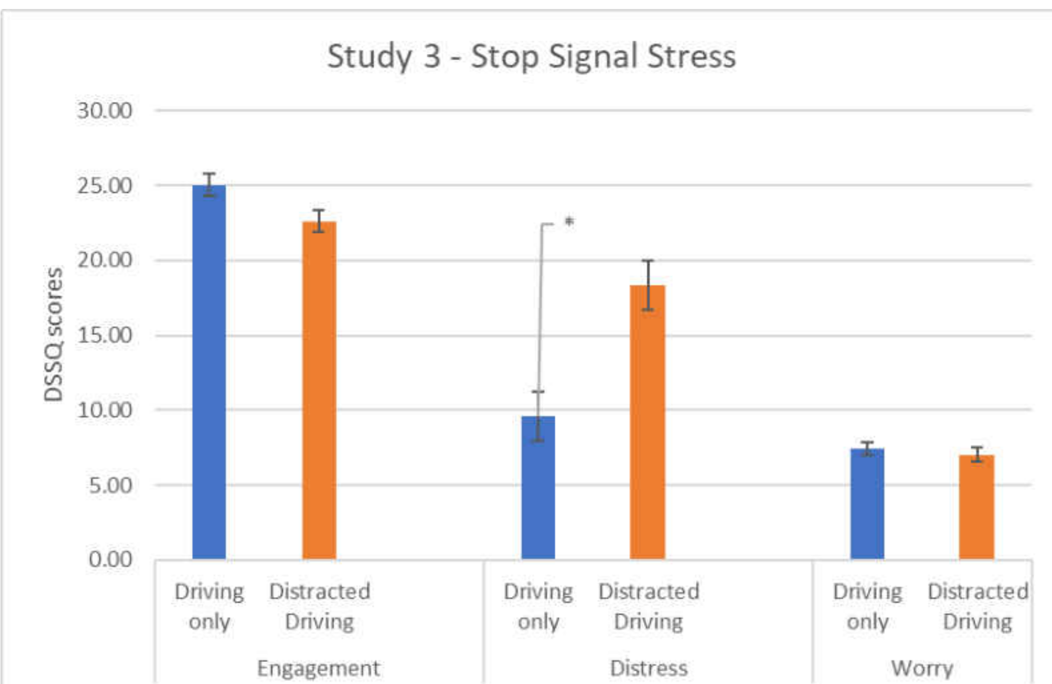
Table 9. Study 3 Stop Signal subjective workload and stress

Stop Signal - NASA TLX scores	*M*	*SD*	*N*	*F*	*p*
Mental Distractor	8.04	2.14	24	18.62	$p < .05$
Mental Driving	5.74	2.28	23		-
Mental Distracted Driving	9.48	0.90	23		-
Physical Distractor	2.00	2.17	24	24.62	$p < .05$
Physical Driving	4.04	2.29	23		-
Physical Distracted Driving	6.39	2.43	23		-
Temporal Distractor	5.08	2.54	24	8.85	$p < .05$
Temporal Driving	3.13	2.74	23		-
Temporal Distracted Driving	5.96	3.55	23		-
Performance Distractor	4.54	2.00	24	11.31	$p < .05$
Performance Driving	6.96	1.30	23		-
Performance Distracted Driving	5.96	3.55	23		-
Effort Distractor	7.83	1.74	24	2.88	$p < .05$
Effort Driving	7.52	2.52	23		-
Effort Distracted Driving	4.91	2.75	23		-
Frustration Distractor	5.54	3.11	24	7.72	$p < .05$
Frustration Driving	3.61	3.34	23		-
Frustration Distracted Driving	6.09	2.89	23		-

Stop Signal - DSSQ scores					
	M	*SD*	*N*	*F*	*p*
Engagement Distractor	22.46	5.43	24	13.57	*p* < .05
Engagement Driving	25.04	3.90	23		-
Engagement Distracted Driving	22.61	5.11	23		-
Distress Distractor	13.42	6.45	24	16.6	*p* < .05
Distress Driving	9.57	8.28	23		-
Distress Distracted Driving	18.35	9.09	23		-
Worry Distractor	7.08	5.88	24	4.1	*n.s.*
Worry Driving	7.43	6.09	23		-
Worry Distracted Driving	7.04	5.75	23		-

Figure 7. Study 3 – Stop Signal subjective workload and stress





Tone Monitoring

Correlation among Tone Monitoring Measures

A series of six bivariate correlations were conducted to evaluate the relationship between Tone Monitoring performance measures – d’, percent accuracy, and response time (in ms) during non-distracted and distracted conditions.

There was a significant correlation between d’ and percent accuracy ($r(20) = .72$, $p < .05$), but not between d’ and response time, and percent accuracy and response time when the Tone Monitoring Task was completed alone. There was also a significant correlation between d’ and percent accuracy ($r(19) = .89$, $p < .05$), but not between d’ and response time, and percent accuracy and response time when the Tone Monitoring Task was completed while simultaneously driving. Response time was significantly correlated with Tone Monitoring when it was completed alone and when it was completed while simultaneously driving ($r(19) = .50$, $p < .05$). However, d' was not correlated with Tone Monitoring when it was completed alone and when it was completed while simultaneously driving. Percent accuracy was also not correlated with Tone Monitoring when it was completed alone and when it was completed while simultaneously driving.

Driving task under single and dual-conditions

Participants made significantly more lane deviations during the distracted condition (M = 3.00, SD = 3.12) compared to the non-distracted (M = 1.67, SD = 1.79); ($t(22) = 2.86$, $p < .05$). They also braked significantly less frequently during the distracted condition (M = 6.96, SD = 7.31) compared to the non-distracted condition (M = 13.83, SD = 4.51); ($t(21) = 4.68$, $p < .05$). There were no significant differences in braking duration, braking response time, or number of collisions between distracted and non-distracted conditions ($p > .05$).

An ANCOVA was conducted to evaluate whether WMC or executive attention moderated the effect of distraction on driving performance. To conduct the analyses, WMC and executive attention were each entered separately as a covariate. The interaction term (e.g., Distraction X WMC) was then analyzed for significant effects. Results showed no moderating effects of WMC or executive attention ($p > .05$).

Effect of rain on driving performance

There was no main effect of rain on driving performance. Participants showed no differences in braking response time, number of lane deviations, collisions, braking duration, and the number of brake presses in either non-distracted or distracted conditions ($p > .05$).

Stop Signal Task

Correlation among Stop Signal Measures

A series of four bivariate correlations were conducted to evaluate the relationship between Stop Signal performance measures – nonstop accuracy and stop accuracy during non-distracted and distracted conditions.

Nonstop accuracy and stop accuracy were not correlated either when the Stop Signal Task was completed alone or while driving. Nonstop accuracy during the Stop Signal task when completed alone was significantly correlated with the Stop Signal task when completed while driving ($r(20) = .57$, $p < .05$). Stop accuracy during the Stop Signal task when completed alone was also significantly correlated with the Stop Signal task when completed while driving ($r(20) = .64$, $p < .05$).

Driving task under single and dual-conditions

Participants braked significantly less frequently during the distracted conditions (i.e., driving only plus distractor task, $M = 4.79$, $SD = 6.21$) compared to the non-distracted conditions (i.e., driving only, $M = 9.53$, $SD = 5.84$); ($t(18) = 4.07$, $p < .05$). There were no significant differences in the number of lane deviations or collisions, braking response time, or braking duration ($p > .05$).

An ANCOVA was conducted to evaluate whether WMC or executive attention moderated the effect of distraction on driving performance. To conduct the analyses, WMC and executive attention were each entered separately as a covariate. The interaction term (e.g., Distraction X WMC) was then analyzed for significant effects. Results showed that neither WMC nor executive attention moderated the effect of distraction on driving performance ($p < .05$).

Effect of rain on driving performance

There was no main effect of rain on driving performance. Participants showed no differences in braking response time, number of lane deviations, collisions, braking duration, and the number of brake presses in either non-distracted or distracted conditions ($p > .05$).

GLT distraction

Correlation among GLT measures

A series of four bivariate correlations were conducted to evaluate the relationship between the GLT sub-tasks, primary verbal recall and secondary price-judgment task during non-distracted and distracted conditions.

There was a significant negative correlation between the primary verbal recall task and secondary price-judgment task during non-distracted conditions ($r(46) = -.42$, $p < .05$), but not during distracted conditions ($p > .05$). Performance on the GLT primary verbal recall task alone was also significantly correlated with performance on the GLT primary verbal recall task while driving ($r(47) = .67$, $p < .05$). Performance on the GLT secondary price-judgment task alone was also significantly correlated with performance on the GLT primary verbal recall task while driving ($r(46) = .79$, $p < .05$).

