MEDIA MULTITASKING AND ITS EFFECT ON MULTISENSORY INTEGRATION

By

Hao Ngo

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Arts in Psychology

Middle Tennessee State University

March 2021

Thesis Committee:

Dr. Paul Foster, Committee Chair

Dr. James Houston, Committee Member

Dr. David Kelly, Critical Reader

ABSTRACT

The present study examined media multitasking and its potential benefit of multisensory integration. Prior research on media multitasking have found that heavy media multitasking is associated with a wider breadth of attention. Research have also found spreading attention across sensory modalities may be more beneficial to detect multisensory stimuli and enhance perception of the environment. Included in the final analyses were 40 (10 men and 30 women) undergraduate college students. Participants completed three questionnaires including the media use questionnaire and completed two psychological assessments to investigate the two extreme media groups and multisensory integration. Collected data were analyzed with a series of 2 (Group: HMM versus LMM) x 2 (Condition: VSAT Trial 2 versus VSAT Trial 3) ANOVAs as well as 2 (Group: HMM versus LMM) x 2 (Condition: LGME Eyes Open versus LGME Eyes Closed) ANOVAs. Results showed that there were no significant difference between the two extreme media groups or between MMI scores and conditions, demonstrating that both groups have similar breadth of attention and did not benefit from either conditions.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Media Multitasking

What is Media Multitasking?

Multitasking is a term frequently used to describe the activity of performing multiple tasks at once during a specified time period. Rothbart and Posner (2015) defined multitasking as accomplishing multiple goals in the same general time period by "engaging in frequent switches between individual tasks" (p. 2). Multitasking enables people to achieve more goals within a given time frame and has always been an essential human behavior as people attempt to complete multiple tasks simultaneously in order to meet pressing demands. Since most research on multitasking has focused on one specific type of multitasking activity, Salvucci and Taatgen (2010) proposed a multitasking continuum in an attempt to organize the broad range of multitasking activities. The continuum proposed by Salvucci and colleagues has concurrent multitasking on one end of the spectrum and sequential multitasking on the opposite end. Concurrent multitasking (dual-tasking), which is the main focus in this present study, is when tasks occur together simultaneously or with very short interruptions (Salvucci & Taatgen, 2010).

The use of media to perform multiple tasks at once has become more prevalent in modern society as technology rapidly proliferates and more professions require individuals to perform multiple tasks, often with some sort of media, simultaneously. Rideout, Foehr, and Roberts (2010) described this phenomenon as media multitasking. Lang and Chrzan defined media multitasking as "performing two or more tasks simultaneously, one of which involves media use" (2015, p. 100). Today's youth are the most techno-savvy generation yet, having grown up on the computer and internet, and have fully embraced the virtual world. As a result, there are many and varied opportunities for media multitasking. Due to their immersion in technology, these individuals are known as the Net generation (Carrier, Cheever, Rosen, Benitez, & Chang, 2009). According to Carrier et al. (2009), individuals born in 1980 or later, are considered to be part of the Net generation while individuals born between 1946 to 1964 are considered to be part of the Baby Boomer generation. The immersion in technology with the likely concomitant increase in media multitasking has even led Rideout et al. (2010) to refer to 8 to 18 year-olds as "Generation M" with the M standing for multitasking.

Carrier et al. (2009) reported members of the Net generation showed significantly more multitasking than other generations and are less likely to find any combinations of tasks to be difficult compared to Baby Boomers. They also found that the Net generation uses a greater number of tasks combined at once and more variety of tasks than older generations. When compared to the Baby Boomer generation, members of the Net generation on average switch from studying to media every six minutes (Rosen, Carrier, & Cheever, 2013). About 81% of the generation M regularly use multiple media at once and spend on average 7 ½ hours a day with media, with total TV consumption alone consisting of over four hours a day (Rideout et al., 2010).

The way young people use media is changing and this may have implications for the use and proliferation of media multitasking. Foehr (2006) suggested that further research might indicate that media multitasking is a valuable life skill as young people are learning how to juggle multiple activities while using existing technologies in new creative ways. Therefore, the effect of media multitasking and its potential benefits is an important area to study as people are using technology in increasingly different ways more than ever before and at a younger age. Further, investigating media multitasking is particularly important given that all behavior is derived from the brain. Hence, the possibility exists that engaging in media multitasking may affect brain structure and function, which can in turn affect other cognitive functions.

Media Multitasking and Its Relations to Brain Functioning

Many investigators have reported that individuals who frequently engage in multitasking behavior show differences in neural structures (Loh & Kanai, 2014, Moisala et al., 2016). These differences in neural structure and function may depend on the type of task and degree of attention. For instance, during multitasking, the amount of attention available to complete the tasks is limited. Generally, the amount of focused attention on any task decreases as the number of task demands increases. Rekart (2011) reported that the total amount of brain activity when two tasks are attempted simultaneously appeared to be less than the total amount of brain activity when each task is completed in isolation. When attending to task relevant stimuli, the information gets prioritized first over task irrelevant stimuli, creating a stronger representation in the neural system and affecting cognitive processes such as attention and memory.

Rothbart and Posner (2015) identified three specialized attention networks in the brain that are associated with multitasking. The executive attention network is one of the three networks and is critical for multitasking because it plays a role in controlling distraction during task performance and switching between tasks. Executive attention includes the anterior cingulate cortex (ACC), which is involved in many higher-level functions such as attention allocation and decision-making, and also plays a role in socio-emotional regulation (Rothbart & Posner, 2015). The role of the ACC in multitasking was demonstrated by Dreher and Grafman (2003) who compared dual-task and task-switching performance by using functional MRI (fMRI). The results of this study indicated that the rostral ACC is activated only when tasks are performed simultaneously. The researchers believe that the rostral ACC is activated during concurrent tasks to monitor any conflicts between different information processing pathways. Hence, the ACC may be a particularly important structure involved in multitasking behaviors.

Many other studies have also demonstrated the importance of the ACC in multitasking. For instance, Loh and Kanai (2014) used voxel-based morphometry (VBM) to assess gray matter and white matter density as a function of degree of media multitasking. The results indicated that individuals who engage in heavier media multitasking have smaller gray matter density in the ACC region. The authors specifically noted that a higher level on the media multitasking index (MMI) is negatively associated with functional connectivity in the ACC region. Zhang et al. (2016) also used VBM analysis and found that ACC gray matter volume is associated with overall performance and time-monitoring abilities in multitasking. Given the negative relationship between media multitasking and ACC gray matter volume and functional connectivity along with the importance of the ACC in cognitive processes, the findings of Loh and Kanai (2014) and Zhang et al. (2016) suggest that individuals who engage in heavier media multitasking may have poorer cognitive control. Ophir et al. (2009) also suggested heavier media multitasking is associated with poorer cognitive control when they demonstrated that individuals with higher MMI have a harder time maintaining attention on task relevant stimuli. Additionally, Sanbonmatsu, Strayer, Medeiros-Ward, and Watson (2013) examined individual differences in multitasking and found that individuals who often engage in multitasking are more impulsive and have a harder time blocking out distractions.

The ACC is located within the medial dorsal region of the frontal lobes and there is a possibility that the frontal lobes more generally are important for multitasking behaviors, particularly given the importance of the frontal lobes in executive functioning. Nasr, Moeeny, and Esteky (2008) reported that the frontal cortex, which is responsible for many executive functions such as response inhibition, is important for blocking out irrelevant information if the individual is aware of its irrelevancy from the beginning of the task. Intact executive functions allows a wide variety of everyday, real world functions such as planning, initiating goal-directed behavior, and performing multiple tasks simultaneously (Sanbonmatsu et al., 2013). The role of the frontal lobes in multitasking is also illustrated in an investigation by Moisala et al. (2016), who used fMRI to assess brain activity during concurrent tasks. The results of this study indicated that a MMI is associated with greater activity in the right prefrontal regions. The researchers interpreted this finding as suggesting that more effort and executive control is required by heavy media multitaskers in order to focus on the tasks in presence of distractors. Also, Bavelier, Achtman, Mani, and Focker (2012) found that frequent gamers, which can be considered analogous to real world multitasking, showed reduced activation of visual and frontal-parietal regions in comparison to nongamers. They suggested that the frequent gamers were more efficient at utilizing their cognitive resources to meet attention demands when the game became more challenging and required more attention from the gamers.

Moisala et al. (2016) suggested the aforementioned increased activity in the right frontal cortex may indicate that this region of the brain is not functioning as efficiently, thus requiring more cortical activity to redirect and maintain attention on tasks. For instance, Burgess (2000) and Denmark, Fish, Jansari, Taylor, Ashkan, and Morris (2019) reported that individuals with frontal lesions often show problems with decision making and planning in their everyday life despite having normal performance on neuropsychological tests. Since the ACC and the right dorsolateral prefrontal cortex are critical for multitasking, poor multitasking performance can be seen in patients with frontal lesions (Burgess, 2000). Dreher, Koechlin, Tierney, and Grafman (2008) also reported that patients with damage to the frontal pole region of the prefrontal cortex (FP-PFC) are impaired in managing multiple task goals. They suggested that increased activity in the FP-PFC during multitasking may be beneficial to manage task goals and cognitive load, thus reducing interference in attentional control in the prefrontal cortex and ACC.

The possibility exists that other brain structures are also altered by media multitasking, especially since research has demonstrated that learning and training can alter neural processes in various regions of the brain in order to learn new tasks and meet environmental demands. Jaeggi, Buschkuehl, Jonides, and Perrig (2008) reported that practice and learning may increase brain processing speed, improve working memory, and ability to multitask because the brain will rewire itself to do routine tasks and demand less cognitive resources to complete the tasks. Foerde, Knowlton, and Poldrack

(2006) also reported that learning while distracted, or multitasking, is altered when they used fMRI to analyze participants' brain activity in the hippocampus and striatum. Generally, the hippocampus is recruited during learning to process, store, and recall information. However, Foerde et al. (2006) found that activity in the right hippocampus was significantly correlated with performance when participants attempted to learn a new task but not when there were distractions. Instead, the striatum was recruited, which is involved in habit and rote learning. This suggests that the striatum may also be activated when multitasking is involved.

In summary, media multitasking can lead to changes in the neural structure, depending on the level of MMI, and affect multitaskers' performance. Since media multitaskers are constantly looking for creative ways to juggle and complete multiple tasks at once, it is very possible that other neural structures are enhanced or altered as well. Learning and training can alter the neural processes in the brain and may provide benefits to multitaskers. There are currently only two studies reported that have investigated the neural profile of media multitaskers (Loh & Kanai, 2014; Moisala et al., 2016). Hence, more research is needed to understand how the brain can differ between heavy and light media multitaskers. Uncapher et al. (2017) also reported that more research is needed to determine whether changes in the brain, such as the reduced gray matter in the ACC, is caused by different levels of media multitasking or vice versa. Due to the structural differences in the brain between individuals who engage in heavy and light media multitasking, cognitive functions, such as problem solving and inhibitory control, are also affected.

