THE EFFECTS OF TEXT MESSAGING ON MEMORY RECALL IN COLLEGE STUDENTS

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ABSTRACT

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Technology is constantly changing, and has enabled communication to be readily available everywhere, to everyone, including students in classrooms. Most devices are portable, capable of talking, texting, and surfing the internet. Many researchers have questioned the impact technology has on individuals, making multitasking a popular research area in cognitive psychology today. Simulated environments have been created and used to examine an individual's performance while using a cell phone as they engage in everyday activities such as driving or walking. Results from the simulated environments have found that when individuals perform a primary task while conversing on a cell phone, they have lower performance on the primary task (Charlton, 2009). The majority of research on multitasking has examined how cell phone use affects driving performance. Because text messaging is a popular form of communication among young adults, an emerging area of multitasking research is now examining the effects of cell phones in learning environments. The purpose of the current study is to examine the various components of text messaging and determine which component is the most distracting for college students. Participants were randomly assigned to the control group, the receiving group, or the combined sending and receiving group. The group the participant was randomly assigned to determined their task with the cell phone during the video. Each participant watched a 10 minute video on memory. After the video ended, participants completed the posttest about the video. An analysis of variance (ANOVA) was used to determine if there was an overall difference between group's posttest scores. Results indicated a significant difference in posttest scores for the three groups. Results indicated the mean score for the control group was significantly different from the receiving group and the combined group. The combined group and receiving group did not differ significantly from one another. An ANOVA was used to determine the overall difference between groups on target questions. There was no statistically significant difference between the groups memory recall for the target questions. Pearson product moment correlation was used to investigate the relationships between participant's perceived multitasking ability and their posttest score. There was a small negative correlation between the two variables, with high levels of individual beliefs about their ability to multitask associated with lower scores on the posttest. These findings go along with the threaded cognition theory, combining a novel task with a well learned task consumes a significant amount of cognitive resources and interferes with learning. The implications of the results and areas of future research are discussed.

CHAPTER 1: INTRODUCTION

Beginning in 1956, George Miller made a significant impact on the knowledge and understanding of the capacity of short-term memory. Miller found the number of items, or chunks of information, an individual can hold in short-term memory is around 7, plus or minus 2 (Miller, 1956). From these findings, researchers in the 1960s and 1970s proposed models to explain the limited capacity of cognitive resources. Baddeley and Hitch (1974) proposed a working memory model to distinguish the differences between short-term memory and working memory. Working memory is a limited capacity system for temporary storage and manipulation of information for complex tasks such as comprehension and learning. Short-term memory is also a limited capacity system where information can be stored for a brief amount of time, but with enough rehearsal a short-term memory can form into a long-term memory. In experimental tasks, working memory was found to consist of dynamic processes which allow people to carry out two tasks simultaneously (Baddeley & Hitch, 1974).

Recently, theories have been developed to help explain the mental processes of multitasking by demonstrating how cognitive resources are divided and how switching tasks impact our cognitive abilities and attention. Cowan (2000) conducted an extensive literature review regarding capacity limits and found a more precise capacity limit is between 3 and 5 chunks of information, which modifies Millers previous findings. Another theory was proposed to assist instructional designers that create learning materials and environments. The cognitive load theory provides guidelines to help decrease cognitive load during learning (Sweller, 2011). Cognitive load is the amount of a person’s cognitive resources needed to carry out a particular cognitive task. Well-practiced tasks have low cognitive loads and use up only a small amount of a person's cognitive resources. Tasks that are difficult or are not well practiced have high cognitive loads and use a large amount of a person's cognitive resources.

Multitasking allows one person to carry out two or more tasks at one time. Combining tasks together gives off the feeling of accomplishing more, in a shorter amount of time. Modern technology has enabled communication and entertainment to be readily available anywhere we go, including in cars, classrooms, and the workplace. The latest computers, iPods, and smart phones are readily accessible, compact, and are constantly changing. Modern technology captures the attention of individuals across all generations. A popular form of communication for teenagers and young adults is text messaging. This type of communication is appearing in classrooms across all education levels and on our daily commute, whether that is walking or driving. Today, a popular research area in cognitive psychology is examining participants in multitasking environments (Bowman, Levine, Waite, & Gendron, 2010). Researchers have studied the effects of multitasking on memory, learning, and performance.

In order to study multitasking, researchers have presented participants with dual-cognitive tasks in experimental settings, placing participants in simulated environments to increase ecological validity. Researchers have extensively studied the effects of driving while conversing on a cell phone in a simulated driving environment (Charlton, 2009). Another popular research area has examined classroom distractions such as email, instant messaging, and distracting websites to see the effects they have on students' ability to retain information presented in class (Fried, 2008). Since the portability and popularity of text messaging is on the rise, a developing research area in multitasking is examining the effects of text messaging while completing academic tasks.

The current study investigates the effects text messaging has on college students' recall of information during a short video. This study will be examining memory recall in individuals who receive text messages, and those who receive and reply to text messages. These stages of text messaging will be examined in isolation to determine which stage is the most distracting for college students.

CHAPTER 2: LITERATURE REVIEW

Models of Multitasking

There have been attempts to develop conceptual models of multitasking that would explain how the brain processes information when it is presented with concurrent tasks. Threaded cognition theory (Salvucci & Taatgen, 2008) and the adaptive control of thought-rational theory (Anderson et al., 2004) are two of the most popular theories in multitasking. These models attempt to explain how concurrent tasks interfere with one another, and why performance decreases when individuals engage in concurrent tasks.

Threaded cognition theory. Salvucci and Taatgen (2008) proposed the threaded cognition theory to explain concurrent multitasking. Concurrent multitasking, which is simply referred to as multitasking, is performing two or more tasks at one time. According to this theory, a task is represented as a cognitive thread. For instance, in the case of text messaging during class, one thread would represent text messaging and another thread would represent attention directed to the material presented in the class. In order to carry out a task, threaded cognition utilizes cognitive resources, perceptual resources, and motor resources. Threaded cognition views multitasking behavior as the execution of multiple task threads, coordinated by a serial cognitive processer and distributed across multiple processing resources (Salvucci & Taatgen, 2008). Threaded cognition allows parallelism at the level of multiple resources, but requires sequential processing at the level of an individual resource. A thread's resource processing can proceed in parallel with another resource with no interference, as long as they do not both require procedural processing at the same time. Interference occurs as soon as a resource is concurrently needed by two or more tasks. That resource will act as a bottleneck, and will delay the execution of the combined process (Borst, Taatgen, & Rijn, 2010). When multiple tasks require the same resource, such as when two tasks require vision, it slows the process down in order to complete the threads. This theory manages multiple threads based on the order in which thread made the request first.

Threaded cognition initially relies on memorized instructions, but transforms a skill to a more highly proceduralized process through learning. Once the instructions are stored as declarative knowledge, a set of interpreter production rules retrieves each instruction and completes its desired actions (Salvucci & Taatgen, 2008). This is a slow process, and a new rule must typically be relearned multiple times. This process explains why multiple new tasks are harder to combine, not because an executive processor can attend to only one task at a time, but because two new tasks heavily depend on declarative memory as a resource that they almost continually need. Multiple threads may result in diminishing interference over time because the learning thread gradually uses the declarative resource less frequently, or the learning thread fires fewer production rules overall, which requires less processing on the procedural resource (Salvucci & Taatgen, 2008).