Driving task under single and dual-conditions

There was a main effect of distraction on braking response time. In general, participants braked more slowly while completing the combined GLT and driving task ($M = 3.66$, $SD = 3.80$) than while completing the driving only task ($M = 1.82$, $SD = 1.21$); ($t(25) = 2.28$, $p < .05$); (see Figure 2).

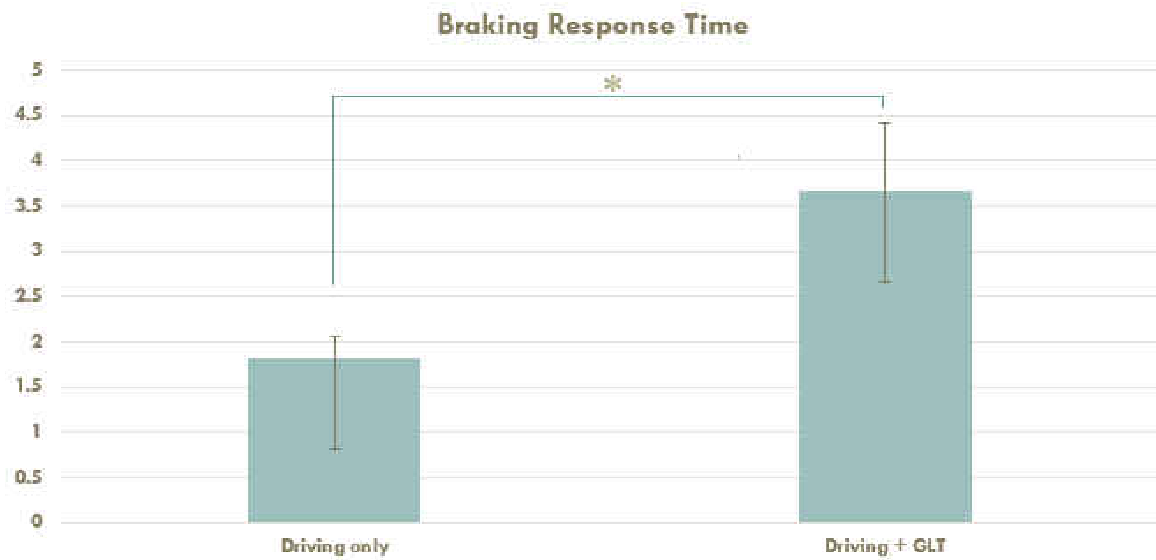


Figure 8. Time to Brake during non-distracted and distracted conditions. There was a main effect of distracted conditions, such that Time to Brake was significantly slower during the distracted trial compared to the non-distracted trial. The presentation of distracted and non-distracted trials was counterbalanced to reduce the possibility of order effects.

An ANCOVA was conducted to evaluate whether WMC or executive attention moderated the effect of distraction on driving performance. To conduct the analyses, WMC and executive attention were each entered separately as a covariate. The interaction term (e.g., Distraction X WMC) was then analyzed for significant effects. Results showed that WMC moderated the effect of distraction on driving ($p < .05$). Executive attention did not moderate the effect of distraction on driving.

Effect of rain on driving performance

There was no main effect of rain on driving performance. Participants showed no differences in braking response time, number of lane deviations, collisions, braking duration, and the number of brake presses in either non-distracted or distracted conditions ($p > .05$).

Effect of gaming experience on task performance

Gaming experience was measured as whether the participant played video games and the total number of hours played per week. The total number of hours played per week was not related to performance on any of the distractor tasks (i.e., GLT, Stop Signal, or Tone Monitoring). An independent samples t-test initially revealed a significant difference in the number of collisions between those who played video games versus those who did not play video games ($t(31) = 2.93$, $p < .05$). However, because the variability was not equivalent across the video game players and non-video game players (i.e., the sample displayed heteroscedasticity), a second independent samples t-test was run using equal variances *not* assumed. In the second analysis, whether a participant played video games was *not* equivalent to the number of collisions. Whether the participant played video games was not related to any of the other distractor task or driving task performance indices.

Because there was no significant relationship between gaming experience and task performance, no further analyses involving adding gaming experience as a covariate were conducted.

Discussion

As predicted, driving while engaging in the GLT distraction led to poorer driving performance than while driving without distraction. Specifically, individuals showed slower braking response time to yellow lights and sudden braking events when they were distracted. The relationship between GLT distraction and braking response time was also partially mediated by WMC, suggesting that WMC affects simulated driving performance while distracted. Completing the Stop Signal task while driving also decreased braking frequency, although its implications on driving safety are less clear.

Similarly, the relationship between GLT distraction and braking response time was partially mediated by executive attention response time and accuracy, suggesting that executive attention affects simulated driving performance while distracted. The relationship between the Stop Signal Task and braking frequency was also partially mediated by executive attention response time and WMC.

Interestingly, there was no effect of rain on driving performance for any of the distractor types. Although it is uncertain why the raining condition did not affect driving behavior, there are a few possible reasons for why this may have occurred. One possible reason is that the poorer visibility conditions elicited by the rain were not necessary for detecting braking events used in this study, which were braking at yellow traffic lights and sudden braking events. Another possible reason is that the rain was not heavy enough to elicit any difficulty in detecting a yellow traffic light. Finally, another possible reason is that perhaps WMC does not affect distracted driving performance via lower-level situational awareness (i.e., hazard perception). Future research would manipulate rainfall to see if heavier rain would interact with WMC and distracted driving. A situational awareness measure or eye-tracking measure can also be used to identify whether the participant notices yellow traffic lights and other potential hazards while driving.

CHAPTER 9: GENERAL CONCLUSIONS

This is the first study to our knowledge that suggests that an individual's working memory ability affects distracted driving performance using a semi-naturalistic distractor task. Unlike previous studies, which presented mixed findings when a naturalistic distractor was used, this study suggests that WMC does affect distracted driving performance, but it depends on the type of distractor used. A distractor involving more memory storage may be more impairing for individuals with smaller WMC, while a distractor involving more executive attention (i.e., inhibiting, shifting, or conflict) may be more impairing for those with attentional disorders. Because each distractor is often characterized by a blend of cognitive attributes, it is likely that WMC and executive attention affects distracted driving performance to varying extents.

In Study 1, it was demonstrated that the GLT positively loaded onto working memory. Both the GLT and complex span tasks met the two-factor criteria for the domain-general theory of working memory, in that they both involved memory storage and executive attention. The GLT required memory storage to maintain a list of food names and executive attention to shift between primary and secondary tasks, while the complex span tasks required memory storage to maintain a list of items or executive attention to shift between primary and secondary tasks. Because GLT positively loaded onto working memory, it was used as the semi-naturalistic, working memory distractor for the following studies.

The Study 2 *pilot* was conducted to evaluate whether a third version of the GLT would be more appropriate than the second version of the GLT as a working memory distractor. Results showed that only the second version, and not the third version, was related to WMC. Secondly, there was no relationship between GLT distraction and braking response time. To more accurately assess the effect of distraction on braking response times, Studies 3 and 4 employed a city scenario to increase the number of potential braking events used to collect data.

In Study 2, participants drove a simulated city scenario while completing one of three distractor tasks (Tone Monitoring, Stop Signal, or GLT). Driving while engaging in each of the distractor tasks led to differential effects on driving performance. These results suggest that the effects of distraction on driving performance are more complex than previously considered. Also, certain types of distractions may engage cognitive processes that are more sensitive to different types of driving impairments.

Finally in Study 3, participants completed one of the same three distractor tasks (Tone Monitoring, Stop Signal, or GLT) while navigating in a simulated city scenario. Completing the GLT while driving led to slower braking response times compared to driving alone (i.e., without the GLT distractor). When WMC and executive attention were added as covariates, the relationship between GLT distraction and driving performance was no longer significant, indicating that WMC and executive attention partially mediated the effect of GLT distraction on driving. This study is the first to demonstrate that WMC does predict distracted driving performance when an appropriate semi-naturalistic distractor is used.

The three distractor tasks appear to show similar patterns of subjective workload and stress. For instance, engaging in any of the tasks while driving results in greater mental demand, greater temporal demand, poorer perceived performance, greater effort, and greater frustration. However, the tasks do differ slightly from each other – for instance, the GLT may be associated with less physical demand and less effort. The Stop Signal Task may also be associated with less effort and frustration. Interestingly, individuals exhibited poorer driving outcomes when engaging in each of the distractor tasks, even when they perceived the tasks as less effortful. These findings suggest deleterious effects of distracted driving, even when the distractions are considered "easy" or effortless.

