MEDIA MULTITASKING’S EFFECT ON COGNITIVE PROCESSING

A Thesis

Presented to the faculty of the Department of Graduate and Professional Studies in

Education

California State University, Sacramento

Submitted in partial satisfaction of

the requirements for the degree of

MASTER OF ARTS

in

Child Development

(Theory and Research)

by

Cynthia Davidson

FALL 2013
MEDIA MULTITASKING’S EFFECT ON COGNITIVE PROCESSING

A Thesis

by

Cynthia Davidson

Approved by:

______________________________, Committee Chair

Kristen Alexander

______________________________, Second Reader

Li Ling Sun

______________________________

Date

ii
Student: Cynthia Davidson

I certify that this student has met the requirements for format contained in the University format manual, and that this thesis is suitable for shelving in the Library and credit is to be awarded for the thesis.

__________________________, Graduate Coordinator  

Susan Heredia  

Date  

Department of Graduate and Professional Studies in Education
Media multitasking (the use of one or more media while also engaged in a real time task such as homework) is becoming an increasingly common behavior among adolescents and young adults. As a result, parents and educators have questioned the implications that media multitasking may have on the cognitive processes required for student learning. The effects of media multitasking during learning were investigated using a true experimental design. Differences in memory for lecture content were examined among 62 college students randomly assigned to a multitasking group or control group. Participants in the multitasking group engaged in text messaging and an internet search while also attending the lecture. Participants in the control group simply attended the lecture. Quantitative analyses revealed a significant difference in memory for lecture content with the control group outperforming the multitasking group. Findings suggest that the cognitive demands required for internet searching and text
messaging interfere with deeper learning, which has important implications for student learning both inside and outside the classroom.

_______________________, Committee Chair

Kristen Alexander

_______________________

Date
Sincere gratitude is extended to the following people that were very instrumental in completing this paper:

Kristen Weede Alexander, Ph.D., Professor and Graduate Program Coordinator of Child Development at California State University, Sacramento, for sponsoring this paper and whose expertise contributed positively to the analysis and interpretation of data;

Li Ling Sun, Ph.D., Professor of Child Development at California State University, Sacramento, for her sponsorship, and whose guidance helped frame and influence the literature review;

Juliana Raskauskas, Ph.D., Associate Professor of Child Development at California State University, Sacramento, for mentoring and sharing her time and insights;

Finally, family and friends for their patience, support and willingness to participate with piloting this study.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgements</td>
<td>vi</td>
</tr>
<tr>
<td>List of Tables</td>
<td>ix</td>
</tr>
<tr>
<td>List of Figures</td>
<td>x</td>
</tr>
<tr>
<td>Chapter</td>
<td></td>
</tr>
<tr>
<td>1. MEDIA MULTITASKING AND COGNITIVE PROCESSING</td>
<td>1</td>
</tr>
<tr>
<td>Purpose of the Study</td>
<td>2</td>
</tr>
<tr>
<td>Significance</td>
<td>3</td>
</tr>
<tr>
<td>Method</td>
<td>4</td>
</tr>
<tr>
<td>Definition of Terms</td>
<td>7</td>
</tr>
<tr>
<td>Limitations</td>
<td>7</td>
</tr>
<tr>
<td>Organization of the Thesis</td>
<td>8</td>
</tr>
<tr>
<td>2. LITERATURE REVIEW</td>
<td>9</td>
</tr>
<tr>
<td>Basic Cognitive Structures</td>
<td>10</td>
</tr>
<tr>
<td>Theoretical Framework</td>
<td>12</td>
</tr>
<tr>
<td>Media Multitasking and Working Memory</td>
<td>22</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Tables</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Media Use and Age Differences among Multitasking and Control Groups</td>
<td>37</td>
</tr>
<tr>
<td>2. Main Effect of Multitasking on Memory</td>
<td>38</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figures</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Results of Memory for Lecture Content</td>
<td>39</td>
</tr>
</tbody>
</table>
Parents and educators share a common concern for students’ academic success in a world of digital distractions (Randal, 2010 as cited in Wallis, 2010). To address this concern, organizations such as the Kaiser Family Foundation (2005) have recommended research in the ways students are media multitasking during class or homework time. Media multitasking includes the use of one or more media while also engaged in a real time task such as homework. Greenfield (2010) claims that media multitasking can fall under any one of three categories. The first category is an individual engaged in one media task while also performing a real life interaction such as texting while talking with friends. Another category is using two or more media at the same time like texting while downloading i-tunes. The final category would be using one media to perform several tasks such as checking e-mail and Facebook while also doing online research and typing a Word document.