ACT-R theory. Anderson et al. (2004) proposed the adaptive control of thought-rational (ACT-R) theory which integrated components of the threaded cognition theory. The ACT-R theory consists of multiple modules in the human memory system that each work on a task in isolation. These modules, however, can be combined to produce coherent cognition. The main components of ACT-R theory include a central production system and modules. There are three types of modules, and each module contains a buffer. Each module is a specialized system devoted to processing different types of information. When a task requires information from a specific module in order to complete the task, the module places a limited amount of information into the buffer. This limited amount of information is referred to as a chunk, which is a unit of knowledge from that specific module. A central production system coordinates the communication between the modules. Located within the central production system is a pattern matcher, which is used to recognize patterns in the buffers, and make changes to the buffers (Anderson et al., 2004).

The different types of modules include the perceptual-motor module, the goal module, and the declarative memory module. The perceptual-motor module interacts with the outside world, and predominately uses visual and motor processes for cognition. The goal module represents the current status of the system, and keeps track of current goals and intentions. There are two types of memory modules, the declarative memory module and the procedural memory module. The declarative memory module serves as memory for factual knowledge. The procedural memory module serves as knowledge for how we do things, and assists the central production system with pattern matching. The production system can detect the patterns that appear in these buffers and decided what to do next to achieve coherent cognition (Anderson et al., 2004).

The ACT-R theory consists of serial and parallel processing. Serial processing within a module occurs when only one chunk, or unit of knowledge, is retrieved at a time. Parallel processing can also occur within each module. An example of this is when taking an exam, the visual system is simultaneously processing the whole visual field, and the declarative system is executing a parallel search through many memories to answer an exam question. A chunk of information is placed into the declarative memory buffer, and if the pattern matcher matches the current state of the buffer, it does not need to make any changes to carry out answering the question, resulting in the production of answering the exam question. Similar to threaded cognition, there are two levels of serial bottlenecks (Anderson et al., 2004). The content of any buffer is limited to a single unit of knowledge. Therefore, only one single memory can be retrieved at a time or only one single object can be encoded from the visual field. Second, only a single production is selected at each cycle to fire (Anderson et al., 2004). Just like threaded cognition, ACT-R theory manages multiple tasks based on the order in which task made the request first.

Unlike the threaded cognition theory, the ACT-R theory has a subsymbolic structure, which allows a large amount of parallel processes to occur, and is responsible for learning processes (Anderson et al., 2004). The more often a fact, or piece of knowledge, is used, the faster retrieval will for that piece of knowledge because the execution of the production will have been previously placed in the buffers, making the pattern matching stronger, and the subsymbolic structure stronger for that piece of knowledge. The subsymbolic structure allows for multitasking, but only for already well-learned material.

Task switching. Multitasking can be represented in terms of the amount of time spent on a task before switching to another task. Previous theories have identified concurrent multitasking and sequential multitasking separately. Salvucci, Taatgen, and Borst (2009) proposed a unified theory of multitasking. This theory is based on a continuum that is split into two parts, concurrent multitasking and sequential multitasking. Concurrent multitasking consists of frequent switching between tasks, a task switch every second. For example, driving while texting. Sequential multitasking consists of fairly long switches between tasks, a task switch every few minutes or hours. This unified theory incorporates the ACT-R cognitive architecture theory and the threaded cognition theory. These two theories use sequential processing to carry out a single task or thread.

When completing a single task, interruptions can arise. The process of interruptions can be broken down into sequential stages, the main stages being the interruption lag and the resumption lag. The interruption lag is the time between an alert of an interruption and the actual start to the interrupting task (Salvucci, Taatgen, & Borst, 2009). The resumption lag is the time between the end of the interruption task and the reinitiating of the original task. The broken down stages of task interruption and resumption can be directly applied to distractions during a classroom lecture. An example of a primary task is when a student is giving full attention to the material being presented during a classroom lecture. The primary task is the only task thread being processed. When an alert for a secondary task interrupts the primary task, two separate threads are present. The alert could be the alerting feature when receiving a text message during a classroom lecture. This is known as the interruption lag. During the interruption lag the individual must rehearse the primary task to strengthen its memory activation, and finish the primary task which could be to finish writing notes before responding to the text message. Once an individual begins the secondary task, such as responding to a text message, it is necessary to continue rehearsing the primary task such as attempting to listen to the material being presented during class. Once the individual sends the text message, or finishes the secondary task, the individual must recall information from the primary task. This is known as the resumption lag. After recalling information from the primary task, the individual resumes the primary task such as to continue taking notes. This process can be repeated multiple times when completing any task.

Interruptions are likely to occur at any time as an individual is working on a task. Interruptions can provide a warning cue or require immediate attention. They can also arise when an individual is working on a task that requires a large amount of cognitive load. Salvucci and Bogunovich (2010) had participants answer emails regarding customer products and prices, and while performing this task they had to answer to an instant message. They were given the ability to answer the instant message as soon as they felt comfortable. The instant messages were timed to arrive during times of high cognitive load, and low cognitive load to distinguish any differences between the workload types. Salvucci and Bogunovich (2010) found 94% of all participant task switches occurred at points of low cognitive load. Participants made the conscious decision to complete the task they were working on before responding to the interruption so they would not have to rehearse the primary task. Salvucci et al. (2009) found participants who did not have time to rehearse the primary task while completing the secondary task had decreased performance. This could be applied to cell phone distractions during a classroom lecture. When responding to a text message, the individual will not be able to rehearse the information being presented as they are text messaging, and will have a longer resumption lag before beginning to listen to the lecture again.

Self-interruptions are likely to occur especially with the portability of technology today. Self-interruption occurs when an individual makes the conscious decision to stop performing one task to perform another task. This type of interruption can last from minutes to hours depending on the task that the individual decides to switch too. A popular form of self-interruption in young adults is checking social media sites, text messages, and emails on a cell phone, these interruptions can occur in any environment. The timing of interruptions whether they are self-induced or from another source can lead to a decrease in primary task performance (Salvucci & Bogunovich, 2010). From the previous findings, it is important to avoid potential interruptions. To avoid technological interruptions, the device should be powered off or on silent when completing any type of task.

Multitasking while Driving

Even though people are instructed to pay full attention while driving, people often engage in multitasking activities when behind the wheel. McEvoy et al. (2005) used cell phone records and interviewed individuals who were admitted to the hospital after being involved in a vehicle accident. They found individuals conversing on a cell phone 10 minutes before the crash were four times more likely to be involved in a motor vehicle accident. Simulated driving environments have been created to further explore the effects of cell phone usage while driving. The simulators have all the realistic features of a vehicle including dashboard instrumentation, steering wheel, gas pedal, brake pedal, and a driver, and passenger seat. The road course is projected onto a screen directly in front of the participant, and to the left and right of the participant. The software for the driving simulators simulates varying roadway conditions and road signs. This software is capable of placing the participant on an interstate or a two-lane road, and evaluates how the participant interacts with other vehicles on the road. Road surface software and sound software are also used to help make the simulation realistic (Strayer, Drews, & Crouch, 2006). With the invention of driving simulators, many studies have shown the use of cell phones have an adverse effect on a driver's performance and cognitive abilities. This could occur because when cognitive resources are being used for a secondary task, they are not available for the primary task.

A vast amount of multitasking research has been conducted in simulated driving environments (Hunton & Rose, 2005). Although this research directly relates to driving, cognitive load, reaction time, and performance arguably can be generalized to other multitasking environments such as the classroom.