In conclusion, the present study highlights the complex interactions between sensory, perceptual, cognitive, and behavioral factors associated with driving performance. The particular effect that distraction has on driving depends on a number of factors, including the type of distraction, the driving performance measure, and the individual's cognitive capabilities. It is strongly suggested that future researchers keep these three factors in mind when carving out new experiments to evaluate distracted driving performance.

CHAPTER 10: THEORETICAL AND PRACTICAL IMPLICATIONS

The findings of this study present theoretical and practical implications. From a theoretical perspective, this study may fill a gap in the literature as to why certain studies did not find a relationship between WMC and driving performance. Although previous literature strongly supported the relationship between attentional ability and driving performance (Avolio et al., 1985; Barkley et al., 2002; Laberge et al., 2005; Reimer et al., 2010), findings from WMC studies have been less consistent (Ross et al., 2014; Guerrier et al., 1999; Lambert et al., 2010). The present research suggests that other studies may not have found a relationship between WMC and driving performance because they did not use distractions loading onto working memory.

Second, this study would support our hypothesis that the relationship between WMC and distracted driving depends on the type of distraction used. Individuals with low WMC may not be equally prone to poor driving across all distraction types. Rather, while some low WMC individuals may generally be unaffected by distractions such as simple conversations, they may be impaired by other distraction types such as debating a controversial topic. The study also suggests an alternative interpretation of previous findings of workload on driving outcome – for instance, poorer driving outcomes arising from "difficult" distraction tasks may simply be attributed to greater working memory involvement rather than greater effort. Such an interpretation highlights the complex relationship between WMC and distracted driving, and that one must be cautious when drawing conclusions between working memory and distracted driving.

Third, this study would support the Grocery List Task as a type of naturalistic distraction which measures WMC. The Grocery List Task was developed based off of the Auditory Reading Span, which is a traditional complex span known to involve both memory storage and executive attention (Kane et al., 2007). In contrast, other distraction tasks in WMC and driving studies may not have used measures which sufficiently loaded onto working memory. These findings may warrant more stringent selection processes used to select distraction tasks when examining WMC and distracted driving – for instance, researchers should be careful to employ tasks known to involve memory storage and executive attention.

Fourth, it supports previous studies which find that cognitive distractors can even affect tasks considered "automatic." Just as physical distractions such as using electronic devices or changing stations on the radio may impair driving performance, cognitive distractions involving no physical manipulation may also impair driving performance. These findings suggest that purely cognitive distractions such as simply being "lost in thought" or "having a lot on one's mind" may be just as dangerous as texting or talking on one's phone. Furthermore, the extent to which cognitive distractions affect driving performance depend on the individual's inherent cognitive abilities.

Lastly, this study may provide support for the domain-general account of WMC. Specifically, if both WMC and executive attention are significant predictors of distracted driving outcome, then this would support the claim that WMC requires executive attention as a necessary condition. However, if only WMC or executive attention is a predictor of distracted driving outcome, then this would provide evidence against the domain-general account of WMC. Additionally, it may suggest that executive attention and WMC are dissociable constructs. Because the present study follows the domain-general account, it is predicted that both WMC and executive attention would be significant predictors of distracted driving outcome.

The practical implications suggest that certain types of distractions in real life may result in different types of driving impairments. The GLT was made to resemble the types of naturalistic distractions one may encounter while driving, such as doing mental calculations while recalling a list of grocery items. It can also resemble other driving-relevant distractions such as problem solving while recalling a series of directions while driving. In general, it resembles self-talk one engages in while driving. Similarly, the Tone Monitoring Task may resemble engaging in self-talk while auditory noises play in the background one must attend to, such as siren noises from a police car or emergency vehicles or conversations from passengers in the car. Finally, the Stop Signal Task may resemble accelerating behavior while driving on a road with merging lanes; i.e., one must distinguish between accelerating when it is *safe* to move forward (i.e., , "go") versus not accelerating when it is *not safe* because of merging traffic (i.e., "no-go"). Because the Stop Signal Task involves motor movement, distractors which resemble the Stop Signal Task may also result in impairments relating to motor movement such as lane deviations. In contrast, because the GLT and Tone Monitoring Tasks are more cognitive and less physical, they may result in impairments relating to slowed response time such as slower braking response.

These tasks also resemble the types of distraction one might engage in while in a semi-autonomous car. For instance, the GLT may resemble mental problem solving or daydreaming when the semi-autonomous vehicle suddenly requires the driver to take over the vehicle. The Tone Monitoring Task may involve listening to multiple audio sources at once such as conversations and potential warning sounds from the vehicle. Finally, the Stop Signal Task may resemble knowing when to physically take over the vehicle versus not take over when the vehicle is no longer able to operate on its own. Based on the findings from the present study, it is possible that individuals with smaller WMC or less efficient executive attention would be slower to respond to vehicle warnings from semi-autonomous vehicles compared to those with larger WMC or more efficient executive attention.

Practical implications may include improving traffic safety, reducing accidents on roadways, and increasing public awareness about the negative effects of distracted driving on safety in different environments. This will also have implications for developing training systems for improving at-risk drivers (e.g., teenage drivers, elderly drivers, brain-injured drivers), and policy-making regarding enacting laws that ban or regulate the use of in-vehicle devices. The study may also inform manufacturing about designing safer in-vehicle devices, and informing consumers about selecting safer devices that would take into account WMC or executive attention.

It is recommended that drivers not use their phone devices while their vehicle is in motion, especially with texting while driving. The study will provide further support for existing campaigns on distracted driving, which focus on the adverse effects of texting (AT&T, 2016; USDOT NHTSA, 2016). The study also supports the possibility that even *non-physical* distractors may impair driving (Strayer, Cooper, Turrill, Coleman, & Hopman, 2016).

Just as teenage drivers and individuals with ADHD may show profound driving impairment as a function of driving distraction (Barkley et al., 2002; Hervey, Epstein, Curry, Tonev, Arnold, Conners, Hinshaw, Swanson, & Hechtman, 2006; Reimer et al., 2010), individuals with working memory impairments may also need to be more cautious by avoiding distracted driving (e.g., text-messaging, conversing on the phone, etc.).

Another major practical implication is the design of semi-autonomous vehicles, as discussed in Louie and Mouloua (2017). Although semi-autonomous purportedly reduces negative consequences of driver-related factors such as driver workload, fatigue, and distraction, semi-autonomous cars are not accident-proof (Lutin, Kornhauser, Lerner-Lam, 2013; Markoff, 2010). The first semi-autonomous vehicle related fatality occurred in July 2016 due to the driver engaging in a secondary task (watching a movie) when vehicle failed to detect a large vehicle crossing its path (Yadron & Tynan, 2016). In fact, in the event that an autonomous vehicle is no longer able to navigate, individuals may be slow to respond to automation failures and slow to switchover to manual control.

Finally, the proliferation of semi-autonomous vehicles will also bring along a variety of human factors problems. For instance, would individuals with poorer executive attention or working memory capacity be disproportionately slower in perceiving a warning to switchover from automated to manual control? How would the warning be designed to optimize speed and accuracy of the individual's response to the warning? Some studies have suggested looking at the number of blinks to measure the level of fatigue while driving (Stern, Boyer, & Schroeder, 1994; Williamson & Chamberlain, 2005; NHTSA, 2013a) - would cognitive ability also be measured for individuals to customize driving experience? Although studies have investigated how operating autonomous vehicles may relate to cognitive states in general, few studies have investigated how individual differences in cognition may affect the operating of an autonomous vehicle (Kaberss & Endsley, 1997; Harris, Goernert, Hancock, & Arthur, 1994; Marinik, Bishop, Fitchett, Morgan, Trimble, & Blanco., 2014; Bainbridge, 1983; Parasuraman, Bahri, Deaton, Morrison, & Barnes, 1992; Parasuraman & Riley, 1997). The present study will help shed some light on the theoretical and practical issues – the author hopes that further research will generally improve the field's understanding of how cognition and technology interact. In doing so, scientists and practitioners may be able to improve the design of technology to improve satisfaction with using the technology and reduce the number of technology-related accidents.