Effects of Media Multitasking on Cognitive Functions

The brain is a complex organ that is capable of many functions, however, there is a limited amount of cognitive resources available in the brain to complete tasks. Many studies have evaluated the effect of media multitasking on cognitive performance and found differences between heavy media multitaskers (HMMs) and light media multitaskers (LMMs). Attention, working memory, and interference management, which consists of filtering out irrelevant stimuli, are some of the popular domains that have been studied. Although it is unclear whether the differences in cognitive functions are caused by the different levels of media multitasking or vice versa, most research has indicated that heavier media multitasking have some detrimental effects on behavior and cognitive performance.

Hwang and Jeong (2018) proposed that task performance is likely to be impaired when there is greater sensory interference competing for cognitive resources. This proposal was based on Kahneman's (1973) capacity model of attention, which described attention as a reservoir of mental activity to complete tasks. The capacity model stated that some tasks are more complex than others and require more mental effort to complete. The degree of effort or attention that is allocated to tasks is determined by a central processor. Performing multiple tasks at once then produces interference, distraction, error, and mental stress (Courage, Bakhtiar, Fitzpatrick, Kenny, & Brandea, 2015). According to Pool, Koolstra, and van der Voort (2003), each task has to compete for the limited information-processing resources and the information presented in concurrent tasks may exceed the attentional capacity. The amount of interference depends on how demanding each of the tasks are.

Rothbart and Rosner (2015) proposed a cognitive dimensional framework of media multitasking. These researchers proposed that individuals tend to choose multitasking behaviors that do not require excessive resource demands and are less likely to disrupt cognitive processing. Sanbonmatsu et al. (2013) reported individuals often engage in multitasking behaviors because they tend to be impulsive and are less able to block out distractions. Sanbonmatsu et al. (2013) and Baumgartner, Weeda, van der Heijden, and Huizinga (2014) also reported engaging in multiple attention demanding tasks simultaneously can be cognitively and physically taxing, resulting in poor performance in executive functions.

Most research on multitasking has reported that greater use of multitasking is associated with poor performance on attentional tasks (Loh & Kanai, 2014; Ralph, Thomson, Cheyne, & Smilek, 2014). Several studies have found that heavy media multitaskers (HMMs) tend to perform worse than light media multitaskers (LMMs) on measures of working memory (Baumgartner et al., 2014; Cain, Leonard, Gabrieli, & Finn, 2016; Sanbonmatsu et al. 2013; Uncapher, Thieu, & Wagner, 2016) and interference management tasks (Lui & Wong, 2012; Moisala et al., 2016; Ophir et al., 2009). Other studies have found the opposite effects or no difference for working memory (Ophir et al., 2009) and interference management (Baumgartner et al., 2014; Cain et al., 2016; Murphy, McLauchlan, & Lee, 2017).

Overall, frequent engagement in media multitasking behavior is associated with poorer performance on executive functions and impulsive behavior due to limited amount of cognitive resources. However, the amount of interference depends on the degree of resources that is required by each of the tasks. Since heavy media multitasking has a negative effect on cognitive performance, many studies have examined the differences between LMMs and HMMs.

Light Media Multitaskers versus Heavy Media Multitaskers

Many studies have used an extreme-group approach to compare individuals and their media consumption by using a Media Use Questionnaire developed by Ophir et al. (2009), which assesses an individual's usage of twelve different media forms. For each media form, participants report the total amount of hours they spend on it each week and how likely they are to use other media forms while using the primary media form. Responses on the questionnaire are used to calculate a media multitasking index (MMI), which is used as an indicator of how much an individual engages in media multitasking during a typical "media consumption hour" (Ophir et al., p.4, 2009). Heavy media multitaskers (HMMs) are distinguished by one standard deviation above the MMI mean while light media multitaskers (LMMs) are distinguished by one standard deviation below the mean (Ophir et al., 2009).

Although research has demonstrated mixed results between the two extreme media multitasker groups, HMMs have typically exhibited lower performance on numerous tasks involving cognitive abilities compared to LMMs (Cain & Mitroff, 2011; Lui & Wong, 2012; Ophir et al., 2009; Ralph et al., (2014); Sanbonmatsu et al., 2013). However, the results of these studies comparing HMMs to LMMs have been rather equivocal. Specifically, some studies have found no difference between HMMs and LMMs (Alzahabi, Becker, & Hambrick, 2017; Murphy et al., 2017) while other studies have found that HMMs performed better than LMMs under certain conditions such as task switching and without a speed-accuracy trade off (Alzahabi & Becker, 2013).

A major study by Ophir et al. (2009) found that HMMs performed significantly worse than LMMs on several cognitive tasks, especially tasks involving attentional filtering of distracting stimuli. They examined individuals who engaged in multiple computerized technologies and found that HMMs processed information differently from LMMs when they had a harder time filtering out irrelevant information from their environment. Compared to LMMs who only focused on task relevant stimuli, HMMs distributed their attention almost evenly to both relevant and irrelevant task stimuli. Lui and Won (2012) found similar findings to Ophir et al. (2009) when they reported that HMMs were more sensitive to task irrelevant information, thus making them have a harder time filtering out distractors.

Additionally, Cain and Mitroff (2011) demonstrated that HMMs do not modulate their performance during a color-singleton search task among green and red shapes, even when they were informed that the color singleton would never be the target. Participants in the never condition were informed that the color singleton would never be the target whereas participants in the sometimes condition were told that the color singleton would be the target sometimes. The HMMs persisted in their wider attentional allocation, even when they were instructed otherwise. The researchers believe that the inability of HMMs to filter irrelevant stimuli causes a feedback loop where HMMs become more accustomed to using multiple medias simultaneously and more frequently.

Ophir et al. (2009) and Lin (2009) both suggested that HMMs are distracted by multiple streams of media because of a difference in orientation rather than a deficit in cognitive control. Cain and Mitroff (2011) shared the same belief as Lin (2009) and suggested that both HMMs and LMMs may have started out with similar attentional profiles. However, HMMs develop a broader attentional breadth of attention as they continue to use multiple media more frequently than LMMs. Due to the greater breadth of attention, HMMs do not automatically filter out any information. They are more readily distracted and distribute attention almost equally to both irrelevant and relevant task stimuli, suggesting that HMMs are less cognitively equipped than LMMs (Ophir et al., 2009). However, HMMs may have an advantage when once irrelevant information becomes important to their tasks since they process both relevant and irrelevant information. Cain and Mitroff (2011) suggested that the LMMs were using top-down distraction filtering better than HMMs. However, since HMMs have a greater tendency to respond to stimuli outside the realm of their immediate task and explore the stimuli, they may be relying more on a bottom-up attention mechanism where the brain process sensory information from the environment and working upwards until a representation of the object is formed (Lin, 2009).

Uncapher and Wagner (2018) reported the wider attentional scope in HMMs resulted in a lower performance on working memory tasks because they continuously allow task irrelevant information to compete with task relevant information. They also reported that there was no significant effect on tasks assessing short-term memory with no distractors. However, when there were distracters present, HMMs' performance was significantly lower than LMMs. Due to the different cognitive style and changes in the brain by media multitasking behaviors, it can be expected that there are other differences between the two extreme media multitasker groups.

To summarize, HMMs process all information, sampling from multiple sources instead of selectively attending to information that is relevant to the task, resulting in a broader attentional breadth or breadth bias (Ziegler, Mishra, & Gazzaley, 2015). The breadth bias in HMMs could be a reason why their performance on tasks involving attention and memory is worse than LMMs. LMMs use top-down attentional control more, where perception is formed from general, broad impressions at the first glance before attending to the small detailed information. This top-down attentional control might allow them to focus on a single task despite the distractions around them. The broader attentional filter in HMMs allows them to integrate seemingly irrelevant information because they are able to view both irrelevant and relevant information almost equally while LMMs would only focus on the relevant information that is important to the task.

Multisensory Integration

Multisensory Integration and Associated Brain Regions

Due to the influx of sensory information from the environment, multisensory integration is critical because it enables us to make sense of the world and have coherent and meaningful perceptual experiences. However, the sensory information received may be strongly influenced by seemingly irrelevant but informative cues (Stein, Stanford, & Rowland, 2014). Multisensory integration is defined as the “process by which inputs from two or more senses are combined to form a product that is distinct from, and thus cannot be easily ‘deconstructed’ to reconstitute the components from which it is created” (Stein et al., p. 4-15, 2014).

Multisensory integration is a highly automatized process and is important for cognitive functioning. Also, multisensory integration may occur without perceptual awareness and even when there are no meaningful relationships between the different sensory inputs (Engel, Senkowski, & Schneider, 2012). Lewkowicz and Ghazanfar (2009) reported that basic multisensory perceptual abilities are gradually developed during the first year of life when the brain is highly plastic and are then fine-tuned over time through the individual's physiological development and experiences that they acquire.

Stein et al., (2014) and Perrault, Rowland, and Stein (2012) reported that the cat superior colliculus (SC) serves as an excellent model to understand multisensory integration since it is the primary site for different sensory modalities (visual, auditory, and somatosensory) to converge. Clemo, Keniston, and Meredith (2012) and Tang, Wu, and Shen (2016) both reported that the SC contains many morphological classes of neurons that are highly correlated with multisensory processing and is involved in reflexive orienting of attention toward stimuli, though mainly visual. The SC neurons have multiple excitatory receptive fields, one for each sensory modality, and may overlap each other in the same space (Stein & Stanford, 2008). When the sensory stimuli are within the overlapping receptive fields, multisensory responses are enhanced.

Another important area of the brain for multisensory integration is the anterior ectosylvian sulcus (AES). The AES is located at the intersection of distinct sensory modality specific regions such as the visual and auditory fields and the SC. Due to the location of the AES, the AES may contain many multisensory neurons at the intersection between the different sensory representations, thereby giving it a strong influence on multisensory integration in the SC (Perrault et al., 2012). Additionally, Stein and

Stanford (2008) reported that early experiences are coded in the AES projections to the SC, suggesting that early experiences have an influence on the multisensory processes.

Although the SC and the AES are critical for multisensory integration, there are also other areas that are as equally important, such as the posterior parietal cortex. The posterior parietal cortex (PPC) plays a role in attention allocation for unimodal and multisensory processing and may help enhance reaction time to sensory stimuli (Yau, DeAngelis, & Angelaki, 2015). The PPC can also help shift spatial attention across and within sensory modalities and serve as a filter for incoming sensory information. Macaluso and Driver (2005) also reported that the PPC mediates interactions between sensory modalities by shaping the process in primary sensory areas. For instance, vision can modulate activity in the somatosensory cortex or vice versa. Due to these findings on the PPC, Yau et al. (2015) suggested that further investigating this area might be beneficial to learn more about attention and multisensory processing.