Regardless of which category adolescents and young adults are utilizing, there are consequences to filtering and organizing information in human memory which may affect how information is encoded, stored and retrieved. This is because media multitasking draws on the same mental resources required for schoolwork according to Rosen (2012). Media multitasking during a lecture or homework is far different than washing dishes and watching television at the same time. For example, once washing dishes becomes
automatized, it becomes a motor act that requires few cognitive resources, freeing up those resources to attend to the television (Carr, 2011). The act of learning and the act of Facebooking or texting both place demands on working memory, which is used for problem solving, reasoning, and the maintenance and transformation of incoming information. As a result of over-taxing working memory, assignments take longer to complete, students become mentally fatigued, and information will be processed and stored differently in memory, which may affect learning and performance. For instance, Rosen’s (2011) study found that students scored worse on a test of lecture content if they responded to more text messages during the lecture than their peers that received fewer or no text messages. This raises the question of whether or not delaying the gratification of media multitasking can play a role in future achievement with grades, test scores, and success in school and even careers. In addition, are students able to resist the lure of technology when they need to be consciously attending learning? The following study is intended to determine if media multitasking, involving not just text messaging but also an internet search, affect memory for an academic lecture and if the role of working memory contributes in any way.

**Purpose of the Study**

The purpose of the current study was to examine the impact that media multitasking has on adolescents’ ability to inhibit irrelevant text messages and on-line
tasks while organizing incoming lecture information. The study aimed to answer the following questions: a.) Are there differences in post lecture assessment scores between a multitasking group and a control group? b.) Does working memory capacity determine memory for an academic lecture? In order to address these questions, the researcher conducted an experiment on two groups: the control group was assessed for memory of lecture content without media multitasking and the multitasking group was assessed for memory of lecture content while media multitasking during the lecture. Participants in the multitasking group engaged in media multitasking, as defined by Greenfield (2010), such as text messaging, while also doing other online activities. Memory for lecture content was operationalized by performance on the assessment task. Both groups were also assessed on measures of working memory with a backward digit span task. Quantitative analysis examined the results of the digit span task as well as the post lecture assessment. Results of this study can be used to bring awareness to parents and educators on the cognitive limitations associated with multitasking, which is becoming an increasingly common behavior as technology is continually integrated into most societies.

**Significance**

The current study was designed to provide a better understanding of the cognitive demands required to media multitask and how this might impact the adolescent brain’s ability to adapt while still developing. A literature review explored theoretical
framework by explaining how information is processed into human memory. In addition, prior research regarding media multitasking’s effect on human memory was discussed. An empirical investigation explored differences between a media multitasking group and a control group on student outcomes. This is particularly important for adolescents as media multitasking is becoming an increasingly common behavior among this age group. For instance, Rosen’s (2012) research indicated that students only spent 65 percent of the period they were observed doing actual schoolwork when also given the opportunity to multitask while learning. Learning can become shallow under such conditions compared to providing full attention to learning (Carr, 2011). As a result, students have greater difficulty transferring what they learned to other contexts because they remember and understand less of the material. The following section briefly describes how the current study investigated these cognitive demands.

**Method**

An experimental design was used to assess media multitasking and the impact it has on the ability to remember lecture content. A control group attended to a lecture presented by the researcher while the multitasking group attended the same lecture as they also engaged in media multitasking. In addition, both groups were given a backward digit span task to assess working memory. Quantitative analyses identified differences
between the two groups and associations between working memory and long term memory for lecture content.

**Participants**

The participants in the study included 62 undergraduate students. Participants were recruited from introductory level child development classes at California State University Sacramento. A demographic survey was given to obtain information on experience with prior technology, gender and age. This was to identify patterns that emerged when comparing level of media multitasking with assessment results for memory of lecture content.