APPENDIX A: IRB APPROVAL

University of Central Florida

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Jennifer Louie**

Date: **March 21, 2017**

Dear Researcher:

On 03/21/2017 the IRB approved the following modifications to human participant research until 10/24/2017 inclusive:

Type of Review:	Submission Response for IRB Addendum and Modification Request Form
Modification Type:	Added Sydney Gass and Tasneem Islam, Removed Edgar Metke, decreased sample size to n-80, updated study instruments, updated consent, added debriefing form
Project Title:	Examining Driving Behaviors
Investigator:	Jennifer Louie
IRB Number:	SBE-14-10718
Funding Agency:	
Grant Title:	
Research ID:	N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

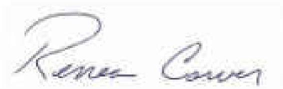
If continuing review approval is not granted before the expiration date of 10/24/2017, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:



Signature applied by Renea C Carver on 03/21/2017 03:00:41 PM EDT

IRB Coordinator

APPENDIX B: DEBRIEFING STATEMENT

Debriefing Statement

For the study entitled:
"Examining Driving Behaviors"

Dear Participant:

During this study, you were asked to complete a series of tasks and a driving scenario. The tasks measured executive attention and working memory capacity. Working memory is the memory system involved with holding and maintaining information over a short period of time. The purpose of this experiment is to determine how students of different levels of working memory capacity perform on a driving measure.

If you have any concerns about your participation or the data, please feel free to contact us. We will be happy to provide any information we can to help answer questions you have about this study.

The responses in this study are de-identified and cannot be linked to you.

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints or think the research has hurt you, please contact the principal investigator or the faculty advisor. Principal investigator: Jennifer Louie, jlouie@knights.ucf.edu. Faculty advisor: Dr. Mustapha Mouloua (407) 823-2910; Mustapha.mouloua@ucf.edu.

IRB contact about your rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901.

Please again accept our appreciation for your participation in this study.

APPENDIX C: CITI TRAINING COMPLETION CERTIFICATE

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)

COMPLETION REPORT - PART 2 OF 2
COURSEWORK TRANSCRIPT**

** NOTE: Scores on this Transcript Report reflect the most current quiz completions, including quizzes on optional (supplemental) elements of the course. See list below for details. See separate Requirements Report for the reported scores at the time all requirements for the course were met.

- **Name:** Jennifer Louie (ID: 4295988)
- **Institution Affiliation:** University of Central Florida (ID: 405)
- **Institution Email:** jlouie@knights.ucf.edu
- **Institution Unit:** Psychology
- **Phone:** 732-939-9159

- **Curriculum Group:** Human Research
- **Course Learner Group:** Group 2.Social / Behavioral Research Investigators and Key Personnel
- **Stage:** Stage 2 - Refresher Course

- **Record ID:** 23238230
- **Report Date:** 27-Sep-2017
- **Current Score**:** 100

REQUIRED, ELECTIVE, AND SUPPLEMENTAL MODULES	MOST RECENT	SCORE
SBE Refresher 1 – History and Ethical Principles (ID: 936)	27-Sep-2017	2/2 (100%)
Biomed Refresher 1 - Instructions (ID: 960)	27-Sep-2017	No Quiz
SBE Refresher 1 – Federal Regulations for Protecting Research Subjects (ID: 937)	27-Sep-2017	2/2 (100%)
SBE Refresher 1 – Informed Consent (ID: 938)	27-Sep-2017	2/2 (100%)
SBE Refresher 1 – Research with Prisoners (ID: 939)	27-Sep-2017	2/2 (100%)
SBE Refresher 1 – Research in Educational Settings (ID: 940)	27-Sep-2017	2/2 (100%)
SBE Refresher 1 – Instructions (ID: 943)	27-Sep-2017	No Quiz
SBE Refresher 1 – International Research (ID: 15028)	27-Sep-2017	2/2 (100%)
SBE Refresher 1 – Defining Research with Human Subjects (ID: 15029)	27-Sep-2017	2/2 (100%)
SBE Refresher 1 – Assessing Risk (ID: 15034)	27-Sep-2017	2/2 (100%)
SBE Refresher 1 – Privacy and Confidentiality (ID: 15035)	27-Sep-2017	2/2 (100%)
SBE Refresher 1 – Research with Children (ID: 15036)	27-Sep-2017	2/2 (100%)

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

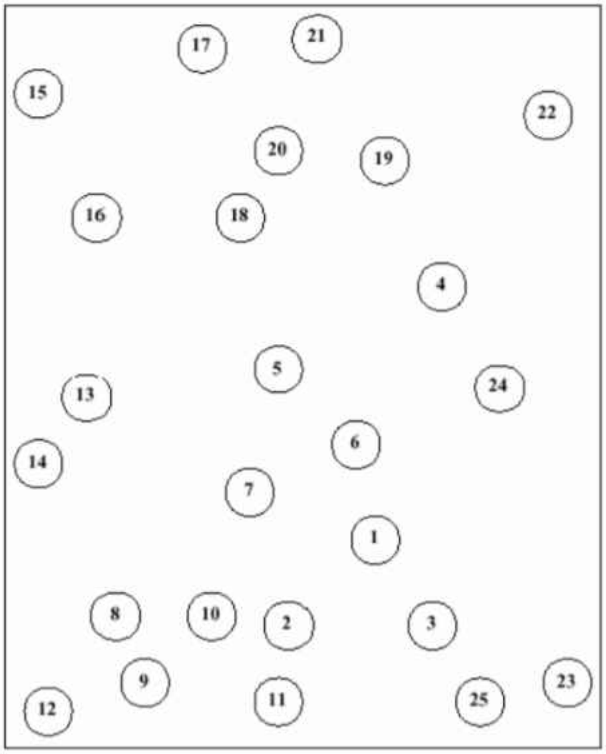
Verify at: www.citiprogram.org/verify/?k3b444428-528e-4e3f-bc20-91a976c757ac-23238230

Collaborative Institutional Training Initiative (CITI Program)
Email: support@citiprogram.org
Phone: 888-529-5929
Web: https://www.citiprogram.org