To summarize, multisensory integration plays a critical role in processing stimuli from the environment to create a better understanding of the world. Several regions of the brain are important for multisensory processes such as the SC, AES, and PPC. However, multisensory integration cannot occur without the process of attention since they are intertwined with each other.

Attention and Its Relation to Multisensory Integration

Since it is not possible for humans to devote their attention to all sensory inputs from the environment, attention plays a key role in multisensory integration because it filters information from the environment and determines what is relevant. Gau, Bazin, Trampel, Turner, and Noppeney (2020) reported that multisensory and attentional mechanisms are closely intertwined due to their roles in regulating the influx of sensory information from the environment. However, the interaction between attention and multisensory integration remains a complex and controversial topic (Macaluso et al., 2016). Although controversial, a multitude of studies indicate that multisensory integration can be modulated by attention (Busse, Roberts, Crist, Weissman, & Woldorff, 2005; Mozolic, Hugenschmidt, Peiffer, & Laurienti, 2008; Talsma, Senkowski, Soto-Faraco, & Woldorff, 2010).

Attention is defined as the "guiding process in which relevant inputs are being selected for detailed processing and perceptual awareness out of the inflow of all incoming information" (Macaluso, Noppeney, Talsma, Vercillo, Hartcher-O'Brien, & Adam, 2016 p. 557–583). Tang et al. (2016) reported endogenous and exogenous attention are the two mechanisms that are involved in filtering information and are constantly competing with each other for control over attention. Endogenous attention is a "goal-driven" because it requires an individual to voluntarily orient themselves toward the stimulus, sensory modality, or specific region of space in order to achieve task goals (Macaluso et al., 2016). Exogenous attention is "stimulus-driven" because it is an involuntary reflex that directs an individual to a salient sensory event, even when the attention capturing stimuli are unrelated to current task (Tang et al., 2016). During cross modal spread of attention, both mechanisms interact with each other, making it difficult to determine whether exogenous or endogenous attention is interacting with multisensory integration (Tang et al., 2016). According to Talsma et al. (2010), multisensory integration is driven by exogenous attention but the multisensory processing is influenced by the top-down attentional control or endogenous attention.

Van der Berg et al. (2008) reported that task irrelevant auditory stimuli helped individuals find target visual stimuli more quickly, which suggests that bottom-up integration can drive attention. This finding is known as the "Pip and Pop" effect because the auditory stimulus was able to draw attention to the salient visual target in a visual search task and reduce search time. Their findings supported the idea that integration of multisensory information can recruit attention (Macaluso et al., 2016). Busse et al. (2005) also found similar results when they reported that attention to one sensory modality can spread to a different sensory modality when they occur simultaneously and strongly affect the processing of irrelevant stimuli in the different modality, even when it is irrelevant to the current task. Both task relevant and synchronous irrelevant stimuli are integrated into one coherent and meaningful object by using the process of endogenous attention or bottom up process. When processing both stimuli from different sensory modalities, Talsma (2015) reported the stimuli are processed in greater depth to form a distinct form or representation than stimuli that are not concurrent in time. Additionally, Talsma et al. (2010) reported that inputs from different modalities that are spatially and temporally aligned are more likely to capture attention and be processed than inputs that are not aligned.

Talsma et al. (2010) provided a framework for the interaction between attention and multisensory integration. He proposed that the complexity of the stimuli from the environment and its competition for attention determines the directionality of the interaction between attention and multisensory integration (Macaluso et al., 2016).

Bottom up multisensory integration will process the presence of an auditory stimulus, which will enhance the salience of the visual stimulus that is occurring at the same time. By enhancing the salient visual stimuli, this will increase the chance of the visual stimulus to capture attention and be processed (Talsma et al., 2010). This also causes a shift of attention to the visual stimulus. Due to other auditory and visual stimuli that may occur in the environment, top down attention will be necessary to enhance both the co-occurring visual and auditory stimuli in order to integrate them and form a neural representation (Talsma et al, 2010). By attending to the visual stimulus and linking it to the auditory stimulus, it leads to an enhanced multisensory integration and spread of attention across space and modality from visual to auditory. This multisensory enhancement can also occur even when attention selection in task relevant sensory modality, such as visual search task, is challenging (Talsma et al., 2010).

Telsma et al. (2010)'s framework suggests that task irrelevant stimuli may conflict with task relevant stimuli but can serve as an attention capturing distractor and increase attentional spread and enhance the perception of that irrelevant stimulus. Mozolic et al. (2008) also reported that integrating spatially or temporally congruent stimuli from multiple sensory modalities can enhance perception. Modality-specific selective attention is used to filter out task irrelevant information and limit distractions. However, this may not be beneficial to individuals when they have to make quick and accurate discriminations between multisensory stimuli.

Mozolic et al. (2008) demonstrated that individuals who divided their attention across modalities had faster reaction times when responding to unisensory and multisensory targets on a black background. They found that attention to a single sensory modality would reduce multisensory integration since participants had slower reaction times when it is only selective visual or selective auditory attention. Significant multisensory integration only occurred when participants attended to both visual and auditory modalities (Mozolic et al., 2008). Due to this finding, they suggested that selective attention attenuates multisensory integration because stimuli from other modalities are ignored and suppressed, thus making less sensory information available for integration. Gau et al. (2020) provided support for Mozolic et al. (2008) when they reported that attending to only one sensory modality withdraws attentional resources and reduces processing of information from other sensory modalities while the occurrence of two different sensory stimuli can boost the salience of an event. Research also found that modality-specific attention will attenuate multisensory integration and make individuals rely more on unisensory information (Macaluso et al., 2016).

To summarize, multisensory integration and attention are intertwined with each other and this can have an effect on how sensory information is processed to form perception. Task irrelevant stimuli may capture attention from one sensory modality and spread it to a different sensory modality. According to several studies, selective attention to one specific sensory modality may not be beneficial for multisensory integration (Gau et al., 2020; Mozolic et al., 2008; Talsma et al., 2010). Instead, a broader attention or more divided attention across sensory modalities may be more beneficial to detect multisensory stimuli and enhance perception of the environment.

Effects of Media Multitasking on Multisensory Integration

Along with new technological advancements, media multitasking provides new streams of sensory input that challenges our brain to adapt to our environment. New sets of information can be distracting and impose a greater cognitive demand in the brain as it has to selectively attend to sensory inputs and sort what is relevant and what is not while completing multiple tasks at once. By having a broader attention across sensory modalities, the brain is provided with large amounts of sensory information that can enhance perception and boost the salience of an event. Additionally, neural structure differences in the brain indicated that heavier media multitasking is associated with poorer cognitive control, which can be associated with the wider attentional scope. Due to the differences in neural structures by different levels of media multitasking and the broader breadth of attention, it is possible that these differences may be beneficial in some situations.

According to Loh and Kanai (2014), HMMs have poorer cognitive control due to reduced gray volume in the ACC, which is also involved in higher level functions such as attention allocation. In addition to reduced gray matter, Moisala et al. (2016) found that HMMs have higher activation in the right superior and medial frontal gyri and medial frontal gyrus. Wiradhany and Koerts (2019) reported that increased activation in those regions are linked to increased top-down attentional control, suggesting that HMMs tend to over rely on exogenous control of attention. By relying more on exogenous control and less on endogenous control of attention, it causes HMMs to have a poorer cognitive control. Sanbonmatsu et al. (2013) also reported that HMMs have trouble filtering out distractors because they are more impulsive, which is associated with a reduced activity in the prefrontal cortex since it is responsible for inhibitory control. Additionally, both Cain and Mitroff (2011) and Lin (2009) reported that HMMs' inability to filter out irrelevant stimuli is due to a broader breadth of attention. Uncapher and Wagner (2018) suggested that HMMs' poor performance on working memory tasks compared to LMMs is due to the wider attentional scope in HMMs. Since HMMs have the tendency to attend to multiple sensory information at once, they may be better at dividing their attention across different sensory modalities, thus making them better at multisensory integration.

Lui and Wong (2012) aimed to study the difference between HMMs and LMMs in their ability to filter irrelevant stimuli and evaluate how frequent media multitaskers could integrate visual and auditory information. They used a visual search task that uses the pip-and-pop paradigm developed by Van der Burg et al. (2008). Participants were asked to fixate on the dot in the center of the computer screen and indicate the orientation of a target line among red and green line segments. The line segments and target are in various orientations (horizontal or vertical) and changed color between red and green at random intervals. A short auditory tone accompanied the color change in the line segments. There were four blocks of trials with two blocks being tone-absent and two blocks tone-present. However, participants were not informed about the meaning of the tone and were told not to attend to the tone.

Lui and Wong (2012) found that HMMs were able to process the sensory inputs better than LMMs by demonstrating that the HMMs' reduced filtering of irrelevant distractors (the short auditory tone) that were associated with the task had actually aided them with their task. They also found a positive correlation between the media multitasking index (MMI) and multisensory integration index in terms of accuracy in detecting the orientation of the target. In the tone-absent condition, HMMs performed significantly worse than LMMs. However, in the tone-present condition, there was no significant difference in performance between the two extreme groups. This suggests that

HMMs have a larger multisensory integration effect when they were able to detect the orientation of the target more accurately than LMMs in the tone-present condition and were less accurate than LMMs in the tone-absent condition.

Based on the findings of Mozolic et al. (2008) and the framework of Talsma et al. (2010), the broader breadth of attention may be beneficial for multisensory integration because HMMs were able to distribute their attention almost evenly to task relevant and irrelevant information (visual and auditory stimuli). Individuals who attended to both visual and auditory modalities were quicker to discriminate the multisensory stimuli (Mozolic et al., 2008) and detect changes in the target's orientation among distractors (Lui & Wong, 2012). Several studies have also reported that attention to one sensory modality can spread attention across another sensory modality (Busse et al. 2005; Gau et al., 2020) and enhance perceptual processing of another stimulus (Talsma et al., 2009). Mozolic et al. (2008) also reported that selective attention on unisensory modality actually limits the amount of sensory information available for integration. This suggests that LMMs who have a greater tendency to focus on task relevant information (a top-down process) would not be as good at multisensory integration because they would focus on unisensory modality and suppress other sensory information.