Reaction time. A consistent finding throughout the literature reveals a decrement in reaction time for individuals conversing on a cell phone (Patten, Kircher, Östlund, & Nilsson, 2004). Driving simulator reaction times are measured by comparing the onset of a stimulus to the participant's braking response. Charlton (2009) measured participant reaction time based on brake response to upcoming road hazards. Participants in the control group did not use a cell phone during the procedure, and when encountering all hazards they had the fastest reaction time. When approaching the one lane bridge hazard, 56.2% of the group conversing on the cell phone did not remove their foot from the accelerator. When approaching the traffic cones that were to direct traffic in another direction, 25% of participants conversing on the cell phone did not remove their foot from the accelerator (Charlton, 2009). Another method of measuring reaction time is by illuminating either a red light or green light to examine participant's reaction times while conversing on a cell phone (Strayer & Johnston, 2001). When the red light is illuminated, participants press the brake, and when the green light is illuminated, participants press the accelerator. Strayer and Drews (2004) found reaction time to be slowed by 18% when the participant was conversing on the cell phone, and participants were twice as likely to be involved in a rear-end collision. Kemker, Stierwalt, LaPointe, and Heald (2009) took a different approach to measuring reaction time; they used a software package that assesses a number of cognitive domains. The software included subtests to measure simple reaction time, choice reaction time, selective attention reaction time, and visual scanning reaction time. They tested participants without a cell phone and while conversing on a cell phone. They found when participants conversed on a cell phone, their reaction time was slower across all subtests than their reaction time with no cell phone (Kemker, Stierwalk, LaPointe, & Heald, 2009). Reaction time for responding to a text message during the video will depend on the amount of attention the student is giving the video. According to the threaded cognition theory, reaction time will be slower because learning new material is a very slow process, and heavily relies on declarative memory. This should occur when any new material is presented in a class because the material has not been stored as declarative knowledge. Once the material has been stored as declarative knowledge, reaction time will be faster.

Vehicle speed and road conditions. Previous research has found that when presented with varying road hazards, participants who are conversing on a cell phone react differently than participants not engaged in conversation (Rakauskas, Gugerty, & Ward, 2004). Encountering expected, or unexpected, road hazards is likely to occur on a daily basis when driving. The driving simulators are also capable of realistically presenting road hazards such as, changing lanes, crossing a one-lane bridge, crossing through a busy intersection, slowing for a car entering traffic, and maneuvering through a road construction site. Charlton (2009) found that drivers talking on a cell phone failed to take action to reduce their speed as they approached the road hazards. However, drivers with a passenger generally reduced their speed until they successfully drove past the road hazard. This finding supports the idea that the difference in conversing on a cell phone and conversing with a passenger is situation awareness. A similar study found participants engaged in a cell phone conversation had more variability in accelerator position, speed variability, and average speed (Rakauskas et al., 2004). Conversing on a cell phone demands a continuous, flowing conversation, and using a cell phone demands cognitive resources. Passengers are more aware of the current driving conditions; they can suppress a conversation until the driver is past the road hazard or help aid the driver with the current driving situation.

Situation awareness. Situation awareness includes perceptions of elements in the environment, comprehension of their meaning, and projection of their status in the near future (Ma & Kaber, 2005). For example, when driving down the highway during rush hour, an individual makes a decision to use or not use their turn signal when switching lanes. Situation awareness is a well-defined research area in aviation, and has now become a popular topic to research in driving simulators. This is because of the amount of technology that is now incorporated into modern vehicles. Adaptive cruise control maintains speed, allows drivers to converse on a cell phone using Bluetooth technology, and provides a wireless navigation system. Researchers have begun to question the effect automatic devices have on driver performance and situation awareness. Ma and Kaber (2005) found participants using automatic cruise control without conversing on a cell phone had improvements in situation awareness, whereas participants conversing on a cell phone had reduced situation awareness and driving comprehension. Charlton (2009) found decrements in situation awareness when the driver was conversing on a cell phone, but opposite results for drivers with passengers in the car. Situation awareness was increased for drivers with passengers in the car because the passengers were able to provide alerting comments, and suppress the current conversation as the driver approached a road hazard. Driving uses several cognitive resources, adding a cell phone takes additional cognitive resources, and combining these two tasks can result in a decrement of situation awareness and overall driving performance.

Type of device. In many states, legislation has tried to restrict the use of cell phones while driving by enacting cell phone laws. When driving, some states only allow hands-free cell phones. Researchers have examined if any differences exist between the effects of hands-free cell phones and handheld cell phones. Patten, Kircher, Östlund, and Nilsson (2004) found participants’ reaction times increased when conversing on a cell phone using both hands free and handheld devices. Most importantly there was no difference in reaction time between participants using a hands-free cell phone and a handheld cell phone. Strayer and Johnston (2001) examined the differences in hands-free and handheld cell phones as participants performed a simulated driving procedure in which participants had to respond to a red or green light. When participants were conversing on either cell phone type, hands-free and handheld, they were twice as likely to miss responding to either the red or green light. Preliminary analysis found no significant difference between hands-free and handheld cell phones. These results indicate that physically holding a cell phone while driving does not interfere with driving performance. According to the threaded cognition theory, multiple threads may result in diminishing interference over time because the learning thread fires fewer production rules, overall, resulting in less processing on the procedural resource. Conversing on any type of phone may be a well learned activity, but the content of the conversation is always different, and would heavily rely on declarative knowledge. Therefore, it may be conversational factors that result in poor driving performance. Strayer and Johnston (2001) further explored conversational factors by having participants listen to a book on tape, and respond to a red or green light in the simulated driving procedure. At the end of the driving procedure, participants completed a posttest to confirm they attended to the material presented to them on the tape while driving. Listening to the book on tape did not have a significant impact on participants' driving performance. This finding adds to the ideas that the active participation in a conversation is the reason for decreased driving performance. Hunton and Rose (2005) examined if there was a difference between a conversation on a hands-free cell phone and a conversation with a passenger in a simulated driving environment. In this study, it was determined that the cell phone demanded more cognitive attention because the individual on the cell phone did not know when to suppress the conversation. This was because the person conversing on the phone with the driver could not see the current driving situation. Drivers with passengers have higher situation awareness compared to drivers conversing on cell phones (Charlton, 2009). Drivers without any passengers, and without conversing on a cell phone, have faster reaction times, faster situation awareness, and overall are the safest drivers.

Content of a conversation. The content of cell phone conversations may consist of different types of information, and may require different levels of processing. Some conversations are simple, and some conversations are more complex, requiring more cognitive resources. Previous studies have examined the effects of verbal communication while driving by using methods such as asking participants to compute math problems or by using variations of the word shadowing technique. Rakauskas, Gugerty, and Ward (2004) pilot tested the difference in easy and difficult naturalistic conversation questions to use in their procedure. An example of a piece of a naturalistic conversation would be, "What is your college major?" They found that, regardless of the intensity of the naturalistic conversation, participants' driving performance was affected, and participants drove with more variation in speed. Patten et al. (2004) used simple and complex mental arithmetic and memory tasks to distract participants, instead of using naturalist conversation. The simple conversation required participants to repeat a number that was spoken to them via cell phone, to the researcher. The complex conversation asked participants to do mental arithmetic while driving. The researchers provided numbers via cell phone to the participants while they were driving, and the participants had to respond with their answers. Because complex mental arithmetic is not a typical activity performed while driving, according to the threaded cognition theory, the executive processor will only be able to attend to one task at a time because the combination of these two tasks are not well-learned. Patten et al. (2004) found that as the content of the conversation increased in difficulty, driver performance decreased. High workload in conversations resulted in decreased driving performance. Briggs, Hole, and Land (2011) examined the impact of an emotionally involving conversation on driving performance.