**Procedure**

Upon approval, students received notification inviting them to participate in the study during class time however they needed to sign consent prior to participation. Second, participants were asked to bring cell phones, tablets and laptops to class on the day of the study. Next, they were randomly divided into either a control group or a multitasking group. The researcher then provided a brief questionnaire to all participants in order to identify perceived levels of media multitasking; high, medium and low. Identifying individual levels assisted with interpreting differences in comparing results of the study. Next, the researcher provided instructions for completing the post lecture assessment. Finally, lecture content was delivered to both groups simultaneously by the researcher for approximately ten minutes. During this time, the treatment group text
messaged with three friends for the entire lecture while also doing an internet search for
the addresses of five different local businesses. Once the lecture was finished, both
groups completed the assessment for memory of lecture content. The multitasking group
was also asked to provide the addresses to the five local businesses and self-report the
number of minutes spent texting.

Data Collection

Participants completed a brief survey to elicit demographic information related to
age, gender and experience with technology. In order to identify levels of media
multitasking, students completed a questionnaire asking them to indicate which of a
variety of media they make use of on a regular basis and their frequency of use.

The ability to manipulate information in working memory was measured using a
backward digit span assessment. Results of the digit span task were compared to the post
lecture assessment results of both the multitasking and control groups. The post lecture
assessment contained a series of sequencing, true/false, fill in the blank, short answer and
multiple choice questions.

Analytical Methods

Differences in student outcomes between the control group and multitasking
group were examined by t-test analysis. ANCOVA explained interactions between levels
of multitasking and any significance that arose from the variables under investigation.
Definition of Terms

For the purpose of this study, media multitasking was a combination of engaging in more than one media at the same time while attending to a real time task, the lecture (Greenfield, 2010). Working memory was considered the ability to actively hold in mind information that is needed to do complex tasks such as reasoning, comprehension and learning and it is limited in both capacity and rate (Seigler & Alibali, 2005).

Limitations

The following study was limited to participants age 18 or older at California State University Sacramento. Most of these participants fell within the range of emerging adulthood, a developmental stage following late adolescence; however some participants were well into adulthood and still included in the study. In addition, the backward digit span task is an individual oral assessment however due to time constraints and lack of assistants it was administered to all participants simultaneously. This means that participants needed to give written responses instead of oral ones. The researcher read a set of numbers for the participants to write down in backward order following a buzzer sound. This was to minimize the risk of responding before the researcher finished reading the list of numbers. Although these modifications were appropriate and necessary to address the whole group, the backward digit span task is typically limited as an individual oral assessment.
Organization of the Thesis

Prior research that supports the following study is discussed in chapter two. This includes a theoretical framework that explains how humans process information. The literature touches on limits to human memory and how children overcome these limits as they continue to develop. Past studies provided information on the challenges of processing multiple streams of information at the same time and how it affects student learning. Chapter three gives a detailed description of the study including participants, procedure and materials for data collection. Following this, chapter four will provide a detailed analysis of the results describing significant or non-significant findings. Finally, chapter five concludes the study with a summary of the findings and how the results of this study may benefit educators, students and future research.
Chapter 2

LITERATURE REVIEW

Adolescents today are spending significant amounts of time using multiple forms of media including phone, computers and television to name a few (Rosen, 2010). This trend has led to concerns among parents and educators about the impact that time devoted to media usage has on students’ learning and achievement. Past studies on the relationship between technology and student achievement have generally focused on the use of a single type of media, with more attention on media such as television, violent video games, computer games or text messaging (Carnagy & Anderson, 2005; Kumari & Ahuja, 2010; Perea, Acha & Carreiras, 2009; Plester, Wood & Joshi, 2009). Little research has addressed the use of multiple media while participants are trying to maintain focus on a real time task such as attending to a lecture or homework. The purpose for this type of study is to address the need to avoid irrelevant distractions during learning. For instance, recent studies have shown that processing multiple streams of information is challenging for cognitive processing. Ophir, Nass and Wagner (2009) found that self-proclaimed media multitaskers are not as adept at inhibiting irrelevant environmental information, task switching or organizing information in working memory as their non-multitasking peers.

The following literature review will discuss the relationships between media multitasking and cognitive processes, specifically the ability to inhibit and organize information in working memory. In addition, the relationship between the development
of working memory and structural brain changes will also be discussed. The theoretical framework provides a foundation for how information is processed and the consequences of overloading working memory’s limited capacity. To better understand the theoretical framework, some cognitive structures will first be examined.