Laurienti, Burdette, Maldjian, and Wallace (2006) demonstrated that although the ability to process unisensory information declines in elderly population, multisensory integration was enhanced in older adults when they integrate congruent stimuli from multiple sensory modalities. The elderly population is able to compensate their deficit in processing unisensory stimuli by enhancing multisensory integration to create meaningful representations of their environment. Hugenschmidt, Mozolic, and Laurienti (2009) also found that selective attention attenuates multisensory integration in young people when they direct their attention to only vision or hearing stimuli. They also found that elderly populations had a reduction in multisensory integration when they selectively attended to one specific sensory modality and integration was the greatest when they divided their attention. This provides support that spreading attention across sensory modalities is more beneficial than selective attention on unisensory modality.

Although there are performance decrements and neural changes associated with HMMs, not all changes are detrimental. It is possible that heavy media multitasking behavior is associated with better multisensory integration due to the broader attentional breadth because it allows more attention to be spread across sensory modalities. Individuals who spread their attention across sensory modalities and process seemingly irrelevant information have better reaction time than individuals who do not (Laurienti et al., 2006; Lui & Wong, 2012; Mozolic et al., 2008; van der Burg et al., 2008). This suggests that modality-specific selective attention seen in LMMs may actually not be as good for multisensory integration as broader attention on multiple sensory modalities.

Limitations of Media Multitasking Studies

A problem with many of the studies on multisensory integration and media multitasking is that these studies often do not represent a complete picture of how media multitasking works because the tasks are usually highly controlled and simplified. The studies are performed in a controlled setting with an experimenter providing instructions. Courage et al. (2015) reported that tasks in laboratory-based settings lack ecological validity because multitaskers in the real world have more flexibility than they would in lab experiments. Unlike traditional lab experiments, where there are well-defined variables, many unexpected environmental variables in the real world can affect the performance of media multitaskers. Lin (2009) suggested that media multitaskers may be more internally driven and in control over what they see as their task or distractions. Due to this internal control, it may affect their performance and cognitive control.

Another problem with much of the existing literature was discussed by Lin (2009), who reported that most research has tended to assess focused cognitive control (Baumgartner et al., 2014; Baumgartner & Sumter, 2017; McAlister & Schmitter-Edgecombe, 2013; Sanbonmatsu et al., 2013; Uncapher et al., 2016) instead of breadth-bias cognitive control (Cain & Mitroff, 2011; Lui & Wong, 2012; Ophir et al., 2009). Additionally, two recent studies (Alzahabi & Becker, 2013; Minear, Brasher, McCurdy, Lewis, & Younggren, 2013) revealed contradictory findings to Ophir et al. (2009) and Lui and Wong (2012) when they reported that HMMs did not perform worse than LMMs on attentional tasks and dual switching. Loh and Kanoi (2015) suggested that HMMs adopted a breadth-biased mode of attention control for tasks that are more bottom-up such as the visual search used by Lui and Wong (2012). However, during top-down tasks, HMMs were more varied in their adoption of breadth-biased attentional control (Loh & Kanoi, 2015).

Furthermore, Lui and Wong (2012) is the only study that examined whether a breadth-bias cognitive control would allow HMMs to perform better on a multisensory integration task. In the study by Lui and Wong (2012), participants' accuracy in their indication of target's orientation in tone-absent condition may have hit ceiling effects so there was a concern about ceiling effects on the results. Since the LMMs performed equally well on both tone-absent condition and tone-present condition, there may be little room for improvement with the presence of the short auditory tone. In order to determine if there were ceiling effects, they excluded data that had a 95% or higher accuracy. They found that ceiling effects were not the primary cause of their findings but it greatly shrunk their sample size by more than half (from N = 43 to N = 16).

Additionally, Lui and Wong (2012) used the visual search task in the *pip-and-pop paradigm* by Van der Burg et al. (2008) to assess how visual and auditory information are processed and integrated. However, it is not clear how the visual search task used is a measure of multisensory integration since the search task is primarily visual and occasionally aided by an auditory stimulus. Van der Burg et al. (2008) reported that the auditory cue can help individuals find their target quicker in a visual search task but the auditory cue is not required to perform the search task. According to the definition by Stein et al. (2014), the visual search for the target and the auditory cue does not produce a distinct form and can be easily "'deconstructed' to reconstitute the components it was created from" (p. 4-15, 2014). Two different sensory inputs are required to integrate while learning a task to produce an output in order for multisensory integration to occur, which is not the case in the *pip-and-pop paradigm*. The visual search task is primarily used to investigate individuals' tendency to automatically attend and process seemingly irrelevant task information. However, it is not a complete measure of multisensory integration.

Due to these limitations, the present study aims to investigate if the broader attentional breadth in HMMs can enhance multisensory integration by using a different task that represents a better and clearer measure of multisensory integration. According to current research findings, HMMs distribute their attention almost equally to both relevant and irrelevant stimuli while performing tasks and develop a broader attentional breadth as they consume multiple media simultaneously. Since media multitasking alters neural structures in the brain, it is very possible that other neural processes are altered as well that can change how sensory information are encoded. Although the HMMs are not able to focus on relevant information as well as LMMs, they may be enhanced by their environment and perform better in certain situations since they may have more experience integrating sensory inputs more than LMMs. Studies have shown that dividing attention across sensory modalities can increase integration compared to modality-specific selective attention (Hugenschmidt et al., 2009; Laurienti et al., 2006; Mozolic et al, 2008). Therefore, HMMs should be processing multisensory information better than LMMs and perform better on tasks when irrelevant information becomes relevant to the task due to their broader attentional bias.

This present study will use two tasks that incorporate two different sensory modalities to investigate if HMMs can process multisensory information better than LMMs. Another aim is to use tasks that mimic real world multitasking better in order to increase the ecological validity of this study. Unlike the visual search with the occasional auditory sound, the two tasks will present two different sensory stimuli simultaneously to produce one output. Participants will have to use information from two different senses in order to perform well on their tasks, although they may not be aware that both sensory stimuli are relevant to their task. One task will include visual and auditory stimuli while the other task will include visual and somatosensory stimuli.

We hope by using visual and somatosensory stimuli, it will make this current study unique as most studies focus on visual and auditory stimuli. Most media multitasking studies focus on visual and auditory stimuli and not much is known about the effects of somatosensory stimuli on media multitasking. Bolognini and Maravita (2007) studied the interaction between visual and somatosensory stimuli and found that unattended touches to one hand enhanced visual sensitivity. Since HMMs tend to spread their attention across sensory modalities more than LMMs, they should be able to incorporate both sensory stimuli better than LMMs. Similar to the pip and pop paradigm, individuals' haptic memory should be aided by the visual and somatosensory stimuli. By using these two tasks, we predict the following:

Hypothesis 1: HMMs will perform better on tasks where task irrelevant information (auditory stimulus) becomes relevant to the task than LMMs on multisensory dual tasks (visual and auditory).

Hypothesis 2: HMMs will be better at incorporating both somatosensory and visual stimuli in comparison to LMMs. In the lateral graphesthesia memory examination, the HMMs should perform better than LMMs on the eyes open condition during the delayed recognition trial.

CHAPTER 2

METHODS

Participants

Students at a university in southeastern United States were recruited from undergraduate psychology courses. Participants received extra credit as compensation for their participation. A total of 40 participants participated in the study, including 10 men and 30 women. The average age of the participants was 21.79 (*SD* = 2.33). Exclusionary criteria had originally included any participants with a history of the following health conditions due to the potential relationship between these conditions and either Visual Search and Attention Test (VSAT), Lateral Graphesthesia Memory Examination (LGME) or both: depression, head injuries, strokes, and any current use of psychotropic medications. However, due to time restraints and difficulty of finding participants due to the COVID-19 pandemic, the data for all participants were included in the analysis despite exclusionary criteria being met for some participants. Specifically, five participants indicated that they had a history of concussion when they were younger with one student indicating that they had a recent concussion within the last few months. Additionally, 13 participants indicated that they have some sort of psychological disorder or mood dysfunction. Out of the 13 participants, 10 of them have indicated they are currently taking psychotropic medications. The media multitasking index (MMI) score is calculated from the MUQ and a median split based on the MMI was used to divide the participants into two groups. Participants with an MMI higher than 4.28 were grouped as heavy media multitaskers (HMM) while participants with an MMI 4.28 or below were grouped as light media multitaskers (LMM). Prior to data collection, approval was obtained from the MTSU Institutional Review Board (See Appendix A).

Measures

Demographic and health form. Participants were first given a demographic and health form prior to completing other measures to see if any exclusionary criteria were met. The demographic form will ask about gender (male, female, other, prefer not to answer), age, height, weight, and education in an open-ended response format. Also, they were asked if they had any history of depression, head injuries or concussions, or any intake of psychotropic medications due to potential confound effects with the VSAT, LGME, or both.

Beck Depression Inventory-II. The Beck Depression Inventory II (BDI-II) is a quick self-report rating inventory that measures characteristic symptoms and attitudes of depression (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961). It consists of 21-items and takes approximately 5 to 10 minutes to complete. Individuals are asked to respond to the 21 items based on a two-week time period. The questionnaire is based on a 4-point scale with each item ranging from 0 to 3 to indicate the degree of severity from 0 (not at all) to 3 (extreme form of each symptom). A total score of 0-13 is considered minimal range while 14-19 is considered mild depression. A total score of 20-28 is moderate and 29-63 is severe depression. The total score from the BDI-II was the variable of interest used in this study.

The BDI-II has a strong psychometric support as a screening measure for the severity of depression and has the capacity to discriminate between depressed and nondepressed subjects. It is normed for ages 13 to 80 years old. The internal consistency is around 0.9 and retest reliability ranged from 0.73 to 0.96 (Wang & Gorenstein, 2013).

Media Use Questionnaire (MUQ). The MUQ is developed by Ophir et al. (2009) to calculate the MMI among university students in their study. It is the most popular and frequently used measurement of media multitasking in many research studies since the MMI is the first measure to assess media multitasking in its full extent (Baumgartner, Lemmens, Weeda, & Huizinga, 2016). The MUQ is a self-administered questionnaire that assesses use of 12 different media forms (e.g. television, web surfing, print media) on the computer and contains 144 items. It should take approximately 20 minutes to complete. Participants report how many hours per week they spend on each media form and the age they started doing that activity. The participants will also be asked to indicate whether or not the amount of time spent on each media form has changed by responding to a four point scale (increased; decreased; stayed the same; N/A). An example of an item on the MUQ is, “Has your time spent doing this activity increased, decreased, or stayed the same in the past 6 months.” Additionally, participants will fill out a media-multitasking matrix to indicate how much time they spend on the 11 media forms while using the primary media concurrently on a five point scale: (never; a little of the time, some of the time, most of the time, N/A). This results in 132 media multitasking combinations with responses are being weighted with a value of 0 (never), .33 (sometimes), .67 (often), or 1 (almost always). An example of the item on the test is, “When you are using “other” computer applications, how often are you also doing the following at the same time:”

From the MUQ, a media multitasking index (MMI) is calculated for each participant to determine whether they are heavy or light media multitaskers. The MMI assesses the total number of hours, $MMI = \sum_{i=1}^{11} \frac{mi*hi}{h_{total}}$, where m*i* represents the summed amount of secondary media use while using primary medium, h*i* constitutes the number of hours spent consuming primary medium *i* per week, and h_{total} represents the estimated sum of hours spent consuming any of the 12 media. The MMI scores were calculated as the weighted sum of the number of media consumed simultaneously and normalized by total hours of each medium consumption. From the MMI, it should produce a relatively normal distribution with a mean and standard deviation. The MMI will be used as the variable of interest in this study and used to create groups of LMM and HMM participants. Individuals with an MMI less than one standard deviation below the mean were considered LMMs while individuals with an MMI greater than one standard deviation above the mean will be HMMs. However, for this study, the median split (*Md*=4.28) was used to split the participants evenly into the two groups.