APPENDIX D: TRAILMAKING TASKS

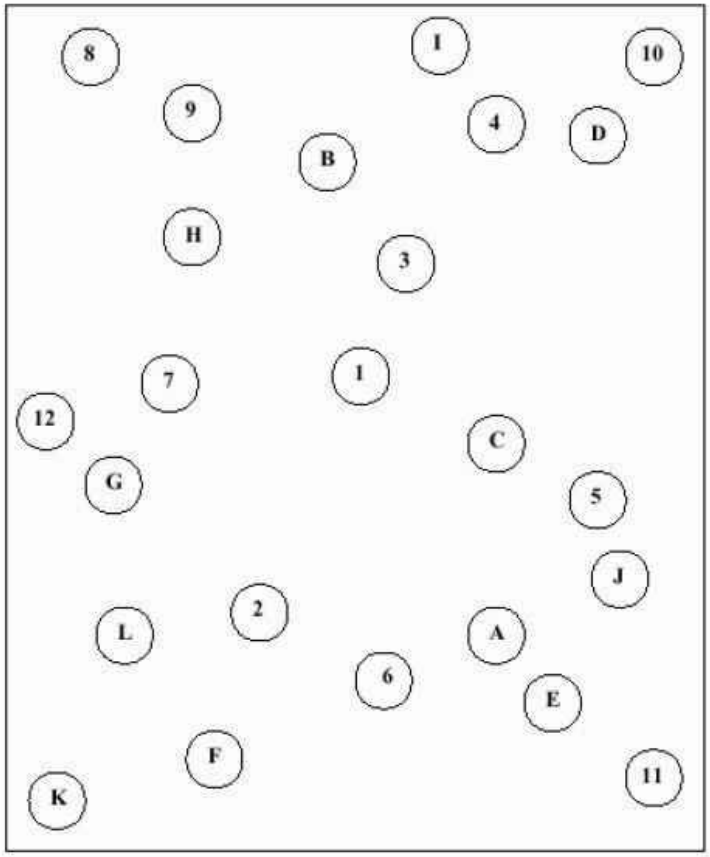
Trail Making Test Part A

Patient's Name: ____________________________ Date: ____________________



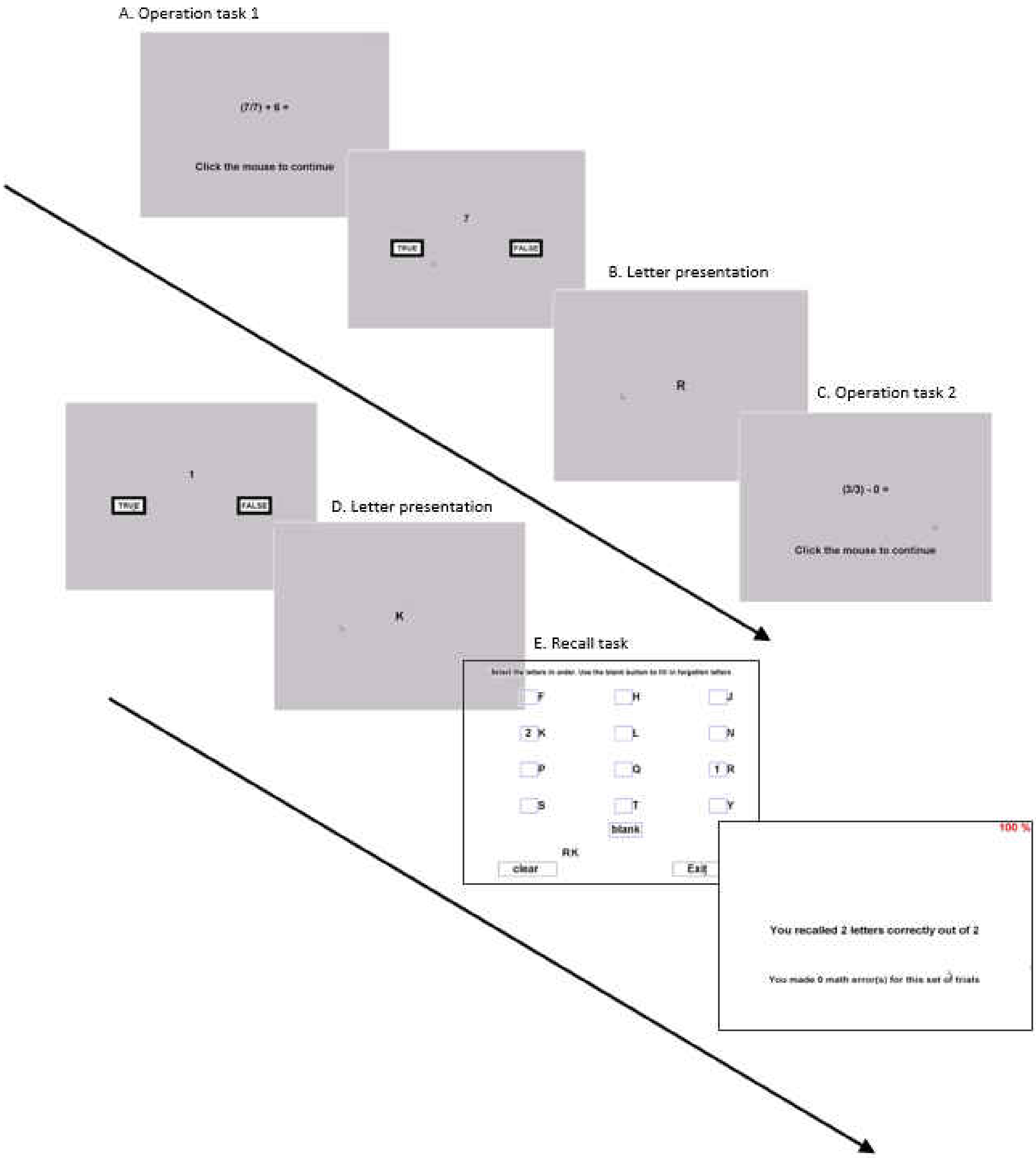
Trail Making Test Part B

Patient's Name: ____________________ Date: ____________________

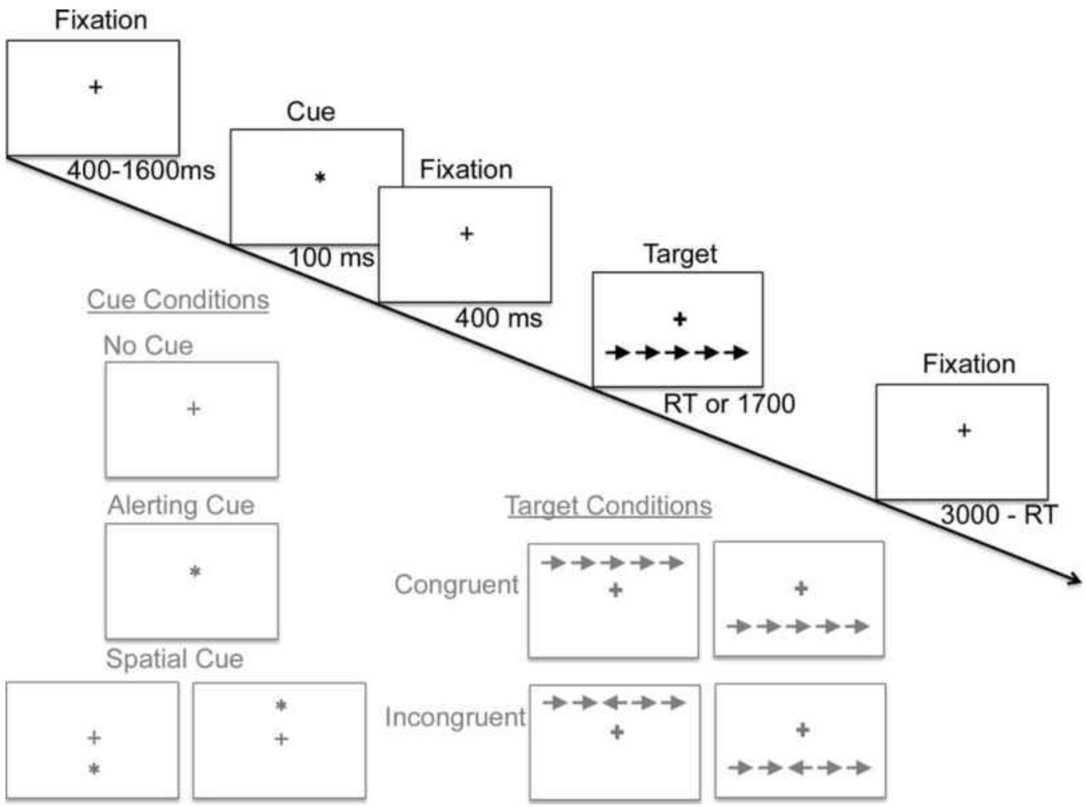


APPENDIX E: COGNITIVE MEASURES

Working memory complex spans



ANT



Attention Network Task (ANT). Retrieved from:

http://www.frontiersin.org/files/Articles/832/fnana-04-002/image_m/fnana-04-002-g001.jpg

APPENDIX F: DISTRACTOR TASKS

Grocery List Task v. 3.0 (adapted from auditory operation span)

Instructions: Imagine you are going to the grocery store to buy food for a friend. I'm going to tell what foods she's looking for. *You* need to tell me if it matches the category I give you. You also need to make sure it's something she's not allergic to. You will have three seconds for each response.

At the end of each list, tell me how many kinds of food she's getting.

Practice:

[She is] allergic to: olives, paprika, carrots, and watermelon

You want to buy 4 boxes of fish. Can we buy salmon? Participant: Yes

You want to buy 10 boxes of vegetables. Can we buy carrots? Participant: No (allergic)

2 boxes of dessert. Sauerkraut? Participant: No (wrong category)

2 boxes of fruit. Watermelon? Participant: No (allergic)

How many kinds of food can you get? 1

Participant #:

____

("c" refers to wrong category; "a" refers to an allergy)

					Correct answer	Primary Accuracy *(food task)*	Secondary accuracy *(how many)*
List 1	*Allergic to:*	lemongrass, mangoes, hummus, molasses, lentils					
(7 items)	2	boxes of	dessert.	Jello?	Yes		
0:00	6	boxes of	vegetables.	Pasta?	No		
	6	boxes of	fruit.	Berries?	Yes		
	7	boxes of	fruit.	Mangoes?	No (a)		
	1	box of	nuts.	Pecans?	Yes		
	2	boxes of	meat.	Celery?	No (c)		
	9	boxes of	meat.	Salami?	Yes		

List 2	*Allergic to:*	cranberries, tuna, shallots, quinoa, hazelnut					
(3 items)	2	boxes of	dessert.	Parfait?	Yes		
1:06	3	boxes of	dessert.	Cupcake?	Yes		
	6	boxes of	spice.	Cinnamon?	Yes		

List 3	*Allergic to:*	salmon, coconut, pepperoni, garlic, halibut					
(3 items)	3	boxes of	meat.	Pepperoni?	No (a)		
1:44	3	boxes of	drinks.	Yeast?	No (c)		

		4	boxes of	meat.	Basil?	No (c)

	Allergi	zucchini, asparagus,				
List 4	*c to:*	corn, olives, sausages				
(3 items)		6	boxes of	nuts.	Walnuts?	Yes
2:20		4	boxes of	nuts.	Almonds?	Yes
				vegetables		
		5	boxes of	.	Zucchini?	No (a)