Participants were measured in an undistracted condition, which was driving in silence, and a distracted condition, which was driving while conversing on a cell phone about spiders. The spider phobia questionnaire was assessed to discriminate phobics from non-phobics. Participants in both groups made a similar number of driving errors in the undistracted condition, and when asked to converse on a cell phone both groups made significantly more driving errors. The spider-phobic group was more emotionally involved, and distracted by the content of the conversation than the non-phobic group. In the distracted condition, spider-phobics showed decreased driving performance, and the eye tracking equipment showed a significant decline in the range of their visual fixations, exhibiting a pattern of visual tunneling (Briggs, Hole, & Land, 2011). The more emotionally engaged the driver is in the content of the conversation, the greater the potential for distraction.

Cognitive workload. Primary tasks when driving include controlling the vehicle, monitoring for hazards in the environment, and taking proactive measures to ensure safe operation while avoiding possible vehicle crashes. Driving demands cognitive resources and motor control. Adding distractors, such as a cell phone, adds an additional demand on cognitive resources and motor control. A driver’s limited capacity to share cognitive task resources between the task of driving, and the task of using the cell phone may impair the driver to the point of unsafe driving. A few studies have examined the perceived workload on participants during a simulated driving task. Rakauskas et al. (2004) used the Rating Scale of Mental Effort (RSME) to measure self-reported perceptions of mental workload, after participants completed the driving simulator procedure. They found as the intensity of the conversation increased, participants reported higher mental workload on the RSME. Even though subjective mental workload was higher when participants were engaged in some type of conversation, participants who did not participate in a cell phone conversation reported low levels of mental workload on the RSME. This suggests that driving without any distractions demands an amount of cognitive attention. Rakauskas et al. (2004) concluded that drivers may cope with the addition of phone conversations by enduring higher workloads or setting reduced performance goals. Drivers set reduced performance goals so that primary task demands are lowered. For example, drivers are satisfied maintaining a slower average speed while they are conversing on a cell phone. Adaptive cruise control has been adopted into almost all modern vehicles with the primary purpose of aiding drivers to be safe motorists. Ma and Kaber (2005) examined participant's situation awareness and cognitive workload when using adaptive cruise control. They measured subjective mental workload after each trial, by asking participants to mark either "low" or "high" on a workload rating scale (Ma & Kaber, 2005). When adaptive cruise control settings were enabled, participants reported lower mental workload. When conversing on a cell phone participants reported a higher mental workload. Ma and Kaber (2005) concluded that when adaptive cruise control was enabled, and when simultaneously conversing on a cell phone participants eliminated all significant workload effects across both conditions. By combining driving with a cell phone conversation, cognitive workload is increased so much that one of the tasks will have to suffer. One task will receive more attention than the other task because they are both demanding the same cognitive resources, and the human brain is not capable of processing them equally. Previous research has shown there is no performance difference between hands-free and handheld cell phones. Even if a person is using a hands-free cell phone, cognitive resources are still being demanded by the driving task and the active participation in the conversation task.

Comparing drivers who use a cell phone to other drivers. Driving is a complex task which involves many task-relevant activities such as following distance, reaction time, and acceleration. Task-irrelevant activities, such as using the cell phone, tend to be combined with driving, and result in decreased driving performance and situation awareness. The National Highway Traffic Safety Administration (2008) found a U-shaped distribution comparing vehicle accident fatalities and age. From 1996 to 2006, the most fatalities occurred in the 16-20 age group and the over 65 age group. Some possible reasons for the U-shaped distribution is because the 16-20 age group has less experience, takes more risks, and is more likely to be intoxicated while driving. Whereas, the over 65 age group has more experience, takes more safety precautions, is less likely to be intoxicated while driving, but has higher health related issues, slower reaction times, and probably poorer vision and hearing.

Researchers began to question the difference in a distracted driver to other drivers on the road such as older individuals and legally intoxicated individuals. Strayer and Drews (2004) examined driving performance in younger adults, age 18-25, and older adults, age 65-74, while conversing on a cell phone. Participants had to follow a car in front of them during this procedure; it was found that both groups drove with a greater following distance when conversing on a cell phone. The most interesting finding was the slower reaction time for both groups when conversing on the cell phone. The cell phone conversations slowed participant’s reaction time by 18% (Strayer & Drews, 2004). Older adult drivers did not suffer much more than younger drivers while conversing on the cell phone, indicating that when conversing on a cell phone a younger driver is the same equivalent as an older driver.

If there are not any major differences between young drivers and older drivers while conversing on a cell phone; what is the difference between drivers conversing on a cell phone and a legally intoxicated driver? Strayer, Drews, and Crouch (2006) examined the difference between legally intoxicated drivers, with a blood alcohol concentration of 0.08, and drivers who were conversing on a cell phone. The only statistically significant differences between drivers who were conversing on a cell phone, and legally intoxicated drivers was found in maximum brake force, brake reaction time, and the time for recovery of speed that was lost when applying the brakes. Otherwise, the risk associated with conversing on a cell phone while driving is comparable to driving while legally drunk (Strayer et al., 2006). From these results conversing on a cell phone shows a decrement in performance by having a reaction time as slow as a 65 year old driver, and is the equivalent of being legally intoxicated.

Supertaskers. While the majority of studies indicate conversing on a cell phone while driving has detrimental effects on driving performance, studies also find individual differences in multitasking performance. Watson and Strayer (2010) examined the theory that driving should be impaired for any motorist who is simultaneously talking on a cell phone. They tested participants twice while driving, once without a cell phone, and once while conversing on a cell phone. Watson and Strayer (2010) found some participants to be “supertaskers” because they showed no performance decrements when asked to perform the dual task in the simulator. These ‘supertaskers’ are able to handle more than one task without it affecting either task (Watson & Strayer, 2010). Although this research directly relates to multitasking performance in a simulated driving environment, this could arguably be generalized to other multitasking environments such as the classroom. Having previous knowledge on a topic may be advantageous for students dividing attention between class material and text messaging.

Multitasking while Walking

The portability of technology allows the internet, music, and telephone conversations to be carried with us everywhere we go. Many college students now walk to class with a headset on, listening to music, or they are having a conversation on their cell phone. This has made researchers question the effect and potential danger multitasking has on individuals while walking. Researchers can study walking performance while multitasking either by observation or with the help of walking simulators (Zhang, Kaber, & Hsiang, 2010).

Another developing area in multitasking research has examined individuals walking while multitasking. Although this research directly relates to walking, attention, cognitive load, and performance can be generalized to other multitasking environments such as the classroom.