Visual Search and Attention Test (VSAT). The VSAT is a visual cancellation task designed to measure visual scanning and sustained attention. The test consists of three different visual cancellation tasks. Each of the tasks consists of 10 rows of stimuli with each row containing 40 stimuli, including 10 randomly placed target stimuli in each of the rows. The first task uses the target letter “F” and requires the participants to find this target letter among many other distractor letters. The distractor letters include A, B, C, D, E, G, H, I, J, K, and L. The second task consists of the target symbol “]” and requires the participant to find this target symbol among many other distractor symbols. The distractor symbols include *, \, /, #, %, |, [, =, +, <, and >. The first two tasks are printed in black ink. The third task consists of the target letter "H" printed in blue ink and distractor letters printed in blue, green and red ink. Some of the distractors also consist of the target letter printed in green and red ink. The final task consists of the target symbol "/" printed in blue ink and distractor symbols printed in blue, red, and green ink. As before, some of the distractor symbols also consist of the target symbol printed in green and red ink. The participants are given 60 seconds for each trial to cross out as many of the target letters/symbols as possible.

The VSAT was normed on a sample of 272 individuals ranging in age from 18 to 85. The test has excellent test-retest reliability (r = .95), but is prone to practice effects with adults experiencing an approximate 11% increase in scores. The results of discriminate function analysis indicated that the VSAT correctly identifies normal from brain damaged individuals, with a sensitivity of .78 and a specificity of .87.

The present investigation will be using a slightly modified version of the VSAT. The VSAT will be administered according to standardized procedures, as described previously. However, distracting auditory information will be added to some of the trials. Specifically, in the first trial, participants will complete the task in silence. In the second trial, participants will complete the task while beeps are presented throughout the trial. Participants will not be given any instructions or information on the beeps. At the end of the trial, they will be asked how many beeps occurred during the trial. In the last trial, participants will repeat the same process again with the beeps being presented. However, during the last trial, they will be given specific instructions to count the beeps in the background. At the end of the trial, they will be asked again how many beeps occurred during the trial. Also, to ensure equality across trial only the third task will be used in this study. To control for practice effects two alternate but equivalent forms will be created, using the exact same stimuli but with a randomized order on the sheet.

The VSAT will be used to test hypothesis 1 to see if HMMs would be better at tasks that have seemingly irrelevant information that later becomes relevant to the task because they spread their attention across sensory modalities. Trial 1 is conducted to get the participants' baseline performance. Trial 2 and 3 are conducted with beeps to see if participants are able to filter the seemingly irrelevant stimuli (the beeps) while they focus their attention on crossing out as many targets as possible in 60 seconds. Participants will be given specific instructions in trial 3 to pay attention to the beeps in order to compare the difference in performance of both groups in trial 2 and 3. The primary dependent variable of interest is the number of beeps the participants report hearing.

Lateral Graphesthesia Memory Examination. The Lateral Graphesthesia Memory Examination (LGME) is a test of haptic learning and memory. The test involves creating a series of target designs on the palms and fingers of each hand by tracing a design and then presenting the target designs along with distracter designs. Ten points on the palm and fingers are used in the creation of the designs, one point at the distal phalange of each finger, one point at the thenar region, one point at the hypothenar region, one point at the median palmer region, one point at the upper palmar region just below the index finger, and one point at the upper palmar region just below the pinky finger. These ten points serve as reference points for the creation of the designs. The designs are created by using a stylus to trace lines along four of the aforementioned points to create a design consisting of three lines each. At each reference point there is a brief pause of approximately one second before tracing a line to the next reference point.

All target designs begin at the distal phalange of the fingers and end in the palm. There are a total of five target designs for each hand, which each hand having different target designs. The beginning of each learning trial involves the presentation of the five target designs in the same order. These five target designs are then presented again along with seven distracter designs. Five of the distracter designs are related in that they also begin in the fingers and two of the distracter designs are unrelated in the they begin and end in the palm. The individual is asked to state “yes” for the target design and say “no” for a design they were not asked to remember, i.e. the distracter designs.

There will be two conditions for all four trials. Participants will complete the LGME with their eyes open for one condition and eyes closed for the second condition. In order to prevent practice effects, participants will alternate between the two conditions. Additionally, to avoid any effects that hand dominance may have on the assessment, participants will alternate between their left and right hand. Half of each HMMs and LMMs group would complete the LGME with their right hand eyes closed while the other half would complete the LGME with the left hand eyes closed. A recognition discrimination score is then calculated for each learning trial by subtracting the total number of false positives from the total number of true positives. A total recognition discrimination score is also calculated by subtracting the number of false positives across all learning trials from the number of true positives across all learning trials. There are a total of three learning trials. A delayed recognition trial is presented 20 to 25 minutes after the third learning trial and this will constitute the primary dependent variable of interest in this study.

The LGME will be used to test hypothesis 2 to see if HMMs would have a better performance than LMMs since they have the tendency to spread attention across sensory modalities. The delayed recognition trial will be used to determine if HMMs' haptic memory was aided by the two different sensory modalities. The LMMs, who tend to use more selective attention on unisensory modality tasks, should perform worse on tasks that are multisensory modalities (somatosensory and visual) and hence exhibit worse performance on the eyes open condition.

Procedure

Following approval from the MTSU Institutional Review Board, the participants were provided with an informed consent form detailing the purpose of the study, potential risks, and potential benefits of the study (See Appendix B). Once participants consented to engage in the study, participants were given the demographic and health form to complete as well as the BDI-II. Once both surveys were completed, verbal instructions were given to the participants for the VSAT and LGME. Since the LGME has a delayed recognition trial, participants were given the MUQ to complete after the third trial. Once participants completed the MUQ, they were then administered the delayed recognition trial of the LGME. The VSAT and LGME were administered according to the procedure described previously.

CHAPTER III

RESULTS

Initial Analysis

Initial analyses were conducted using a one-way between groups ANOVA to determine any group differences in age and BDI scores between the two groups, using an alpha of .05. The LMM group consisted of 20 participants with an average age 21.90 (*SD* = 2.15) and an average BDI score of 13.25 (*SD* = 8.87). The HMM group also consisted of 20 participants with an average age 21.68 (*SD* = 2.56) and an average BDI score of 13.70 (*SD* = 10.28). Results indicated that there were no significant differences between the LMMs and HMMs for age, $F(1, 37) = .082$, $p = .777$, and BDI scores, $F(1, 38) = .022$, $p = .883$. This demonstrated that there were no confound effects due to age or depression.

Primary Analyses

The first hypothesis was that HMMs will perform better on tasks where task irrelevant information (auditory stimulus) becomes relevant to the task than LMMs on multisensory dual tasks (visual and auditory). The HMMs group should be able to answer how many beeps were heard during the task more accurately than LMMs. To evaluate this hypothesis, results from VSAT were analyzed by using a 2 (Group: LMMs vs HMMs) x 2 (Trial: Trial 2 vs Trial 3) mixed factorial ANOVA to assess whether or not HMMs performed better than LMMs when seemingly irrelevant stimuli (beeps) become relevant to the task, with a between subjects factor of Group and a repeated factor of Trial. The primary dependent variable of interest is the number of beeps the participants reported hearing. The results indicated that the main effect for Group was not significant, $F(1, 38) = 1.36$, $p = .251$. The main effect for Trial was also not significant, $F(1, 38) = .123$, $p = .728$. The results also indicated no significant interaction between the Group and Trial, $F(1, 38) = .708$, $p = .405$. The number of beeps the participants reported hearing in Trial 2 were similar for LMMs (*M* =10.90, *SD* = 4.280) and HMMs (*M* = 9.40, *SD* = 4.97). Similarly, the number of beeps reported in Trial 3 were similar for LMMs (*M* = 10.05, *SD* = .826) and HMMs (*M* = 9.75, *SD* = .716).

Given these nonsignificant findings, additional analyses were then conducted to examine differences in baseline performance between the groups when there were no beeps (Trial 1) to when there were beeps in the second trial. This analysis was conducted by using a 2 (Group: LMMs vs HMMs) x 2 (Trial: Trial 1 vs Trial 2) mixed factorial ANOVA, with a between subjects factor of Group and a repeated factor of Trial. However, as before, the main effect for Group was not significant, $F(1, 38) = .251$, $p = .620$. The main effect for Trial was also not significant, $F(1, 38) = 2.46$, $p = 2.46$. Finally, the Group by Trial interaction was also not significant, $F(1, 38) = .323$, $p = .573$. Table 1 contains the descriptive statistics for the VSAT.

Finally, correlations were conducted to determine if there were any significant relationships between performance on the VSAT and MMI scores. These analyses might be particularly important given the sample size for each group and the use of a medial split. To control for experiment-wise error rate an alpha of .025 was used as the criterion for determining statistical significance, which was determined using a Bonferonni correction. The results indicated no significant correlation between the MMI score and performance on either Trial 2 (*r* = -.316, *p* > .05) or Trial 3 (*r* = -.078, *p* > .05) of the VSAT.

The second hypothesis was that HMMs will be better at incorporating both somatosensory and visual stimuli in comparison to LMMs. The HMM group should perform better than LMM group on the eyes open condition during the delayed recognition trial of the LGME. Results from the LGME were analyzed by a 2 (Group: LMM x HMM) x 2 (Condition: Eyes Closed vs Eyes Open) mixed factorial ANOVA with a between subject factor of Group and repeated factor of Condition. The delayed recognition score was the primary dependent variable of interest in this study. The results indicated there was no significant main effect for Group, $F(1, 38) = .287$, $p = .595$. The main effect for Condition was also not significant, $F(1, 38) = 2.78$, $p = .103$. Results also indicated there was no significant interaction between the Group and Condition, $F(1, 38) = 1.05$, $p = .311$. The delayed recognition scores for eyes closed were similar for LMMs ($M = 7.65$, $SD = 1.76$) and HMMs ($M = 7.85$, $SD = 1.63$). Similarly, the delayed recognition scores in the eyes open condition were similar for LMMs ($M = 8.70$, $SD = 1.69$) and HMMs ($M = 8.10$, $SD = 1.74$).