	Allergi	mushrooms, kimchi, horseradish, sauerkraut,				
List 5	*c to:*	coleslaw				
(5 items)		5	boxes of	grains.	Pasta?	Yes
2:55		1	box of	meat.	Carrots?	No (c)
		5	boxes of	salad.	Coleslaw?	No (a)
		9	boxes of	fruit.	Tangerine?	Yes
		4	boxes of	Portobello.	Mushrooms?	No (a)

		apples, anchovies, oranges, cranberries,				
List 6	*Allergic to:*	blueberries				
(8 items)		2	boxes of	drinks.	Tea?	Yes
3:46		6	boxes of	grains.	Onion?	No (c)
		3	boxes of	fruit.	Figs?	Yes
		9	boxes of	legumes.	Peas?	Yes
		6	boxes of	nuts.	Cashews?	Yes
		4	boxes of	dairy.	Plums?	No (c)

					Strawberries	
		7	boxes of	grains.	?	No (c)
		3	boxes of	vegetables.	Bacon?	No (c)

			avocado, cilantro, crabmeat, croissants,			
List 7	*Allergic to:*		cabbage			
(8 items)		1	box of	vegetables.	Spinach?	Yes
4:55		5	boxes of	dairy.	Jam?	No (c)
		2	boxes of	spice.	Nutmeg?	Yes
		6	boxes of	pasta.	Ravioli?	Yes
		9	boxes of	fruit.	Avocado?	No (a)
		8	boxes of	vegetables.	Cabbage?	No (a)
				preserved		
		5	boxes of	food.	Pickles?	Yes
		6	boxes of	meat.	Vanilla?	No (c)

			salami, tea, figs, oregano,			
List 8	*Allergic to:*		pecans			
(6 items)		5	boxes of	vegetables.	Cucumber?	Yes
6:05		1	box of	fruit.	Grapes?	Yes
		6	boxes of	herbs.	Oregano?	No (a)
		6	boxes of	grains.	Oatmeal?	Yes
		7	boxes of	vegetables.	Lettuce?	Yes
		4	boxes of	bread.	Biscuits?	Yes

			Artichoke, rigatoni, broccoli, hushpuppies,			
List 9	*Allergic to:*		molasses			
(7 items)		2	boxes of	vegetables.	Artichoke?	No (a)
7:02		7	boxes of	dairy.	Cheese?	Yes
		5	boxes of	dairy.	Peppers?	No (c)
				condiments		
		2	boxes of	.	Vinegar?	Yes
		8	boxes of	dessert.	Croutons?	No (c)
		1	box of	vegetables.	Broccoli?	No (a)
		5	boxes of	spread.	Margarine?	Yes

GLT alone

ends here

	Allergic					
List 10	*to:*		ginger, waffles, flour, lentil, tamarind			
(7 items)		6	boxes of	dessert.	Radish?	No (c)
8:05		9	boxes of	spice.	Paprika?	Yes
		8	boxes of	starch.	Flour?	No (a)
		9	boxes of	legumes.	Lentil?	No (a)
		1	box of	fruit.	Tamarind?	No (a)
		4	boxes of	vegetables.	Spinach?	Yes
		6	boxes of	breakfast food.	Waffles?	No (a)

	Allergic	
List 11	*to:*	salami, cinnamon, basil, jello, yeast

(4 items)		1	box of	fruit.	Cherries?	Yes
9:05		3	boxes of	dairy.	Olives?	No (c)
		9	boxes of	nuts.	Almonds?	Yes
		7	boxes of	meat.	Chicken?	Yes

	Allergic					
List 12	*to:*		Ginger, corn, pepperoni, pasta, celery			
(5 items)		5	boxes of	vegetables.	Corn?	No (a)
9:47		4	boxes of	dairy.	Tomatoes?	No (c)
		1	box of	spice.	Ginger?	No (a)
		2	boxes of	fruits.	Coconut?	Yes
		8	boxes of	spice.	Garlic?	Yes

	Allergic					
List 13	*to:*		Lentils, salmon, coleslaw, chocolate			
(6 items)		9	boxes of	fish.	Salmon?	No (a)
10:36		6	boxes of	fruit.	Apples?	Yes
		7	boxes of	dessert.	Chocolate?	No (a)
		2	boxes of	meat.	Sausage?	Yes
		1	box of	dairy.	Orange?	No (c)
		2	boxes of	vegetables.	Asparagus?	Yes

	Allergic					
List 14	*to:*		Anchovies, tangerines, walnuts, mushrooms, croissants			
(6 items)		2	boxes of	spice.	Tuna?	No (c)

11:30	1	box of	fish.	Anchovies?	No (a)
	4	boxes of	pastry.	Croissants?	No (a)
	4	boxes of	preserved food.	Kimchi?	Yes
	6	boxes of	nuts.	Halibut?	No (c)
	2	boxes of	nuts.	Sauerkraut?	No (c)

List 15	*Allergic to:*	wasabi, plums, strawberries, tea, zucchini			
(8 items)	5	boxes of	dairy.	Horseradish?	No (c)
12:28	2	boxes of	fruit.	Nectarines?	Yes
	9	boxes of	fruit.	Cranberries?	Yes
	1	box of	fish.	Blueberries?	No (c)
	5	boxes of	seafood.	Crabmeat?	Yes
	4	boxes of	pastry.	Quinoa?	No (c)
	3	boxes of	grains.	Couscous?	Yes
	9	boxes of	nuts.	Hazelnuts?	Yes

List 16	*Allergic to:*	Tortillas, berries, shallots, onions, cashews			
(2 items)	5	boxes of	bread.	Tortillas?	No (a)

13:37		6	boxes of	onion.	Shallots?	No (a)

List 17	*Allergic to:*		Ravioli, grapes, cucumbers, lettuce, hummus			
(6 items)		5	boxes of	fruits.	Prunes?	Yes
14:04		2	boxes of	vegetables.	Cilantro?	Yes
		4	boxes of	condiments.	Wasabi?	Yes
		4	boxes of	spread.	Hummus?	No (a)
		8	boxes of	syrup.	Molasses?	Yes
		7	boxes of	fruits.	Apricots?	Yes

List 18	*Allergic to:*		Nutmeg, avocadoes, hushpuppies, spinach, peas			
(4 items)		7	boxes of	bread.	Lemongrass?	No (c)
14:59		5	boxes of	snacks.	Applesauce?	Yes
		5	boxes of	meat.	Barley?	No (c)
		1	box of	dough.	Hushpuppies?	No (a)

List 19	*Allergic to:*		Seasoning, pasta, legumes, blackberries, tomatoes

					No
(2 items)	8	boxes of	herbs.	Rigatoni?	(c)
					No
15:40	8	boxes of	spice.	Seasoning?	(a)

Grocery List Task v. 2.0 (adapted from auditory operation span)

Instructions: We are now going to do the Grocery List Task. In this task, imagine you are going to the grocery store and need to pick up a list of items. Each item comes in a varying number of boxes. I will tell you the price of each item, and how many boxes you need to buy. Please verify the total cost of each item by saying yes or no. We will give you four seconds to respond before moving on to the next item. At the end of the list, I will ask you for all the items.

For instance, you need to pick up 2 boxes of $2 bacon. $4? [[Yes / No]]

3 boxes of $9 onion. $21? [[Yes / No]]

2 boxes of $3 garlic. $3? [[Yes / No]]

1 boxes of $9 tuna. $9? [[Yes / No]]

Recall the list. (Correct response = "bacon, onion, garlic, and tuna")

Do you understand the task? (If they seem like they are still a bit uncomfortable, try another practice list:

1 boxes of $7 corn. $7? [[Yes / No]]

4 boxes of $1 chocolate. $8? [[Yes / No]]

2 boxes of $2 chicken. $5? [[Yes / No]]

Recall the list. (Correct response = "corn, chocolate, chicken."