Inattentional blindness. Before the rise and portability of technology, students walked to class either alone or with a friend. Today, a typical walk to class for students can include listening to music or having a conversation on their cell phone. Hyman, Boss, Wise, McKenzie, and Caggiano (2010) observed individuals crossing through a common area on a university quadrangle. Individuals were classified based on their behavior, cell phone users, listeners to music, lone walkers with no electronics, and individuals walking with another person. Most importantly, the observers recorded the time it took each individual to cross, if the individual stopped, the number of direction changes made by an individual, whether the individual weaved while crossing, if the individual was involved in a collision or near-collision, and if the individual explicitly acknowledged other people by waving, nodding or talking. Cell phone users walked the slowest, changed directions more frequently, and were less likely to acknowledge other people than individuals in the other conditions. From these findings, researchers wanted to examine the difference in individual's awareness of their surroundings (Hyman, Boss, Wise, McKenzie, & Caggiano, 2010). For this segment of the study, a clown dressed in brightly colored clothing, riding a unicycle around a sculpture was placed near the middle of the diagonal walk. When individuals were exiting the diagonal path, observers stopped them to ask them two questions. The interviewers asked if they had seen anything unusual, if they answered yes, they were to specifically tell what they seen. If the individual did not mention seeing the clown, they were asked directly if they had seen a clown on a unicycle. Only 25% of cell phone users noticed the clown on the unicycle, 51% of single individuals, 61% listening to music, and 71% of people in pairs noticed the clown on the unicycle (Hyman et al., 2010). Therefore 75% of individuals conversing on a cell phone did not notice the clown on the unicycle, and this may be because participating in a conversation requires so many cognitive resources and attention. When individuals are engaged in cognitively demanding tasks, they may not be aware of potentially dangerous stimuli in the environment, and they might miss more than a clown on a unicycle.

Classroom Distractions

Before the advent of modern technology, classroom distractions consisted of students whispering amongst one another or notes being passed during class. Technology has replaced many traditional classroom distractions, only in a different form. Many secondary school classrooms and college classrooms have integrated technology for teaching and communication purposes. Technology has been brought into the classroom to provide learning opportunities, and unfortunately has brought unwanted distractions. Many college professors make their own rules regarding laptop use in their classroom, and they try to enforce a no cell phone policy. In a national study, 95% of 18 to 34 year-olds reported owning a cell phone, making a cell phone the most popular piece of technology for adults (Zickuhr, 2011). Wireless internet connections, throughout academic buildings on college campuses, make distractions easily accessible for college students who carry a cell phone or laptop to class lectures. The introduction and popularity of technology in classrooms have made researchers question the effects of various technological interruptions on learning. Methods used to examine the effects of classroom disruption involve simulated environments, perceived academic performance, and actual classroom behavior through the use of spyware. The more distraction and interruptions a student leaves themselves susceptible to during class, the lower their performance will be for the material discussed during class.

Computers. Similar to other modern technology devices, computers have evolved into small, easily portable devices. The latest laptops and tablets are the size of a notebook or smaller. For some students, laptops have replaced the traditional pen-and-paper style of note taking. Even though computers allow students to take notes, they have the potential to create distractions since all academic buildings on college campuses have wireless internet capabilities. This poses a concern for professors. Because the use of laptops during a class lecture has not been universally accepted across universities, an ongoing debate continues regarding the actual role laptops play in classrooms, i.e., if they aid or hinder learning for students. Because there is no universal policy, professors create their own laptop policies, and some professors have gone to the extent of banning the use of laptops during class lectures. Distractions from laptops have the potential to distract the individual using the laptop, and distract the students seated around the individual with the laptop. Researchers have used self-report surveys and spyware software to study computer behavior during an actual class lecture.

Non-course related material. Kraushaar and Novak (2010) studied students in a management information systems course, which required laptops be brought for classroom assignments. The methods used were self-report, and spyware software was installed on the student's computers, with the student's permission. Based on the spyware software data, students engaged in non-course-related windows 42% of the time, but when self-reporting students underestimated the actual amount of time spent checking their email, instant messaging, and surfing non-course-related websites (Krraushaar & Novak, 2010). Students who exhibited greater activity on non-course-related websites also reported lower academic performance such as their grade point average. From this finding, more cognitive resources were being allocated to non-course-related websites than course-related websites and the class lecture. Fried (2008) examined in-class laptop behavior over a 10 week period, from two sections of a General Psychology course, through a self-report survey. This course did not have any restrictions regarding in-class laptop use. Students who brought laptops to class reported using them 48.7% of the class period on average during the lecture, 81% reported that they checked their email, 68% reported that they instant messaged, 43% reported surfing the net, and 25% reported playing games (Fried, 2008). Students who brought their laptops devoted almost half the lecture to distracting, non-course related activities. High school ranking, ACT scores, and attendance was used to examine the relationship between student learning and laptop use. Students who reported higher use of laptops during class, had lower previous academic performance, and reported not feeling they understood the material that was presented in class very well. Students who did not use laptops during class reported clearly understanding the lecture, they showed an increase in course performance, and they had higher previous academic performance. Students were asked to report anything in the class that distracted them away from the class lecture. The single most reported distractor was laptop use by students seated around them which accounted for 64% of all responses, this was the issue that most interfered with students ability to give full attention to the class lecture, and learn the material presented in class (Fried, 2008). If spyware software was installed on the student's computers in this study, it is possible that self-reported distraction was underestimated. Students who avoid potential distractions by not bring laptops to class still have hindered learning environments because of the students seated nearby with laptops. Laptop distractions interrupt more than the individual receiving or creating the distraction, and this can be generalized for cell phones that appear in the classroom as well.

Instant messaging. Instant messaging allows one person to communicate in separate conversations with many people at the same time. Before the popularity of social media sites, certain websites would have software dedicated only for instant messaging which allowed people to create a “buddy list” of people whom the user wanted to keep in contact with. Today, many social media sites have incorporated instant messaging into their user interface. When users log into their instant messaging software or social media website anyone can contact them, and the conversation will pop-up at the bottom of the screen. Instant messaging can create multiple interruptions (Levine, Waite, & Bowman, 2007).

Researchers have become interested in the effects instant messaging has on attention, comprehension, academic performance, and perceived multitasking abilities. Levine, Waite, and Bowman (2007) conducted a descriptive study to explore the relationship between instant messaging and college students’ perceptions of their own ability to focus on academic tasks. Participants reported that when their computer was turned on, 73.4% of the time instant messaging was enabled, a typical instant messaging conversion lasts on average 75.2 minutes with approximately 2.93 people, and 30% reported that during their instant messaging sessions they were completing academic work (Levine et al., 2007). Participants who reported being quick to respond when they received an instant message were more likely to report feeling distracted during their most recent instant message session. As the amount of time participants spent instant messaging increased, the easier it was for them to be distracted away from academic tasks, while the amount of time spent reading books was negatively related to distractibility. Junco and Cotton (2011) found similar results: 93% reported active instant messaging use while completing academic tasks and 57% reported that they knew instant messaging had a detrimental effect on their academic work. Even though students report that instant messaging has detrimental effects on their academic performance, they continue to leave instant messaging available on their computer while completing schoolwork. Fox, Rosen, and Crawford (2009) found students who report spending more time per day using instant messaging also reported lower GPAs. Instant messages are very similar to text messages because when they are enabled, they can cause an interruption at any time. The user decides when to answer the interruption, either immediately or once they finish processing the task they are currently engaged in such as attending to academic material they know they will be tested on in the future.

Cell phones. The capabilities of cell phones have changed considerably over the past few years. They are very portable, and in addition to talking, they are able to surf the internet, access social media sites, and text message. College students carry their cell phones with them everywhere they go, including the classroom. Through a cell phone survey, 92% of students report text messaging during class time (Tindell & Bohlander, 2012). With the escalating presence of cell phones appearing in higher education classrooms, a new topic of research is examining the interruptions of cell phones on students recall for material presented during the class lecture. Self-report surveys have been the predominant method of studying the prevalence of cell phones, and text messaging during class. Rosen, Lim, Carrier, and Cheever (2011) examined the effects of text messaging during a classroom lecture, which is the first study to examine this during an actual class.