**Basic Cognitive Structure**

There are three structural characteristics that lend support to the theoretical framework. They are sensory memory, working memory and long term memory. Sensory memory is the capacity for briefly retaining the large amounts of information that people encounter daily (Seigler & Alibali, 2005). This limited capacity to briefly retain new information in sensory memory is an important prerequisite to working memory. Sensory memory increases with age, which assists children in overcoming limits to the amount of information to which they can attend. For instance, Cowen and colleagues (Cowen, Nugent, Elliot, Ponomarev, & Saults, 1999) conducted a study with first-grade students, fourth-grade students and adults to assess the amount information that one can attend to simultaneously. Participants were asked to play a computer game while also listening to a list of spoken digits. Their results demonstrated that the ability to recall digits while simultaneously presented with other information increased with age.

Working memory is the ability to actively hold in mind information that is needed to do complex tasks such as reasoning, comprehension and learning. These tasks require active monitoring or manipulation of information while facing interfering processes and
distractions. Working memory is limited in both capacity and rate but age and experience assist in overcoming these limits. For instance, older children are able to rehearse information at a more rapid rate than younger children which enables working memory to process information more efficiently (Seigler & Alibali, 2005). However, without rehearsal cognitive functioning is limited as information is lost within 15 to 30 seconds. The nature of working memory is to chunk information into meaningful units in order to overcome these limits. For instance, it is easier to remember seven digits when they are chunked together as a meaningful phone number rather than as seven isolated digits.

Long term memory is the continuous storage of information. There are no limits to how much or how long that long term memory can maintain information (Seigler & Alibali, 2005). Long term storage is not an all or nothing form of recall because information can be called back into working memory as necessary. For instance, watching a video requires working memory to analyze and integrate the incoming information while long term memory makes sense of the video by relating the information to prior knowledge (Miller, 2011). Therefore, long term and working memory occur simultaneously. As the demand of long term memory increases it becomes possible to work with more information in working memory, making the act of rehearsal more efficient. According to Seigler and Alibali (2005), the amount and type of experiences that children have facilitate these changes in demand to long term memory. Sensory, working and long term memory all play a role in how information is processed.
These three structural characteristics of the cognitive system are all linked with the following theories.

**Theoretical Framework**

There are several theories that explain how the human brain might process information while facing competing stimuli. Two of these theories, Information Processing and Cognitive Load, stress the manner in which information is processed. A third theory, Attentional Network, explains how cognitive and structural mechanisms assist the process of attending to information.

**Information Processing**

Theories of information processing have evolved from adult studies of mind as computer analogies. However, over time, developmentalists began to question further how children think and process information (Miller, 2009). These theories have identified two basic assumptions of human cognition (Seigler & Alibali, 2005) that apply to children as well. One assumption states that thinking is limited in the amount of information that can be attended to simultaneously. Overcoming these limits is a function of age-related and experience-related differences. For instance, older children are able to retain more information in working memory than younger children. This difference might be due to an increase in rehearsal speed as children age (Seigler & Alibali, 2005). The other component states that thinking is flexible which affords
children the ability to adapt to various interactions in their daily environment. Information Processing theories assume that change is produced by continuous self-modification. Outcomes generated by children’s activities change how they think. In other words, thinking is viewed as continuous change at all ages as opposed to age-defined transitional periods.