Quantity	Cost	Item	Question	Primary Accuracy	Secondary Accuracy
List 1 (7 items)					
0:00 min					

2	boxes of	$1	Jello	$2	TRUE
6	boxes of	$4	Pasta	$24	TRUE
6	boxes of	$7	Berries	$36	FALSE
7	boxes of	$1	Mango	$7	TRUE
1	box of	$5	Pecans	$6	FALSE
2	boxes of	$4	Celery	$8	TRUE
9	boxes of	$6	Salami	$54	TRUE

List 2 (3 items)

1:03 min

2	boxes of	$1	Parfait	$3	FALSE
3	boxes	$1	Cupcake	$4	FALSE

	boxes of				
6	boxes of	$7	Cinnamon	$49	FALSE

List 3 (3 items)					
1:30 min					
3	boxes of	$1	Pepperoni	$4	FALSE
3	boxes of	$1	Yeast	$2	FALSE
4	boxes of	$8	Basil	$40	FALSE

List 4 (3 items)					
1:57 min					
6	boxes of	$4	Walnuts	$24	TRUE
4	boxes of	$5	Almonds	$25	FALSE
5	boxes	$1	Zucchini	$6	FALSE

	of				

List 5 (5 items)

2:25 min

5	boxes of	$3	Pasta	$15	TRUE
1	box of	$8	Carrots	$8	TRUE
5	boxes of	$9	Coleslaw	$45	TRUE
9	boxes of	$9	Tangerine	$81	TRUE
4	boxes of	$4	Mushrooms	$20	FALSE

List 6 (8 items)

3:07 min

2	boxes of	$9	Tea	$27	FALSE
6	boxes of	$2	Onion	$12	TRUE
3	boxes	$9	Figs	$36	FALSE

	of				
9	boxes of	$7	Peas	$70	FALSE
6	boxes of	$8	Cashews	$48	TRUE
4	boxes of	$4	Plums	$12	FALSE
7	boxes of	$1	Strawberries	$14	FALSE
3	boxes of	$5	Bacon	$20	FALSE

List 7 (8 items)

4:22 min

1	box of	$7	Spinach	$7	TRUE
5	boxes of	$6	Jam	$36	FALSE
2	boxes of	$4	Nutmeg	$8	TRUE
6	boxes of	$2	Ravioli	$12	TRUE

9	boxes of	$4	Avocado	$45	FALSE
8	boxes of	$8	Cabbage	$64	TRUE
5	boxes of	$2	Pickles	$15	FALSE
6	boxes of	$4	Vanilla	$24	TRUE

List 8 (6 items)

5:35 min

5	boxes of	$5	Cucumber	$30	FALSE
1	box of	$4	Grapes	$4	TRUE
6	boxes of	$4	Oregano	$24	TRUE
6	boxes of	$9	Oatmeal	$54	TRUE
7	boxes of	$5	Lettuce	$35	TRUE
4	boxes	$3	Biscuit	$16	FALSE

of

List 9 (7 items)					
6:31 min					
2	boxes of	$3	Artichoke	$6	TRUE
7	boxes of	$4	Cheese	$5	FALSE
5	boxes of	$5	Peppers	$30	FALSE
2	boxes of	$7	Vinegar	$21	FALSE
8	boxes of	$5	Croutons	$32	FALSE
1	boxes of	$7	Broccoli	$14	FALSE
5	boxes of	$6	Margarine	$36	FALSE

List 10 (7 items)

7:35 min					
6	boxes of	$9	Radish	$54	TRUE
9	boxes of	$2	Paprika	$18	TRUE
8	boxes of	$6	Flour	$48	TRUE
9	boxes of	$4	Lentil	$45	FALSE
1	boxes of	$8	Tamarind	$16	FALSE
4	boxes of	$2	Spinach	$8	TRUE
6	boxes of	$1	Waffles	$12	FALSE

List 11 (4 items)					
8:40 min					
1	boxes of	$1	Cherries	$2	FALSE

3	boxes of	$6	Olives	$18	TRUE
9	boxes of	$8	Almonds	$81	FALSE
7	boxes of	$8	Chicken	$56	TRUE

List 12 (5 items) *9:16 min*					
5	boxes of	$8	Corn	$40	TRUE
4	boxes of	$2	Tomatoes	$8	TRUE
1	boxes of	$1	Ginger	$1	TRUE
2	boxes of	$7	Coconut	$14	TRUE
8	boxes of	$7	Garlic	$56	TRUE

List 13 (6 items) *10:02 min*					
9	boxes of	$4	Salmon	$45	FALSE
6	boxes of	$3	Apples	$18	TRUE
7	boxes of	$7	Chocolate	$42	FALSE
2	boxes of	$1	Sausage	$2	TRUE
1	boxes of	$8	Orange	$1	FALSE
2	boxes of	$7	Asparagus	$21	FALSE

List 14 (6 items) *11:01 min*					
2	boxes of	$1	Tuna	$2	TRUE

1	boxes of	$9	Anchovies	$9	TRUE
4	boxes of	$4	Croissants	$4	FALSE
4	boxes of	$1	Kimchi	$4	TRUE
6	boxes of	$6	Halibut	$42	FALSE
2	boxes of	$8	Sauerkraut	$16	TRUE

List 15 (8 items)					
5	boxes of	$8	Horseradish	$8	FALSE
2	boxes of	$6	Nectarines	$18	FALSE
9	boxes of	$1	Cranberries	$9	TRUE
1	boxes of	$4	Blueberries	$4	TRUE

5	boxes of	$1	Crabmeat	$1	FALSE
4	boxes of	$2	Quinoa	$12	FALSE
3	boxes of	$7	Couscous	$21	TRUE
9	boxes of	$5	Hazelnut	$45	TRUE

List 16 (2 items) *13:03 min*					
5	boxes of	$9	Tortillas	$45	TRUE
6	boxes of	$2	Shallots	$12	TRUE

List 17 (6 items)					
5	boxes	$4	Prunes	$25	FALSE

	of				
2	boxes of	$8	Cilantro	$2	FALSE
4	boxes of	$1	Wasabi	$8	FALSE
4	boxes of	$5	Hummus	$25	FALSE
8	boxes of	$5	Molasses	$40	TRUE
7	boxes of	$3	Apricots	$21	TRUE

List 18 (4 items)					
7	boxes of	$5	Lemongrass	$35	TRUE
5	boxes of	$6	Applesauce	$36	FALSE
5	boxes of	$5	Barley	$5	FALSE

1	boxes of	$2	Hushpuppies	$2	TRUE

List 19 (2 items)					
8	boxes of	$2	Rigatoni	$24	FALSE
8	boxes of	$5	Seasoning	$40	TRUE

Grocery List Task v. 1.0 (adapted from auditory reading span)

Instructions: For this task, imagine you're going to the grocery store and need to remember a list of items. I will read this list of items out loud. You'll also need to complete several chores when you get back home - I will ask you questions about each of these chores. Please take at least 10 seconds to answer each question. Even if you find it difficult, answer them to the best of your ability. At the end of each trial, recall the list of grocery items.

(Practice: Bacon, Onions, Garlic, and Tuna. You need to wash the dishes. Name the different types of steps you will take to wash the dishes. Recall the list.).

Grocery List - Chore 1

Jello

Pasta

Berries

Chore: You're getting ready to go on a long vacation. Name the things you pack.

Grocery List - Chore 2

Mango

Pecans

Celery

Salami

Parfait

Cupcake

Cinnamon

Pepperoni

*Chore***:** You need to do the laundry. Name the steps you take to do the laundry.

Grocery List - Chore 3

Yeast

Basil

Walnuts

Almonds

Zucchini

*Chore***:** You need to write a resume. Name all the things you would include in your resume.

Grocery List - Chore 4

Pasta

Carrots

Coleslaw

Tangerine

Mushrooms

Chore: You are moving into a new apartment or dorm soon. Name the things you will need to purchase for your new room.

Grocery List - Chore 5

Tea

Onion

Figs

Peas

Cashews

Plums

Chore: You need to write a research paper for school. Name the steps you take to write the paper.

Grocery List - Chore 6

Strawberries

Bacon

Spinach

Jam

Chore: Your internet is not working. Name the steps you take to resolve the issue.

Grocery List - Chore 7

Nutmeg

Ravioli

Avocado

Cabbage

Pickles

Vanilla

Cucumber

Chore: You need to clean your room. Name the steps you need to take to clean your room thoroughly.

<u>Grocery List - Chore 8</u>

Grapes

Oregano

Oatmeal

Lettuce

Biscuit

Chore: You need to plan what courses to take for next semester. What courses do you still need to take in order to graduate?

<u>Grocery List - Chore 9</u>

Artichoke

Cheese

Peppers

Chore: You need to do recycling today. Name the different types of categories you can sort the recycling.

<u>Grocery List - Chore 10</u>

Vinegar

Croutons

Broccoli

Margarine

Radish

Paprika

Chore: You need to get ready for school. Name all the things you need to do to get ready.

<u>Grocery List - Chore 11</u>

Flour

Lentil

Olives

Spinach

Waffles

Cherries

Chore: You need to get ready for a date. Name the different tasks you need to do to get ready.

<u>Grocery List - Chore 12</u>

Olives

Almonds

Chicken

Corn

Chore: You have an exam tomorrow. List all the things you need to do to prepare for the exam.

<u>Grocery List - Chore 13</u>

Tomatoes

Ginger

Coconut

Chore: You need to schedule a doctor's appointment. Name the information you need to provide to schedule the appointment.

<u>Grocery List - Chore 14</u>

Garlic

Salmon

Apples

Chocolate

Chore: You need to contact a teammate about a group project. Name the different ways you can contact him or her.