Text messaging. A popular form of communication for young adults is text messaging. Text messaging is especially useful when a person cannot have a conversation due to being in class, or in an environment where they are expected to remain silent. Rosen et al. (2011) examined the direct impact of text message interruptions on memory recall in a real classroom environment. Participants in four undergraduate psychology courses were randomly assigned to one of three groups; one group received zero texts, one group received four texts, and one group received eight texts from the researcher. Participants were instructed to respond promptly if they received a text message from the researcher. A text message was timed to arrive to participants when material that was on the posttest was being covered in the videotaped lecture. Participants viewed a 30-minute videotaped lecture on lifespan development, and were tested on the material following the video. Participants used their own personal cell phones, and were also able to text message individuals besides the researcher. Allowing participants to text outside the researcher defined different groups; no/low texting group (0-7 text messages), moderate texting group (8-15 text messages), high texting group (16 or more text messages). Participants in the high text messaging group scored significantly worse on the posttest than participant's in the group that did not receive any texts from the researcher. Participants in the moderate text messaging group did not score significantly different on the posttest than participants in either the high text messaging group or the no/low text messaging group. Regarding participant's attitudes of text messaging during a class lecture, 75% agreed that receiving and sending text messages disrupts one's ability to learn from the lecture, while 40% agreed it was acceptable to text during a lecture (Rosen, Lim, Carrier, & Cheever, 2011). Because this is the first empirical study to examine the effects of text messaging on memory recall during a class lecture, several limitations exist. This study did not specifically examine the components that make up text messaging such as sending and receiving. This gave me the idea to break down the different components that make up text messaging to see which component causes the most disruption to an individual.

Statement of the Problem

Multitasking is a task people attempt daily. Sometimes we multitask without realizing or intending to multitask. The common myth people hold is that by multitasking we are accomplishing more, but this is not the case. A popular research area in multitasking is simulated driving procedures while conversing on either a hands-free or handheld cell phone. Simulated driving experiments have shown performance decrements for participants driving while conversing on any type of cell phone (Charlton, 2009; Ma & Kaber, 2005; Rakauskas et al., 2004; Strayer & Drews, 2004).

Multitasking has evolved over the years with the invention of technology. The latest computers, iPods, and smart phones are readily available, portable, and constantly changing to improve human interface. Even though technology is changing in order for us to keep up with our lives more efficiently, human cognitive abilities are remaining the same. We are being constantly bombarded with technology. Technology has been adopted into vehicles and classrooms as a teaching device and communication tool. Modern technology has raised concern about human performance and human cognitive abilities. A new area of research is examining the distraction of cell phones on students learning ability, attention span, and academic performance on students across all age levels. It has been hypothesized that as students combine text messaging with classroom material, their memory for the material will decrease because of the limited cognitive resources available to processes these two tasks.

When cognitive resources are being divided between text messaging and attending to the material in the classroom material, one of the tasks will suffer because both tasks are not receiving full attention. According to the ACT-R theory, the subsymbolic structure allows multitasking for already well learned material. Even though text messaging may be a well learned activity, the material presented is not well learned. Both the ACT-R theory and the threaded cognition theory manage multiple tasks based on the order in which task made the request first. If the thread goal is to send a text message it will complete the thread before attending to the material again. When reviewing the literature, there was no research examining the exact amount of cognitive resources used when reading in the adult population. The only literature found on the amount of cognitive resources used when reading was in childhood development. The amount of cognitive resources used during a reading task is an area that needs to be further researched.

Participants attending to classroom material and text messaging will be setting reduced performance goals for the material because they are attending to a text message, and will miss information presented. Because students do not have a vast amount of knowledge on the material presented in class, the material is considered a high workload task. If a student is text messaging an individual outside of class, that individual will be demanding attention because they are not in class to know the classroom situation. Whereas, talking to a student sitting beside you in class will know the classroom situation, and will know when to stop talking to listen to the classroom material. In addition, if students find themselves emotionally engaged in the text messages, they will have decreased performance on the material covered.

The purpose of this study is to examine the various effects cell phones have on college students' ability to retain information presented to them. The different stages of a text message will be examined in isolation of all other cell phone capabilities, in order to determine which stage is the most distracting for college students.

Hypotheses

Hypotheses 1: The threaded cognition theory presumes that individuals can only run one thread or task at a time in isolation. According to this theory, humans must learn to complete a thread in isolation before combining the thread with another thread. Individuals who are using more cognitive resources will have poor performance on the posttest because humans have limited cognitive abilities.

i. Participants who are assigned to the cell phone conditions will have lower memory recall for material presented during the video because even though they may be an expert at text messaging, they will not be an expert on material presented in the video, and will not be able to successfully combine the two threads. The participants who do not receive a cell phone will have higher memory recall for material presented during the video because they will have more cognitive resources available.

ii. Participants in the sending and receiving group will be using more cognitive resources, and will score lower on the posttest than the receiving only group.

Hypotheses 2: I hypothesize that participants who are assigned to the cell phone conditions will have lower memory recall for the target questions. The participants assigned to the control group will have higher memory recall for the target questions.

Exploratory Analyses: Exploratory analyses will be performed to examine the relationship between individual's beliefs about their ability to multitask and their posttest score.

CHAPTER 3: METHOD

Participants

Participants included 120 undergraduate students from Western Carolina University enrolled in a psychology course. Participants received course credit for their participation. The current study's sample consisted primarily of Caucasian, female students. Approximately 88% of the participants were Caucasian, followed by approximately 5% African American. The sample consisted of 69% females and 31% males. The mean age of the participants was 18.50, with approximately 92% between the ages of 18 to 20.

Materials

Video. Participants watched a ten minute video developed by NOVA scienceNOW (NOVA, 2009). The video covered material on memory. This video provided facts and empirical evidence on short-term and long-term memory. They also examined the popular study on the famous psychology subject named H.M. Participants watched this video individually on a computer screen.

Prearranged text messages (Appendix A). Prearranged text messages were developed to text participants during the procedure. They consisted of open-ended questions requiring a multiple-word response. Three text messages were timed to arrive during the time a key concept, which is assessed in the posttest, was presented in the video.

Posttest multiple choice exam (Appendix B). A 12 item multiple-choice exam was developed with questions covering material from the entire 10 minute period. The items on the exam consist of applying and making inferences about the information presented. Three target questions were also included in the 12 item multiple-choice exam. The target questions were developed to correlate with material that was being presented during the video. The participants that were assigned to the cell phone conditions received a text message during the time information was being presented in the video about the target questions. These questions were specifically designed to examine the distraction the cell phone has on memory.

Multitasking questionnaire (Appendix C). This questionnaire examined participants' typical texting behavior, opinion of text messaging during a college lecture, and whether text messaging affects their ability to learn the material. Participants were also asked questions about the video they watched, whether or not it was interesting to them, and how much they thought they paid attention to the video. This questionnaire also examined participants' multitasking ability, the types of tasks they combine together, and forms of media they combine together.

Demographic questionnaire (Appendix D). This questionnaire was developed to assess basic demographic information, which includes age, gender, ethnicity, GPA, and class standing.

Procedure

Participants were randomly assigned to the control group, or one of the treatment groups. The control group was not given a cell phone, but watched the video, completed the posttest, and questionnaires. The receiving group received three text messages during the video. The receiving group was instructed to read the text message as soon as possible, and to not respond. The combined sending and receiving group received three messages, and sent three messages to the researcher during the video. Participants in the combined group were instructed to respond as soon as possible when they received a text message from the researcher.