Many of the information processing theories agree that two processes, automatization and encoding, facilitate how information is handled in sensory, working and long term memory (Case, 1985; Sternberg, 1999). Automatization is the change of processing information in a controlled manner to processing it automatically (Seigler & Alibali, 2005). This change occurs with experience. For instance, learning to text message on a cell phone for the first time requires controlled processing. Actions such as proper thumb placement are deliberate and demand concentration, especially while learning all of the functions on the key pad. However, with time and experience the process of sending a text message becomes automatic; like riding a bike, driving a car or walking. Automatization is a very useful process because it can free up mental resources for other tasks such as the ability to carry on a conversation while walking, riding a bike or driving. This enables the process of encoding new information. Encoding is the ability to store and retrieve information (Miller, 2011). For instance, the ability to transform a written word into a mental image requires the process of encoding. Even though the many theories of information processing agree that automatization and encoding guide human thinking, they vary in their beliefs of how these processes actually function.
Two types of information processing theories that explain the processes of automatization and encoding are Neo-Piagetian and Psychometric. Neo-Piagetian theories propose that children overcome processing limits through biological growth that facilitates the development of working memory and automatization (Seigler and Alibali, 2005). One such theorist, Robbie Case, claims that biological maturation increases the efficiency and capacity of working memory which in turn improves the process of automatization. This furthers the development of problem solving and reasoning as children mature. As children continue to practice certain cognitive operations, tasks that require all working memory resources become easier to accomplish. This frees up part of working memory for other processing. For instance, a young child’s thinking about space will focus on either the shape or location of an object but not both. However, an older child is able to form mental representations with both shape and location of objects simultaneously. Case refers to this age related cognitive limit as part of the central conceptual structures in children’s thinking. In other words, there is an internal network of concepts and relationships that play a role in allowing children to think about a wide range of information at a higher level (Seigler and Alibali, 2005).

Psychometric theories focus more on intelligence such as how people analyze, evaluate, compare, contrast and critique (Seigler & Alibali, 2005). According to Robert Sternberg’s theory of intelligence, children need to encode, infer and apply information. Sternberg refers to three components of intelligence that assist with these processes. They are the knowledge acquisition component, metacomponents and performance components. The performance component places emphasis on basic problem solving.
First, children need to encode by identifying the attributes of given information. Then, they infer how the new information might relate to prior knowledge. Finally, all the information is applied to a more global understanding of the situation. This component is necessary for the act of carrying out a specific task.

The knowledge acquisition component involves acquiring relevant knowledge in order to solve a problem. Children need to selectively encode, combine and compare information in the knowledge acquisition component. This enables children to distinguish relevant from irrelevant information as well as integrate meaningful information and relate newly encoded information to previously stored information. The knowledge component allows children to learn while carrying out the performance component.

The metacomponents involve constructing, selecting and coordinating strategies that govern the performance and knowledge acquisition components. Metacomponents are responsible for the planning how to solve problems and monitor progress. According to Sternberg (1984), this is an important component for developmental growth which is necessary for people to transfer knowledge from one context to another.

Neo-Piagetian and Psychometric theories are complimentary to Information Processing even though they take differing perspectives. Although the intelligence perspective of psychometric demonstrates how information is encoded and applied, the Neo-Piagetian perspective emphasizes that biological development is a necessary building block for intelligence. Another type of information processing theory is Seigler’s Theory of Cognitive Evolution. This theory assumes there is competition
among ideas within the human cognitive system (Seigler & Alibali, 2005). For example, children’s thinking is varied about any given subject or task. This varied thinking competes for the best idea or strategy to use. As children get older, they become better at utilizing this competitive way of thinking and their more advanced ideas become stronger. Seigler views this way of thinking as cognitive waves that overlap each other. For instance, children have a variety of ways of thinking about a specific topic. These ways of thinking overlap and compete with each other. With experience, some of these waves will become more dominant and others less dominant. Like the Neo-Piagetian and Psychometric theories, Seigler’s Cognitive Evolution theory applies to how children remember and problem solve.

Another theory that has evolved from the Information Processing Theories is John Sweller’s Cognitive Load Theory. This theory addresses the cognitive demands of taking in a variety of information from competing sources, which has become increasingly common with technological advances. This theory highlights the limits to working memory that continue through adulthood and how those limits can affect learning.

**Cognitive Load Theory**

Generally, an information processing approach to learning emphasizes the limitations of working memory and strategies for overcoming these limits. However, questions concerning how the type and characteristics of stimuli being processed affect memory have evolved from this theoretical approach. Theories in this approach address
the cognitive demands that occur during learning. One such theory is called Cognitive Load.

Cognitive Load Theory is a theory of cognition and learning, proposed by John Sweller (1988), to understand the relationships between working memory load, schema acquisition and long term memory. According to Sweller, working memory load is the limit to the amount of information a person process for long term storage. Long term storage is important for recalling information in order to complete a task. A schema is a cognitive construct that organizes information for efficient storage. The manner in which we acquire information can affect how the schema is stored in long term memory. Schema acquisition can increase working memory by chunking elements of information together which allows for more efficient long term storage. For example, a person’s knowledge of soccer is organized into schemas. These schema determine how new information about the sport will be maintained. This process of schema acquisition can increase the amount of information that can be held in working memory by chunking individual elements into a single more global element. Thus, the individual elements of ball - kick - pass - take - use feet only are chunked together in one schema to define soccer.