Given these nonsignificant findings, additional analysis were then conducted to examine immediate recognition scores for both groups. The results from the immediate recognition data were analyzed by a 2 (Group: LMM x HMM) x 2 (Condition: Eyes Closed vs Eyes Open) mixed factorial ANOVA with a between subject factor of Group and repeated factor of Condition. The results indicated a significant main effect for Condition, $F(1, 38) = 9.25$, $p = .004$, with the Eyes Closed condition having a lower overall mean ($M = 24.60$, $SE = .614$) than the Eyes Open condition ($M = 26.56$, $SE = .63$).

The main effect for Group was not significant, $F(1, 38) = .108$, $p = .744$. The Group by Condition interaction was not significant, $F(1, 38) = .055$, $p = .816$.

Finally, correlations were conducted to determine if there were any significant relationships between performance on the LGME and MMI scores. These analyses might be particularly important given the sample size for each group and the use of a medial split. To control for experiment-wise error rate an alpha of .025 was used as the criterion for determining statistical significance, which was again based on a Bonferroni correction. The results indicated no significant correlation between the MMI score and either the delayed recognition Eyes Closed condition ($r = -.047$, $p > .05$) or the delayed recognition Eye Open condition from the LGME ($r = -.027$, $p > .05$). Correlations were also conducted using the immediate recognition scores. However, as before, there were no significant correlation found between the MMI score and the immediate recognition Eyes Closed condition ($r = -.043$, $p > .05$) or the immediate recognition Eyes Open condition ($r = .047$, $p > .05$).

CHAPTER IV

DISCUSSION

The purpose of this study was to evaluate if heavy media multitasking could have some enhanced benefits on multisensory integration due to the broader breadth of attention associated with heavy media multitasking. According to current results, the hypothesis predicting HMMs would have a better performance on tasks where task irrelevant information becomes relevant to the task was not supported. The HMMs did not perform better than the LMMs on trial two of the VSAT as predicted. Participants in both groups gave responses that were close to the answer in both trials. An additional analysis was conducted to determine if the presence of the beeps had any effect on group performance. This was accomplished by examining performance between the no beeps in the first trial as compared to the presence of beeps in the second trial. The results indicated that the beeps did not have an effect as expected.

This finding indicated that HMMs were no more distracted by the beeps while crossing out the target letters than the LMMs. This contradicts the findings by Lui and Wong (2012) who reported that HMMs were able to process sensory inputs and performed better than LMMs in the tone present condition versus the tone absent condition. It also contradicts Ophir et al. (2009), Lin (2009), and Cain and Mitroff (2011) who believe HMMs are more easily distracted by seemingly irrelevant stimuli because they distribute their attention evenly to all stimuli. Both groups seem to have the same breadth of attention in this study. The HMM group did not benefit from the task irrelevant beeps in both of the VSAT trials, suggesting that HMM does not have a wider breadth of attention as research indicated.

The second hypothesis predicted that HMMs would be better at incorporating both somatosensory and visual stimuli than LMMs. The HMMs should perform better in the eyes open condition during the delayed recognition trial of the LGME because the LMMs tend to use more selective attention on unisensory than multisensory modality tasks. The present findings did not support this hypothesis since there were no group differences between the eyes open and eyes closed condition in the delayed recognition trial of the LGME. Additional analyses also revealed no group differences when analyzing the immediate recognition scores. Hence, the HMM group did not benefit from multisensory tasks involving vision and haptic sensation. This also suggests that HMMs does not seem to have enhanced multisensory integration in comparison to LMMs since both groups have similar performance.

Studies like Lui and Wong (2012) investigated the two extreme media multitasker groups by using tasks that involved the pip and pop effect, where auditory stimuli helped aid search for target visual stimuli more quickly, to mimic real world circumstances. However, this approach may not truly reflect multisensory integration or a reflection of the real world since the task irrelevant tone only has an advantageous effect when it was synchronized with the target change. Los and Van der Burg (2013) have found auditory stimuli aid faster reaction time to visual target stimuli through temporal preparation in manual choice- RT task, allowing the searcher to anticipate the target, rather than multisensory integration. However, they emphasized that many processes may contribute to multisensory integration including temporal preparation. Since there are mixed results between the two extreme groups, more research is needed to truly understand the difference between the two groups and if there are some benefits to media multitasking such as enhanced multisensory integration.

Overall, this present study has demonstrated that there are no significant differences between the two extreme media multitasker groups or any significant interaction between the groups and two conditions. Many research studies have reported that HMMs typically exhibited lower performance on numerous tasks that involved cognitive abilities in comparison to LMMs but the present research does not support this claim. It is possible that media multitasking may not have a detrimental effect like many studies have indicated. The tasks used in the studies often lack ecological validity since the tasks are highly controlled and simplified in comparison to the complexity that media multitaskers face in the real world. This would also explain contradictory findings in media multitasking literature. The current study is a better reflection of media multitasking in the real world and we have found that HMMs and LMMs both have similar performance on short-term memory and sustained attention, supporting the notion that media multitaskers could have is a difference in orientation of how information is filtered and processed rather than a deficit in cognitive control.

As Lui and Wong (2012) suggested, media multitasking does not always have detrimental effects. In fact, media multitasking can have positive effects. Loh and Lim (2020) reported a positive relationship between media multitasking and creativity, depending on the individual’s level of fluid intelligence and attentional impulsivity. Due to contradictory findings in media multitasking literature, we should consider the possibility that media multitasking is not as harmful as some preliminary research has indicated.

Limitations

There were some limitations to this study. First, the total sample size was small with a total of 40 participants, causing a potential reduction in statistical power. There is a possibility that different results could be found with a larger sample size and more statistical power. Additionally, some participants had met some exclusionary criteria that were included in the analyses, such as recent concussions or current use of psychotropic medications. There is a possibility that these conditions may have caused some confound effects due to the potential relationship with the VSAT, LGME, or both. Different results may be seen if participants with exclusionary criteria had been excluded from the data analysis as was originally planned.

In addition to the sample population, the method used to divide participants up into groups were different. In this present study, we used a median split to divide participants equally into two groups: LMMs or HMMs. However, many research studies that have an extreme-group approach to compare individuals and their media consumptions followed the method done by Ophir et al. (2009). The LMMs and HMMs were determined by one standard deviation above the mean for the HMM group and one standard deviation below the mean for the LMM group. In the study conducted by Ophir et al. (2009), only 41 participants out of 266 had an MMI score that were one standard deviation above or below the mean and were invited to complete the rest of the study. They did not use participants who were not one standard deviation above or below the mean. Since this study used a median split, there were many participants that had an MMI score very close to the median. There is a strong possibility that this could have caused different results since the data included participants who had an MMI score close to the mean.

In addition to the median split, we used a different paradigm from Ophir et al. (2009) and Lui and Wong (2012). Both used tasks that include the pip and pop effect to mimic real world circumstances. We believe the LGME would be a better measurement of multisensory integration, since individuals have to integrate visual and somatosensory stimuli into one output to perform well on that task. Since the methods used were different, the current study results cannot be adequately compared to previous studies. This could explain why there were no significant main effect or interaction between the groups and dependent variables in comparison to the other studies.

Furthermore, the LGME is a new measure and research is needed to examine its construct validity, especially for measuring multisensory integration. The LGME is designed to examine individuals ‘short-term memory and ability to recall information by touch. Uncapher and Wagner (2018) reported many research have found that heavy media multitaskers perform significantly worse on memory tasks, especially short-delay memory tasks. When analyzing the immediate recognition scores, we found that the eyes condition does have a significant effect, suggesting that there some underlying cause between performance and eyes condition. Additionally, there have been no studies that looked at somatosensory and media multitasking. It is possible that tactile stimuli does not have a strong association with media multitasking compared to visual and auditory stimuli.

This study showed that heavy media multitaskers did not have enhanced multisensory integration in both assessments. We did not find that heavy media multitasking behavior is associated with better multisensory integration due to the broader attentional breadth. Due to the discussed limitations and research found on positive effects of media multitasking and enhanced multisensory integration in older adults, we believe there are meaning information that have yet to be explored. Several studies have reported that selective attention to one specific sensory modality may not be beneficial for multisensory integration because it limits the amount of sensory information available for integration. The present findings could be strengthened if we had used individuals with true MMI scores that are one standard deviation above or below the mean. We believe that if we repeat this study again with proper participants with no exclusionary criteria and strong assessments, we may find different results than the current findings.

REFERENCES

Alzahabi, R., & Becker, M. W. (2013). The association between media multitasking, task-switching, and dual-task performance. Journal of Experimental Psychology: Human Perception and Performance, 39(5), 1485.

Alzahabi, R., Becker, M. W., & Hambrick, D. Z. (2017). Investigating the relationship between media multitasking and processes involved in task-switching. Journal of experimental psychology: human perception and performance, 43(11), 1872.

Baumgartner, S. E., Lemmens, J. S., Weeda, W. D., & Huizinga, M. (2017). Measuring media multitasking: development of a short measure of media multitasking for adolescents. *Journal of Media Psychology: Theories, Methods, and Applications*, *29*(2), 92.

Baumgartner, S. E., & Sumter, S. R. (2017). Dealing with media distractions: an observational study of computer-based multitasking among children and adults in the Netherlands. *Journal of Children and Media*, *11*(3), 295-313.

Baumgartner, S. E., Weeda, W. D., van der Heijden, L. L., & Huizinga, M. (2014). The relationship between media multitasking and executive function in early adolescents. *The Journal of Early Adolescence*, *34*(8), 1120-1144.

Bavelier, D., Achtman, R. L., Mani, M., & Föcker, J. (2012). Neural bases of selective attention in action video game players. Vision research, 61, 132-143.

Beck, A. T., Ward, C. H., Mendelson, M., Mock, J., & Erbaugh, J. (1961). An inventory for measuring depression. *Archives of general psychiatry*, *4*(6), 561-571.

Bolognini, N., & Maravita, A. (2007). Proprioceptive alignment of visual and somatosensory maps in the posterior parietal cortex. *Current Biology*, *17*(21), 1890-1895.

Burgess, P. W. (2000). Strategy application disorder: the role of the frontal lobes in human multitasking. *Psychological research*, *63*(3-4), 279-288.

Busse, L., Roberts, K. C., Crist, R. E., Weissman, D. H., & Woldorff, M. G. (2005). The spread of attention across modalities and space in a multisensory object. *Proceedings of the National Academy of Sciences*, *102*(51), 18751-18756.