Before beginning the experiment, participants gave informed consent. If they were assigned to one of the treatment groups, they were asked what type of phone they used for text messaging, and were allowed to choose from a flip phone, touch screen phone, or a blackberry. The phones were pre-paid Verizon phones. Depending on the group the participant was randomly assigned to determined their task with the cell phone during the video, and they were then informed of their role during the study. Participants were informed of a posttest that followed the video. Each participant watched the 10 minute video on memory. After the video ended, participants completed the posttest about the video. They also completed the demographic questionnaire and multitasking questionnaire.

CHAPTER 4: RESULTS

How does text messaging influence memory recall while watching a short video?

Hypothesis 1 was based on the threaded cognition theory. I hypothesized that college students who are assigned to the cell phone conditions will have lower memory recall for material presented during the video because, even though, they may be an expert at text messaging, they will not be an expert on material presented in the video, and will not be able to successfully combine the two threads. The participants who do not receive a cell phone would have higher memory recall for material presented during the video because they will have more cognitive resources available. I also hypothesized that participants in the sending and receiving group will be using more cognitive resources, and will score lower on the posttest than the receiving only group. A one-way between groups analysis of variance was conducted to investigate the effect the cell phone had on memory recall for the posttest. Participants were randomly assigned to one of three groups: the combined group, the receiving group, or the control group. There was a statistically significant difference at the $p < .05$ level in posttest scores for the three groups: F (2, 117) = 4.64, $p = .01$. Despite reaching statistical significance, the actual difference in mean scores between the groups was quite small. The effect size, calculated using eta squared, was .07. Post-hoc comparisons using the LSD test indicated that the mean score for the control group (M = 9.93, SD = 1.14) was significantly different from the receiving group (M = 9.03, SD = 1.49). The mean score for the control group (M = 9.93, SD = 1.14) was significantly different from the combined group (M = 9.25, SD = 1.46). The combined group and receiving group did not differ significantly from one another. Table 1 reports the significance between the group's scores on the posttest. Table 2 reports the means and standard deviations of the posttest scores for each group.

Table 1

Means and Standard Deviations of Posttest

Group	Mean	Standard Deviation	N
Control	9.93	1.14	40
Receiving	9.03	1.49	40
Combined	9.25	1.46	40

Table 2

Post-hoc comparisons of the Posttest Scores

Group	Group	*P*
Control	Receiving	.004*
Control	Combined	.03*
Combined	Receiving	.47

*Note. *p<.05*

How does text messaging influence memory recall for specific information?

Hypothesis 2 stated that participants who are assigned to the cell phone conditions will have lower memory recall for the target questions. The participants who do not receive a cell phone will have higher memory recall for the target questions. A one-way between-groups analysis of variance was performed to investigate the effect the cell phone had on memory recall for target questions. There was no statistically significant difference between the groups memory recall for the target questions: F (2, 116) = 1.82, p =.17. Post-hoc comparisons using the LSD test indicated that the mean score for the control group (M = 2.50, SD = .60) was not significantly different from the receiving group (M = 2.28, SD = .75). The mean score for the control group (M = 2.50, SD = .60) was not significantly different from the combined group (M = 2.23, SD = .67). The mean score for the combined group (M = 2.23, SD =.67) was not significantly different from the receiving group (M = 2.28, SD = .75).

Do individuals believe they are good at multitasking?

Exploratory analyses were conducted to examine the relationship between individual's beliefs about their ability to multitask and their posttest score. The relationship between individuals' beliefs about their ability to multitask and their posttest score was investigated using Pearson product-moment correlation coefficients. There was a small, negative correlation between the two variables, r = -.17, n = 119, p = .07, with high levels of individual beliefs about their ability to multitask associated with lower scores on the posttest.

CHAPTER 5: DISCUSSION

Purpose of the Study

Multitasking research has blossomed over the years with the invention of portable technology. Human cognitive abilities remain the same as technology is constantly changing in order for us to keep up with our lives more efficiently. It is very hard to ignore technology as it appears in vehicles and classrooms today. A popular area in multitasking research is the use of simulated driving procedures while conversing on either a hands-free or handheld cell phone. Simulated driving procedures have shown performance decrements for participants driving while conversing on any type of cell phone (Charlton, 2009; Ma & Kaber, 2005; Rakauskas et al., 2004; Strayer & Drews, 2004).

Modern technology has raised concern about human performance and human cognitive abilities. A new area of research is examining the distraction of cell phones on learning ability, attention span, and academic performance in students across all age levels. It has been hypothesized that as students combine text messaging with classroom material, their memory for the material will decrease because of the limited cognitive resources available to process the two tasks. Rosen et al. (2011) examined the effects of text messaging on memory recall during a class lecture. Since this was the first empirical study to examine the effects of text messaging on memory recall during a class lecture without the use of a survey, several limitations exist.

This study did not specifically examine the components that make up text messaging, such as sending and receiving. This gave me the idea to break down the different components that make up text messaging to see which component causes the most disruption to an individual. The purpose of the current study was to examine the various effects cell phones have on college students' memory recall during a short video, in a controlled environment.

Results and Implications

The current study used college students at Western Carolina University to examine the various effects text messaging has on the ability to retain information presented to them during a short video. Participants were randomly assigned to the control group, receiving only group or the combined sending and receiving group. After watching a short video, participants completed a posttest on the material presented during the video, and a multitasking questionnaire that assessed their attitudes about multitasking.

Based on the threaded cognition theory, it was hypothesized that college students who are assigned to the cell phone conditions will have lower memory recall for material presented during the video. College students may be an expert at text messaging, but they will not be an expert on the material presented in the video, and will not be able to successfully combine the two threads because combining two new tasks requires declarative memory. The participants who do not receive a cell phone will have higher memory recall for material presented during the video because they will have more cognitive resources available and they will perform one task in isolation. When the analyses were examined, the cell phone groups were significantly different from the control group, supporting the threaded cognition theory. Because the participants in the cell phone groups were not experts on the material presented during the video, they could not successfully combine the video thread with the text messaging thread, resulting in lower posttest scores than the participants in the control group. According to the threaded cognition theory, instructions for new tasks must be stored as declarative knowledge; a set of production rules retrieves each instruction and completes actions (Salvucci & Taatgen, 2008). A new rule must be relearned multiple times, and this explains why multiple new tasks are harder to combine. During the procedure, the control group ran the video thread in isolation resulting in higher posttest scores than the cell phone groups. Additionally, it was hypothesized that participants in the sending and receiving group will be using more cognitive resources, and will score lower on the posttest than the receiving only group. This was not supported by the data, and therefore the results appear to suggest that there is no difference between the receiving only group and the combined sending and receiving group. The cell phone was a distraction for both of the cell phone groups, and consumed a significant amount of cognitive resources.