Schema acquisition also plays a role in other learning processes such as automatization. An example of this would be learning to walk, ride a bike, drive a car or even read. As these tasks become automatic it is easier to overcome limits to working memory. In the beginning, learning these skills is controlled as learners consciously attend to every step and what to do next. Eventually learners grasp an understanding of
the many little steps involved in the process of reading words, riding a bike or driving and these tasks become more automatic. This enables the learner to overcome limits to working memory by chunking these elements together into schema for long term storage. These combinations of elements create a knowledge base which allows an individual to shift from novice learner to expert learner (Sweller, 1988). For novice learners, learning is controlled and they have not yet acquired the schemas of an expert. However, learning for an expert becomes more automatic as schema acquisition occurs through the familiarity of the material or event. This shift from novice to expert is particularly important as instructional material is processed in working memory.

Sweller (1988) proposes reducing working memory load so learners can shift from novice to expert. In a learning environment, students must select words and images that are then processed in working memory. This information is then integrated with prior knowledge into long term memory. Clark and Mayer (2008) refer to two types of processing that assist with the integration of working memory and prior knowledge; essential processing and generative processing. Essential processing consists of selecting the relevant material which is dependent on the complexity of the material being processed. Generative processing refers to a deeper understanding of the material which depends on the motivation of the learner. Generative processing assists with organizing and integrating information for schema acquisition (Clark & Mayer, 2008). Although both essential and generative processing help reduce cognitive load in order to process information more efficiently in working memory, with generative processing learner motivation can affect the manner in which schema is acquired. For instance, external
factors, such as multitasking, may affect a learner’s level of motivation which in turn can impact the level of cognitive load. According to Sweller (1988), there are three types of cognitive load; intrinsic, extraneous and germane.

Intrinsic load refers to the difficulty of the content being learned. For example, calculus and trigonometry are more difficult than geometry and basic algebra. Intrinsic load is unchangeable. Extraneous load refers to the design of the instructional material and can add unnecessary load. For instance, it is better to receive audio-visual instruction than just a visual plus text because working memory has less information to process. When extraneous load does happen it is difficult to filter irrelevant information.

Germane load refers to the effort one uses to process and construct information and to acquire schema. A person’s level of interest and motivation has a lot to do with germane load. Although intrinsic load is unchangeable, external factors can impact extraneous and germane load. Essential and generative processing can be very useful in reducing extraneous and germane load. Both extraneous and germane load can influence the cognitive demands of media multitasking which is becoming an increasingly common behavior among adolescents. Another theory that brings light to the cognitive demands required for learning is Posner’s Attentional Network Theory.

**Attentional Network Theory**

Attention has important implications for education and cognitive demands. According to Posner and Rothbart (2007), learning occurs by a change in synaptic strength which implies that specific experiences can modify synaptic connections. These
connections are crucial for attention. The Theory of Attentional Network defines attention as the regulation of various brain networks by certain attentional networks that maintain a state of alertness, orienting and regulation of conflict (Posner & Rothbart, 2007).

There are three components of the attentional network; alerting, orienting and executive control. The alerting network is the ability to maintain sensitivity to incoming information. Alertness can either be sustained over a period of time or measured in terms of reaction time. According to Callejas, Lupianez, Funes and Tudela (2005), this prepares for a fast response such as catching a ball or responding to an auditory stimulus. The alerting network can influence the orienting network by producing a faster orientation to a stimulus. The orienting network requires selecting information which directs attention to the source of information and enhances processing (Callejas et al., 2005).

The orienting network allocates attention to relevant information. This process is dependent on the type of stimulus in the environment or task to be performed. For example, it is more difficult to orient attention toward a teacher’s voice if the alerting network maintained sensitivity to several other distractions in the classroom that occurred simultaneously with the teacher’s voice. However, once attention is oriented toward a particular stimulus the executive control network chooses the appropriate response.