<u>Grocery List - Chore 15</u>

Sausages

Orange

Asparagus

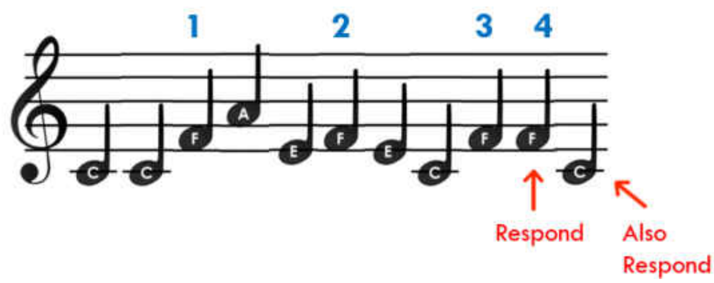
Tuna

Chore: You're throwing a birthday party for a friend. Name the things you do to prepare for the party.

Tone monitoring (adapted from Miyake et al., 2000; Blakeley et al., 2006)

Instructions: You will be presented with a series of low, medium, and high tones. Press the left button whenever the low tone is presented four times, the middle button whenever the medium tone is presented four times, or the right button whenever the high tone is presented four times. You can start a practice trial by pressing the "start" button on the app.

For example, when the *F* tone is played for the fourth time:




09:07
TestFlight
Test Setup
Subject Name
Trial Details
Number of Trials: 99
Experiment Duration: 0:04:57
Inter-Trial Interval: 3 seconds
Device Volume: [16]
Sequence
Sequence Type: Random Equal Number
Custom Sequence: Disabled
Tones
Tone 1 - 300 hz - Enabled
Tone 2 - 800 hz - Enabled
Tone 3 - 1200 hz - Enabled
Duration: 0.5 seconds
Volume: 10
Music
Pre-Test
Begin Test
Setup
Results
Help


09:07
◄ TestFlight
Test Setup
Setup
Results
Help


09:07
◄ TestFlight

Stop-Signal Task (Miyake et al., 2000)

Instructions (difficult): In the task, you will hear a series of low or high tones. Simply press the left side of the screen you hear a low tone, or the right side when you hear a high tone. Press the button as quickly and as accurately as you can before the next tone begins. In some trials the phone will also vibrate - do not press the button when you feel the vibration. You may begin when you're ready.

"Stop Signal Task" Task Flow

Page Description

Enter Participant ID

Select Condition

Experimenter selects Condition 1 or Condition 2

General Instructions

- "In this task, you will hear a series of low or high tones. Simply press the left side of the screen when you hear a low tone, or the right side when you hear a high tone. The tone will continue to play until you press a side or the trial times out.

- Press the button as quickly and as accurately as you can before the tone ends. Press “continue” to listen to the tones.
- [Participant presses “continue” button].

Acclimation

- “Press here for the low tone” [low tone]
- “Press here for the high tone” [high tone]
- Prompt appears
- “You can continue listening to the tones until you feel comfortable. When you are ready to begin, press “Practice” to begin the practice trials.”
- Participants can continue pressing the low and high tones until they are ready to begin the Block 1 practice trials.

Block 1 practice

- “Press the left side of the screen when you hear a low tone and the right side of the screen when you hear a high tone. Do not look at the screen.”
- [Preparation page]
- If participant completes 17 trials AND scores 100% on the last 9 trials
    - Then allow participant to begin Block 1 experimental trials
    - “This concludes the practice. The next set of trials will be recorded. When you are ready to begin the study, press ‘Start’.”
    - Pressing start button takes participant to [Block 1 Experimental Trials page].
- Otherwise, continue to present practice trials until participant scores 100% on the last 9 trials

Block 1 Experimental trials

- [Preparation page]
- [Refer to “Experimental Trials” page in draw.io]
- After all trials have been presented, show blank loading page for 5 s, then go to [Block 2 practice page].

Block 2 practice

- “For these trials, press the left side of the screen when you hear a low tone and the right side of the screen when you hear a high tone. However, when you feel a vibration, do NOT respond. The tone will continue to play until you press a side or the trial times out. Do not look at the screen.”

- [Preparation page]
- If participant completes 17 trials AND scores 100% on the last 9 trials
- Then allow participant to begin Block 2 experimental trials
    - "This concludes the practice. The next set of trials will be recorded. When you are ready to begin the study, press 'Start'." Pressing start button takes participant to [Block 2 Experimental trials page].
- Otherwise, continue to present practice trials until participant scores 100% on the last 9 trials

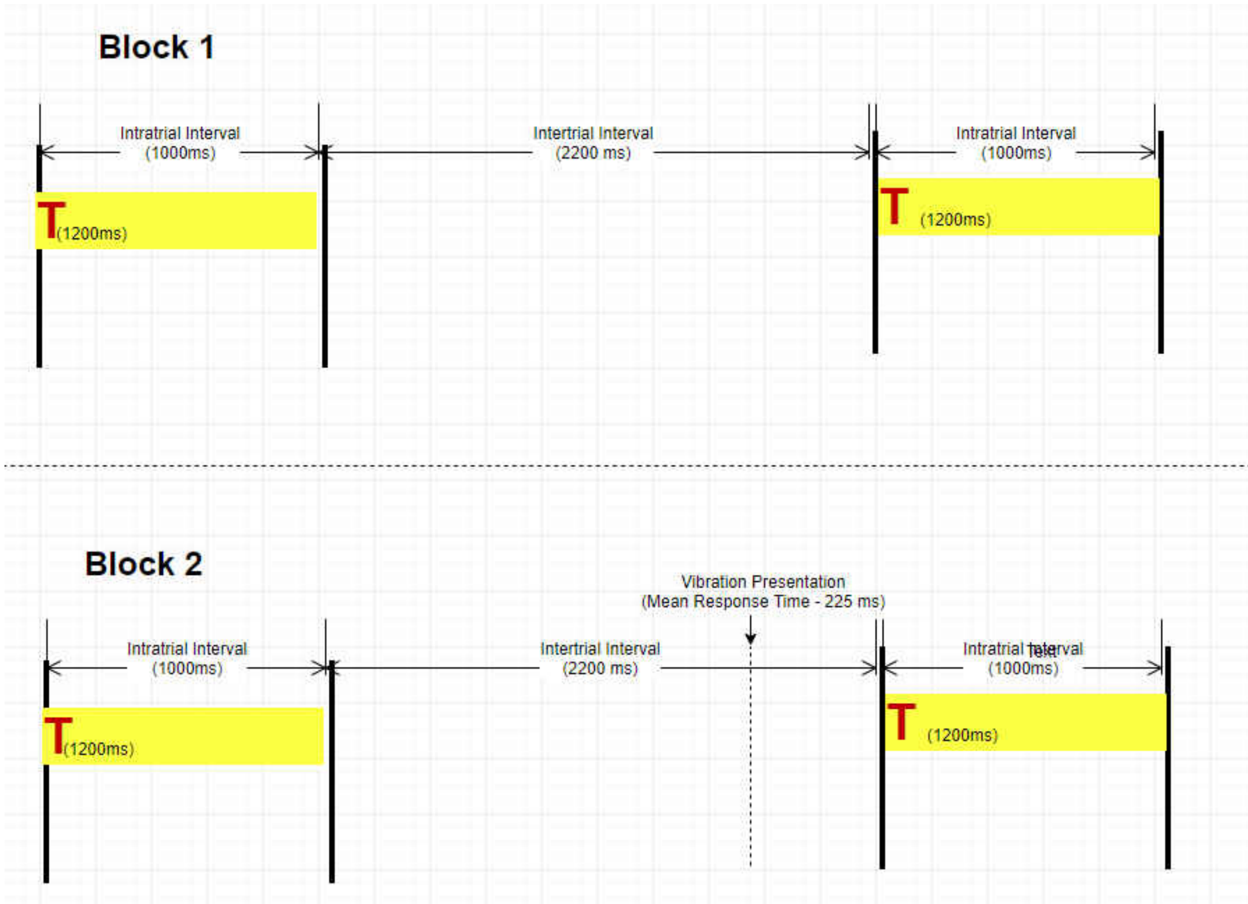
Block 2 Experimental trials

- [Preparation page]
- [Refer to "Experimental Trials" page in draw.io]

Preparation page

- Shows the following countdown:
    - Ready… set… go! [[Let's try to make this into an audio recording, to minimize the likelihood of the participant looking down at the screen.]]

Time between onset and tone - block 1 average response time - 225 Ms.


Block 1
Intratrial Interval
(1000ms)
Intertrial Interval
(2200 ms)
Intratrial Interval
(1000ms)
T(1200ms)
T (1200ms)
Block 2
Vibration Presentation
(Mean Response Time - 225 ms)
Intratrial Interval
(1000ms)
Intertrial Interval
(2200 ms)
Intratrial Interval
(1000ms)
T(1200ms)
T (1200ms)

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