Cain, M. S., Leonard, J. A., Gabrieli, J. D., & Finn, A. S. (2016). Media multitasking in adolescence. *Psychonomic Bulletin & Review*, *23*(6), 1932-1941.

Cain, M. S., & Mitroff, S. R. (2011). Distractor filtering in media multitaskers. *Perception*, *40*(10), 1183-1192. doi: 10.1068/p7017

Carrier, L. M., Cheever, N. A., Rosen, L. D., Benitez, S., & Chang, J. (2009). Multitasking across generations: Multitasking choices and difficulty ratings in three generations of Americans. *Computers in Human Behavior*, *25*(2), 483-489.

Clemo, H. R., Keniston, L. P., & Meredith, M. A. (2012). Structural Basis of Multisensory Processing. In The neural bases of multisensory processes. CRC Press/Taylor & Francis; 2012. Chapter 1

Courage, M. L., Bakhtiar, A., Fitzpatrick, C., Kenny, S., & Brandeau, K. (2015). Growing up multitasking: The costs and benefits for cognitive development. *Developmental Review*, *35*, 5-41.

Denmark, T., Fish, J., Jansari, A., Tailor, J., Ashkan, K., & Morris, R. (2019). Using virtual reality to investigate multitasking ability in individuals with frontal lobe lesions. *Neuropsychological rehabilitation*, *29*(5), 767-788.

Dreher, J. C., & Grafman, J. (2003). Dissociating the roles of the rostral anterior cingulate and the lateral prefrontal cortices in performing two tasks simultaneously or successively. *Cerebral cortex*, *13*(4), 329-339.

Dreher, J. C., Koechlin, E., Tierney, M., & Grafman, J. (2008). Damage to the fronto-polar cortex is associated with impaired multitasking. *PLoS One, 3*(9).

Engel AK, Senkowski D, Schneider TR. Multisensory Integration through Neural Coherence. In: Murray MM, Wallace MT, editors. The Neural Bases of Multisensory Processes. Boca Raton (FL): CRC Press/Taylor & Francis; 2012. Chapter 7

Foehr, U. G. (2006). Media multitasking among American youth: Prevalence, predictors and pairings. Henry J. Kaiser Family Foundation.

Gau, R., Bazin, P. L., Trampel, R., Turner, R., & Noppeney, U. (2020). Resolving multisensory and attentional influences across cortical depth in sensory cortices. *Elife*, *9*, e46856.

Hugenschmidt, C. E., Mozolic, J. L., & Laurienti, P. J. (2009). Suppression of multisensory integration by modality-specific attention in aging. *Neuroreport*, *20*(4), 349.

Hwang, Y., & Jeong, S. H. (2018). Multitasking and task performance: Roles of task hierarchy, sensory interference, and behavioral response. *Computers in Human Behavior*, *81*, 161-167.

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences*, *105*(19), 6829-6833.

Kahneman, D. (1973). *Attention and effort* (Vol. 1063). Englewood Cliffs, NJ: Prentice-Hall.

Lang, A., & Chrzan, J. (2015). Media multitasking: Good, bad, or ugly?. *Annals of the International Communication Association*, *39*(1), 99-128.

Laurienti, P. J., Burdette, J. H., Maldjian, J. A., & Wallace, M. T. (2006). Enhanced multisensory integration in older adults. *Neurobiology of aging*, *27*(8), 1155-1163.

Lewkowicz, D. J., & Ghazanfar, A. A. (2009). The emergence of multisensory systems through perceptual narrowing. *Trends in cognitive sciences*, *13*(11), 470-478.

Lin, L. (2009). Breadth-biased versus focused cognitive control in media multitasking behaviors. *Proceedings of the National Academy of Sciences*, *106*(37), 15521-15522.

Loh, K. K., & Kanai, R. (2014). Higher media multi-tasking activity is associated with smaller gray-matter density in the anterior cingulate cortex. *Plos one*, *9*(9).

Loh, K. K., & Lim, S. W. H. (2020). Positive associations between media multitasking and creativity. *Computers in Human Behavior Reports*, *1*, 100015.

Los, S. A., & Van der Burg, E. (2013). Sound speeds vision through preparation, not integration. *Journal of Experimental Psychology: Human Perception and Performance*, 39(6), 1612.

Lui, K. F., & Wong, A. C. N. (2012). Does media multitasking always hurt? A positive correlation between multitasking and multisensory integration. *Psychonomic bulletin & review*, *19*(4), 647-653.

Macaluso, E., & Driver, J. (2005). Multisensory spatial interactions: a window onto functional integration in the human brain. *Trends in neurosciences*, *28*(5), 264-271.

Macaluso, E., Noppeney, U., Talsma, D., Vercillo, T., Hartcher-O'Brien, J., & Adam, R. (2016). The curious incident of attention in multisensory integration: bottom-up vs. top-down. *Multisensory Research*, *29*(6-7), 557-583.

Minear, M., Brasher, F., McCurdy, M., Lewis, J., & Younggren, A. (2013). Working memory, fluid intelligence, and impulsiveness in heavy media multitaskers. *Psychonomic bulletin & review*, *20*(6), 1274-1281.

McAlister, C., & Schmitter-Edgecombe, M. (2013). Naturalistic assessment of executive function and everyday multitasking in healthy older adults. *Aging, Neuropsychology, and Cognition*, *20*(6), 735-756. doi: 10.1080/13825585.2013.781990

Moisala, M., Salmela, V., Hietajärvi, L., Salo, E., Carlson, S., Salonen, O., ... & Alho, K. (2016). Media multitasking is associated with distractibility and increased prefrontal activity in adolescents and young adults. *NeuroImage*, *134*, 113-121.

Mozolic, J. L., Hugenschmidt, C. E., Peiffer, A. M., & Laurienti, P. J. (2008). Modality-specific selective attention attenuates multisensory integration. *Experimental brain research*, *184*(1), 39-52.

Murphy, K., McLauchlan, S., & Lee, M. (2017). Is there a link between media-multitasking and the executive functions of filtering and response inhibition?. Computers in Human Behavior, 75, 667-677.

Nasr, S., Moeeny, A., & Esteky, H. (2008). Neural correlate of filtering of irrelevant information from visual working memory. *PLoS One*, *3*(9). doi: 10.1371/journal.pone.0003282

Ophir, E., Nass, C., & Wagner, A. D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences*, *106*(37), 15583-15587.

Perrault TJ Jr., Rowland BA, Stein BE. The Organization and Plasticity of Multisensory Integration in the Midbrain. In: Murray MM, Wallace MT, editors. The Neural Bases of Multisensory Processes. Boca Raton (FL): CRC Press/Taylor & Francis; 2012. Chapter 15

Foerde, K., Knowlton, B. J., & Poldrack, R. A. (2006). Modulation of competing memory systems by distraction. proceedings of the National Academy of Sciences, 103(31), 11778-11783. doi: 10.1073/pnas.0602659103

Pool, M. M., Koolstra, C. M., & Van der Voort, T. H. (2003). The impact of background radio and television on high school students' homework performance. Journal of Communication, 53(1), 74-87.

Ralph, B. C., Thomson, D. R., Cheyne, J. A., & Smilek, D. (2014). Media multitasking and failures of attention in everyday life. Psychological research, 78(5), 661-669.

Rekart, J. L. (2011). Taking on multitasking. *Phi Delta Kappan,93*(4), 60-63. doi:10.1177/003172171109300415

Rideout, V. J., Foehr, U. G., & Roberts, D. F. (2010). Generation M 2: Media in the Lives of 8-to 18-Year-Olds. *Henry J. Kaiser Family Foundation*.

Rosen, L. D., Carrier, L. M., & Cheever, N. A. (2013). Facebook and texting made me do it: Media-induced task-switching while studying. *Computers in Human Behavior*, *29*(3), 948-958.

Rothbart, M. K., & Posner, M. I. (2015). The developing brain in a multitasking world. *Developmental Review*, *35*, 42-63.

Salvucci, Dri. D., & Taatgen, N. A. (2010). A Unifying Theory of Multitasking. In *The Multitasking Mind* (pp. 3–24). Oxford University Press.

Sanbonmatsu, D. M., Strayer, D. L., Medeiros-Ward, N., & Watson, J. M. (2013). Who multi-tasks and why? Multi-tasking ability, perceived multi-tasking ability, impulsivity, and sensation seeking. *PloS one*, *8*(1), e54402.

Stein, B. E., & Stanford, T. R. (2008). Multisensory integration: current issues from the perspective of the single neuron. *Nature Reviews Neuroscience*, *9*(4), 255-266.

Stein, B. E., Stanford, T. R., & Rowland, B. A. (2014). Development of multisensory integration from the perspective of the individual neuron. *Nature Reviews Neuroscience*, *15*(8), 520-535.

Steenbergen, L., Sellaro, R., Stock, A. K., Beste, C., & Colzato, L. S. (2015). Action video gaming and cognitive control: playing first person shooter games is associated with improved action cascading but not inhibition. PloS one, 10(12). doi: 10.1371/journal.pone.0144364

Talsma, D. (2015). Predictive coding and multisensory integration: an attentional account of the multisensory mind. *Frontiers in Integrative Neuroscience*, *9*, 19.

Talsma, D., Senkowski, D., Soto-Faraco, S., & Woldorff, M. G. (2010). The multifaceted interplay between attention and multisensory integration. *Trends in cognitive sciences, 14*(9), 400–410. doi:10.1016/j.tics.2010.06.008

Tang, X., Wu, J., & Shen, Y. (2016). The interactions of multisensory integration with endogenous and exogenous attention. *Neuroscience & Biobehavioral Reviews, 61*, 208-224.

Uncapher, M. R., Thieu, M. K., & Wagner, A. D. (2016). Media multitasking and memory: Differences in working memory and long-term memory. *Psychonomic bulletin & review*, *23*(2), 483-490. doi: 10.3758/s13423-015-0907-3

Uncapher, M. R., Lin, L., Rosen, L. D., Kirkorian, H. L., Baron, N. S., Bailey, K., ... & Wagner, A. D. (2017). Media multitasking and cognitive, psychological, neural, and learning differences. *Pediatrics*, *140*(Supplement 2), S62-S66.

Uncapher, M. R., & Wagner, A. D. (2018). Minds and brains of media multitaskers: Current findings and future directions. Proceedings of the National Academy of Sciences, 115(40), 9889-9896.

Van Den Berg, B., Appelbaum, L. G., Clark, K., Lorist, M. M., & Woldorff, M. G. (2016). Visual search performance is predicted by both prestimulus and poststimulus electrical brain activity. Scientific reports, 6(1), 1-13.