The job of the executive control network is to filter any irrelevant information in order to focus on the target stimulus. This network is very important for planning, decision making, detecting error and giving a novel response (Callejas et al., 2005).
Executive control continues to improve throughout development. According to Siegler and Alibali (2005), younger preschool children can sort pictures based on one dimension such as either color or shape. However, when asked to switch dimensions they tend to stick with the first category while their older peers switch from sorting by color to shape when instructed to do so. The authors suggest that this improvement in executive processing is brought about through age-related changes in development.

In addition to the three components of alerting, orienting and executive control in the attentional network, Posner and Rothbart (2007) refer to various brain regions that carry out psychological function when activated. For instance, the frontal lobe is required in order to scan the environment to locate a target of attention. As the frontal lobe of adolescents is still developing, it may be difficult for them to meet such demands placed on working memory when they are engaged in multitasking behaviors. This can impact their ability to orient their attention when learning new content, which raises the question of how experiences with technology may affect the three components of the attentional network system in adolescents. Past research has focused on technology, specifically media multitasking, and the impact it has on adolescent cognitive processing. Next is a review of this literature as it informs the understanding of processing and multitasking in the developmental phase of emerging adulthood.
Media Multitasking and Working Memory

Several studies have explored the impact that media multitasking can have on student learning. For instance, Hembrooke and Gay (2003) study demonstrated the immediate consequences that media multitasking has on working memory. Their results showed that students allowed to multitask with their laptops during a lecture suffered on traditional measures of memory for lecture content compared to the control group. The researchers concluded that students in the treatment group were distracted by e-mail, Instant Messaging (IM) and the internet which was detrimental to their results on measures of memory for lecture content. Another study by Ophir et al. (2009) claims that processing multiple streams of information can be challenging for human cognition. The authors examined relationships between chronic media multitasking and their cognitive control abilities. Results demonstrated that heavy medial multiaskers have greater difficulty filtering irrelevant information as well as ignoring irrelevant representations in memory. This suggests that heavy media multitaskers are distracted by consuming multiple streams of information at the same time.

One explanation for this distraction is that verbal and spatial information are stored separately. Clark and Mayer (2008), discuss the separate storage capacity for verbal and spatial information in working memory. They claim that those who engage in media multitasking are receiving an overload of spatial information which creates a deficit in performance. This overload affects the ability to store information and draw connections with long term memory. However, when demands on working memory are
lessened than performance can improve. According to Clark and Mayer, a learner must coordinate and monitor five processes in working memory when attending to a multimedia environment. The learner needs to first select relevant words, second select relevant visuals, and then build connections among the relevant words. Next, the learner builds connections among the visuals and finally integrates the words and pictures together along with prior knowledge. The authors suggest that student performance can improve if the medium is designed to assist with these five processes. For instance, the multimedia message would need to be limited in the amount of words and these words should be placed close to the visual. However most media contain too many disconnected chunks of information that disrupts attention. This disruption forces a learner to continually shift their attention between the varying information.

Studies confirm that dividing attention, such as one must do when multitasking, disrupts memory encoding which reduces subsequent recall (Ophir et al., 2009; Wallis, 2010). In fact, Ophir et al. found that low media multitaskers out performed high media multitaskers on a classifying task where participants were asked to switch back and forth between groups of numbers and letters. These results were surprising considering that high media multitasking demands one to shift attention. One explanation is that when two channels of information differ semantically viewers will focus on one channel, recalling less information overall (Wallis). Hembrooke and Gay (2003) also claim that the ability to engage in simultaneous tasks is limited. Their study revealed that students with laptops were distracted by the Web, e-mail, IM, etc. and therefore unable to perform as well on measures of memory for lecture content as the
students without laptops. The authors attribute these results to the heightened level of distractions that mobile devices and wireless technology bring to the classroom. Their research suggests that the processing channels information is filtered through are limited. Once this information is temporarily stored it must be processed further for long-term storage. However, if these processing channels become overloaded then necessary information is filtered out. Some research offers structural explanations to support the results of such studies.