It was hypothesized that participants who are assigned to the cell phone conditions will have lower memory recall for the target questions. The participants who do not receive a cell phone will have higher memory recall for the target questions. There was no statistically significant difference between the groups' memory recall for the target questions. The process of interruptions can be broken down into sequential stages, the main stages being the interruption lag and the resumption lag. The interruption lag is the time between an alert of an interruption and the actual start to the interrupting task (Salvucci et al., 2009). For this procedure, the interruption lag consisted of watching the video and being alerted by a sound that indicated a new text message had been delivered, and then the participant would begin to read and respond to the text message. The resumption lag is the time between the end of the interruption task and the reinitiating of the original task. For this procedure, the resumption lag consisted of sending a text message or reading a text message, and then recalling information from the primary task while continuing to watch the video. The resumption lag can help to explain why the target items were not affected but overall performance on the posttest was different between the groups. These results also indicate that the target questions were too easy, and there were not enough target questions to make a significant difference between the groups. Prearranged text messages were designed to text participants in the cell phone conditions during the video. Three text messages were timed to arrive when the video was covering material on the target questions. The accuracy of the researcher sending the text messages to the participants could have had early or late timing flaws, allowing the participants to get enough information from the video to correctly answer the target questions. In addition, the cell phone signal might have been weak, delaying the timing of the text message received by the participant.

Exploratory analyses were performed to investigate the relationship between individual's beliefs about their ability to multitask and their posttest score. Previous research found that 75% of participants agreed that receiving and sending text messages disrupts one's ability to learn from the lecture, while 40% agreed it was acceptable to text during a lecture (Rosen et al., 2011). The relationship between individuals' beliefs about their ability to multitask and their posttest score was investigated using Pearson product-moment correlation coefficients. There was a small, negative correlation between the two variables, with high levels of individual beliefs about their ability to multitask associated with lower scores on the posttest. Individuals who reported that it was acceptable to text message during class, and reported sending and receiving text messages to anyone during class scored lower on the posttest. These results are consistent with previous research on self-reported text messaging habits during classroom lectures.

Limitations

There are several limitations for the current study. First, the video posttest was developed to consist of items that required applying and making inferences about the information presented. The video posttest consisted of twelve items. In this study, the Cronbach alpha coefficient was -.18. This indicates the posttest consisted of too many easy questions.

Another limitation is the material covered in the video. Since the sample largely included freshman undergraduate students from the psychology participant pool, participants could have been exposed to the material in the video prior to the procedure. The final limitation is the sample used in this study. Our sample included largely Caucasian, freshman, undergraduate students enrolled in a small southern university. The current study cannot be generalized to the general population.

Directions for Future Research

Future research should continue to examine the effects text messaging has on memory recall in classroom environments. This study design could be incorporated into an actual learning environment. It would be important to control for outside text messages that could be received by participants. This could be done by providing a cell phone to the participants, similar to the current study where participants were able to use the phone that most resembled what they use to text message. It is also important to obtain a diverse sample including varying ethnicities and class levels in college.

Technology is constantly changing, and there will always be distractions to contend with inside and outside the classroom. Multitasking is not a new phenomenon, but a new variable we have to take into consideration as we try to find the best way for students to learn in environments where distractions are present.

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APPENDICES

APPENDIX A

Prearranged text messages

Sending and Receiving Condition
1. What do you normally get on your sub at Subway?
2. What is your ideal job after graduation?
3. What do you like to do on Saturdays?

Receiving only condition
1. What do you normally get on your sub at Subway?
2. What is your ideal job after graduation?
3. What do you like to do on Saturdays?

APPENDIX B

Video Posttest

1. According to the video, the most-studied patient ever was, and continues to be today:
    A. William Scoville
    B. Chad Cohen
    C. Brenda Milner
    D. Henry Gustav Molaison
2. Neuroanatomist Jacopo Annese, dissected H.M.'s brain into _____ slices.
    A. 1,000
    B. 2,000
    C. 3,000
    D. 4,000
3. H.M. let surgeon William Scoville remove slivers of the brain from _____.
    A. Both sides of the brain
    B. The left hemisphere
    C. The right hemisphere
    D. The area in the front
4. William Scoville removed a seahorse-shaped structure from H.M., this structure is known as the_____.
    A. Thalamus
    B. Hippocampus
    C. PKMzeta
    D. Long Term Memory
5. H.M. could remember everything EXCEPT
    A. Childhood trauma
    B. Elementary and High School
    C. A person's name that he was just introduced to
    D. Work in the assembly plant
6. The ability to establish long-term memory is localized to
    A. The synapses
    B. The neurotransmitters
    C. The hippocampus
    D. The nerve cells
7. How was HM capable of performing well on the star exercise?
    A. He remembered practicing the exercise
    B. He could remember a motor skill
    C. He could remember events
    D. He could form short-term memories

8. Brenda Milner had H.M. draw the outlines of a star without looking at the star, but looking into a mirror. After three days and 10 trials, his performance was nearly perfect. This showed that H.M. could remember a motor skill, but not recall a fact or an event. This was a key discovery because:
    A. It showed there were different kinds of memory, dependent on different parts of the brain.
    B. It showed there were different kinds of memory, dependent on the same parts of the brain.
    C. It showed that precise molecules help create memories.
    D. It showed that precise molecules erase memories.
9. How are long-term memories formed?
    A. When one cell speaks to another cell repeatedly
    B. When one cell speaks to another cell, and only a few signals are sent
    C. When PKMzeta is present
    D. When the chemical ZIP is present
10. Nerve cells communicate by sending electrical signals, which trigger the release of chemicals across tiny gaps called _____.
    A. Neurotransmitters
    B. Synapses
    C. Receptor Sites
    D. Axon Terminals
11. What is PKMzeta's role in long-term memory?
    A. It does not allow long-term memories to form.
    B. It does not allow short-term memories to form.
    C. It fixes the connections amongst the neurons that were active together.
    D. It erases the connections amongst the neurons that were active together.
12. When the rat was injected with the chemical called ZIP, what was the rat's behavior?
    A. The rat avoided the shock zone.
    B. The rat forgot that there was a shock zone.
    C. The rat did not move.
    D. The rat ran around frantically.

APPENDIX C

Multitasking questionnaire

1. What is your typical texting behavior inside class?
   a. Send and receive to anyone
   b. Only send if I receive a text message from a friend or family member
   c. Only during emergency situations
   d. Never text message in class

2. What is your opinion of sending and receiving text messages during a college lecture?
   a. Acceptable
   b. Acceptable sometimes depending on the type of material being covered
   c. Acceptable sometimes depending on if the material being presented is boring
   d. Both B and C
   e. Not acceptable

3. Do you think text messaging affects your ability to learn the material being presented?
   a. Yes
   b. No

4. Do you think you are a good at multitasking?
   0- Not at all
   1- Slightly
   2- Somewhat
   3- Average
   4- Above Average
   5- Excellent

5. What forms of media do you combine together during class? (circle all that apply)
   a. Computer-based video (YouTube or online television episodes)
   b. Music
   c. Computer games
   d. Instant messaging
   e. Text messaging
   f. Email
   g. Web surfing
   h. Performing offline computing (word processing, excel, power point, etc.)

6. Did you think the material in the video was interesting?
   a. Yes
   b. No
   c. It was not bad, but it was not the most interesting video

7. How well do you think you paid attention to the video?
    a. 10 minutes (the entire video)
    b. 7-9 minutes
    c. 4-6 minutes
    d. 1 – 3 minutes
    e. Did not pay attention at all

8. How distracting do you think the cell phone was?
    a. Very distracting
    b. Somewhat distracting
    c. Not distracting
    d. Did not have a cell phone

APPENDIX D

Demographic questionnaire

1. Your age at the time of the study _______________

2. Your class level
   a. Freshman
   b. Sophomore
   c. Junior
   d. Senior

3. Gender
   a. Male
   b. Female

4. What is your ethnic background?
   a. Asian
   b. African-American
   c. Hispanic/Latino
   d. Native American
   e. White/Caucasian
   f. Other_____________________

5. What is your cumulative GPA? _______________