Van der Burg, E., Olivers, C. N., Bronkhorst, A. W., & Theeuwes, J. (2008). Pip and pop: nonspatial auditory signals improve spatial visual search. Journal of Experimental Psychology: Human Perception and Performance, 34(5), 1053.

Wang, Y. P., & Gorenstein, C. (2013). Psychometric properties of the Beck Depression Inventory-II: a comprehensive review. *Brazilian Journal of Psychiatry*, *35*(4), 416-431.

Wiradhany, W., & Koerts, J. (2019). Everyday functioning-related cognitive correlates of media multitasking: a mini meta-analysis. *Media Psychology*, 1-28.

Yau, J. M., DeAngelis, G. C., & Angelaki, D. E. (2015). Dissecting neural circuits for multisensory integration and crossmodal processing. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*(1677), 20140203.

Zhang, R. T., Yang, T. X., Wang, Y., Sui, Y., Yao, J., Zhang, C. Y., ... & Chan, R. C. (2016). Structural neural correlates of multitasking: A voxel-based morphometry study. *PsyCh journal*, *5*(4), 219-227.

Ziegler, D. A., Mishra, J., & Gazzaley, A. (2015). The acute and chronic impact of technology on our brain. The Wiley handbook of psychology, technology, and society, 3-19.

APPENDICES

APPENDIX A

IRB Expedited Form

IRB
INSTITUTIONAL REVIEW BOARD
Office of Research Compliance,
010A Sam Ingram Building,
2269 Middle Tennessee Blvd
Murfreesboro, TN 37129
FWA: 00005331/IRB Regn. 0003571

MIDDLE TENNESSEE STATE UNIVERSITY

IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE

Tuesday, December 08, 2020

Protocol Title *Media Multitasking and Its Effects on Multisensor Integration*
Protocol ID **21-2056 7i**

Principal Investigator **Hao Ngo** (Student)
Faculty Advisor Paul Foster
Co-Investigators NONE
Investigator Email(s) *htn2j@mtmail.mtsu.edu; paul.foster@mtsu.edu*
Department Psychology
Funding **NONE**

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU IRB through the **EXPEDITED** mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the category *(7) Research on individual or group characteristics or behavior*. A summary of the IRB action is tabulated below:

IRB Action	APPROVED for ONE YEAR		
Date of Expiration	**11/30/2021**	*Date of Approval:* 12/8/20	*Recent Amendment:* NONE
Sample Size	ONE HUNDRED (100)		
Participant Pool	*Target Population:* Primary Classification: **Healthy Adults (18 or older)** Specific Classification: **MTSU Psychology SONA Research Pool**		
Type of Interaction	☐ Virtual/Remote/Online interaction ☒ In person or physical interaction – Mandatory COVID-19 Management		
Exceptions	NONE		
Restrictions	1. Mandatory SIGNED Informed Consent. 2. Other than the exceptions above, identifiable data/artifacts, such as, audio/video data, photographs, handwriting samples, personal address, driving records, social security number, and etc., MUST NOT be collected. Recorded identifiable information must be deidentified as described in the protocol. 3. Mandatory Final report (refer last page). 4. CDC guidelines and MTSU safe practice must be followed		
Approved Templates	*IRB Templates:* Signature Informed Consent and SONA Recruitment Script *Non-MTSU Templates:* NONE		
Research Inducement	Class Credit (applicable only for MTSU SONA students)		
Comments	COVID-19 Management Plan Applies (refer next page)		

Post-approval Requirements

The PI and FA must read and abide by the post-approval conditions (Refer "*Quick Links*" in the bottom):

- ***Reporting Adverse Events:*** The PI must report research-related adversities suffered by the participants, deviations from the protocol, misconduct, and etc., within 48 hours from when they were discovered.
- ***Final Report:*** The FA is responsible for submitting a final report to close-out this protocol before **11/30/2021** **(Refer to the Continuing Review section below)**; REMINDERS WILLNOT BE SENT. **Failure to close-out or request for a continuing review may result in penalties** including cancellation of the data collected using this protocol and/or withholding student diploma.
- ***Protocol Amendments***: An IRB approval must be obtained for all types of amendments, such as: addition/removal of subject population or investigating team; sample size increases; changes to the research sites (appropriate permission letter(s) may be needed); alternation to funding; and etc. The proposed amendments must be requested by the FA in an addendum request form. The proposed changes must be consistent with the approval category and they must comply with expedited review requirements
- ***Research Participant Compensation:*** Compensation for research participation must be awarded as proposed in Chapter 6 of the Expedited protocol. The documentation of the monetary compensation must Appendix J and MUST NOT include protocol details when reporting to the MTSU Business Office.
- ***COVID-19:*** Regardless whether this study poses a threat to the participants or not, refer to the COVID-19 Management section for important information for the FA.

Continuing Review (The PI has requested early termination)

Although this protocol can be continued for up to THREE years, The PI has opted to end the study by **11/30/2021**
The PI must close-out this protocol by submitting a final report before 11/30/2021 Failure to close-out may result in penalties that include cancellation of the data collected using this protocol and delays in graduation of the student PI.

Post-approval Protocol Amendments:

The current MTSU IRB policies allow the investigators to implement minor and significant amendments that would fit within this approval category. ***Only TWO procedural amendments will be entertained per year*** *(changes like addition/removal of research personnel are not restricted by this rule).*

Date	Amendment(s)	IRB Comments
NONE	NONE.	NONE

Other Post-approval Actions:

The following actions are done subsequent to the approval of this protocol on request by the PI/FA or on recommendation by the IRB or by both.

Date	IRB Action(s)	IRB Comments
NONE	NONE	NONE

COVID-19 Management:

The PI must follow social distancing guidelines and other practices to avoid viral exposure to the participants and other workers when physical contact with the subjects is made during the study.

- The study must be stopped if a participant or an investigator should test positive for COVID-19 within 14 days of the research interaction. This must be reported to the IRB as an "adverse event."
- The MTSU's "Return-to-work" questionnaire found in Pipeline must be filled by the investigators on the day of the research interaction prior to physical contact.
- PPE must be worn if the participant would be within 6 feet from the each other or with an investigator.
- Physical surfaces that will come in contact with the participants must be sanitized between use
- **FA's Responsibility:** The FA is given the administrative authority to make emergency changes to protect the wellbeing of the participants and student researchers during the COVID-19 pandemic. However, the FA must notify the IRB after such changes have been made. The IRB will audit the changes at a later date and the FA will be instructed to carryout remedial measures if needed.

Data Management & Storage:

All research-related records (signed consent forms, investigator training and etc.) must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application.

The data must be stored for at least three (3) years after the study is closed. Additional Tennessee State data retention requirement may apply (*refer "Quick Links" for MTSU policy 129 below*). The data may be destroyed in a manner that maintains confidentiality and anonymity of the research subjects.

The MTSU IRB reserves the right to modify/update the approval criteria or change/cancel the terms listed in this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board
Middle Tennessee State University

Quick Links:

- Post-approval Responsibilities: http://www.mtsu.edu/irb/FAQ/PostApprovalResponsibilities.php
- Expedited Procedures: https://mtsu.edu/irb/ExpeditedProcedures.php
- MTSU Policy 129: Records retention & Disposal: https://www.mtsu.edu/policies/general/129.php

APPENDIX B

Tables

Table 1

VSAT Descriptive Statistics

Trial	M HMMs (LMMs)	SD HMMs (LMMs)
VSAT Trial 1	61.40 *(63.90)*	13.85 *(8.53)*
VSAT Trial 2	64.50 *(11.18)*	65.35 *(11.94)*
VSAT Trial 2 Beeps	10.90 *(9.40)*	4.28 *(4.97)*
VSAT Trial 3 Beeps	10.05 *(9.75)*	.826 *(.716)*

Table 2

LGME Descriptive Statistics

Trial and Condition	M HMMs (LMMs)	SD HMMs (LMMs)
IR Eyes Closed	24.50 *(24.70)*	3.49 *(4.24)*
IR Eyes Open	26.30 *(26.80)*	3.81 *(4.14)*
DR Eyes Closed	7.65 *(7.85)*	1.76 *(1.63)*
DR Eyes Open	8.70 *(8.10)*	1.69 *(1.74)*

APPENDIX C

FIGURES

Figure 1

Number of Beeps Heard during VSAT Trails

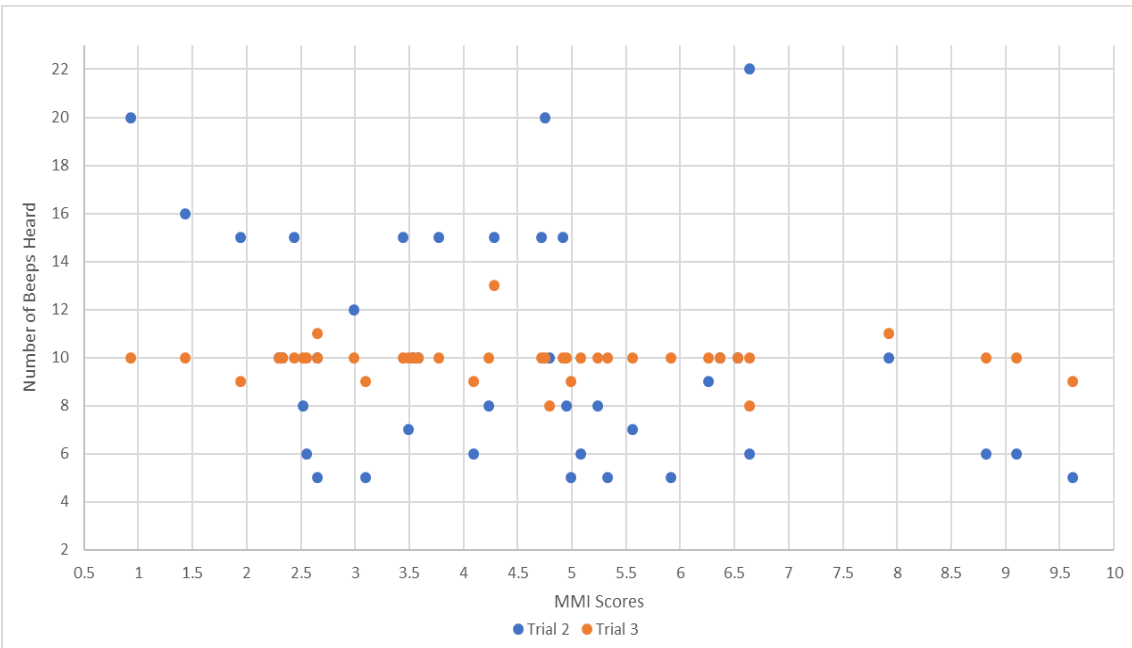

Figure 2

Delayed Recognition Scores in Eyes Condition