**Inhibiting and Organizing Information in Working Memory**

People commonly divide attention between two or more tasks on a regular basis with seemingly little or no disruptions to memory. However, the ability to inhibit extra environmental distractions when dividing attention between two or more tasks can be taxing on adolescent cognition. When referring to cognitive processing, inhibition is defined as the ability to block dominant information or automatic responses when necessary. Inhibition is required to do a task correctly because it allows an individual to override a more dominant or automatic response that may be incorrect (Atkins, Bunting, Bolger & Dougherty, 2012). Adolescents may have difficulty shifting attention between two or more tasks because certain cognitive processes required to inhibit incorrect information are still developing.

Casey et al. (2000) propose neurological reasons for the inability to shift attention during adolescence. Their research suggests that the ability to inhibit irrelevant
information during attentional output tasks relies heavily on the pruning of gray matter which is still underway during adolescence. This makes the brain more vulnerable to external stressors. Media multitasking, for instance, is an external stressor that may affect the plasticity of a developing brain. This development is necessary for cognitive processes to function at their full potential. The still developing, higher cognitive processes of working memory and inhibition are linked to intelligence (Atkins et al., 2012). Therefore it is beneficial for adolescents to overcome perceptual distraction in order to optimize performance on attentional output tasks that rely on the ability to organize information.

The experience of media multitasking commands all three components of the attentional network to work together. First, one needs to alert to incoming information, then orient to selecting the appropriate information and finally select a response through executive control. This process can be very rewarding for individuals because media multitasking is a stimulating activity that is linked with instant gratification. However, too much of this type of reward can lead to a failure to pay attention to less stimulating activities. Kumari and Ahuja (2010) studied the effects that video viewing can have on attention. Participants were given a digit span task to assess attention and results showed that heavy viewers performed poorly compared to light viewers. These results suggest that extended use of media displaces the opportunity for other beneficial activities. Prolonged exposure to any stimulus can deprive the brain of other experiences that might be important for learning, problem solving and judgment. This might explain why single task learners tend to have a richer, more flexible understanding of the task than multi-task
learners. Such richer understanding will contribute to ones learning and future problem solving abilities.

The brain is naturally designed to focus on concepts sequentially which is why multitasking is a myth when it comes to paying attention (Medina, 2008). When a person is actively typing a word document for school and suddenly the e-mail alert chimes there is a shift in attention from the paper to the e-mail. This is because the sensory memory is activated by the e-mail alert forcing one to disengage from writing the document because the rules for writing a paper are different than the rules for writing an e-mail. Medina points out switching tasks like this can be time consuming.

Shifting attention in order to switch between one or more task is not only time consuming but may also alter the process of encoding information needed for schema acquisition. This is because task switching overloads working memory as multiple streams of information are taken in simultaneously. According to Medina (2008), encoding information always involves translating information from one form to another. For instance, the more elaborate and deep that information is encoded at a moment of learning, the stronger the memory will be of the acquired learning.

According to Carr (2011), the human brain has to reorient itself every time there is a shift in attention. The overload of information that accompanies media multitasking causes the need to shift between two tasks at once. This cost in task switching can be especially taxing to the cognitive development of adolescents since structural changes to the brain continue throughout the second decade of life. Carr claims the opportunity for deeper, abstract thinking is limited when focus is placed on the shifting of attention.
This may explain why previous research has indicated that students who multitask do not perform as well on memory assessments as those who do not multitask (Hembrooke & Gay, 2003; Ophir et al., 2009; Pea et al., 2012). Frequent multitasking, especially at the moment of learning, enables for only partial encoding. Therefore, it is important for students to provide their full attention in novice learning situations in order to retrieve information more accurately. In other words, memory works best if the conditions during retrieval are the same as the environmental conditions during encoding.

In real life situations adolescents attempt to complete multiple tasks at once, consequently this will affect encoding and retrieval conditions. Attention is not shared concurrently when divided between two competing sources. Instead attention switches dynamically between two or more tasks (Atkins et al., 2012), which may make inhibiting irrelevant information difficult while encoding new information. This is because task switching involves shifting back and forth between multiple operations or mental sets according to Atkins et al. (2012). The more operations adolescents’ deal with, the more difficult it is for them to inhibit irrelevancies. The ability to inhibit and task switch work together as a part of working memory known as the executive function.

The executive function is thought to improve from childhood to adolescence as developmental changes occur (Atkins et al., 2012; Choudhury, 2006). These changes carry well into adulthood as well. Executive function relies heavily on the development of neurological regions underlying working memory. These regions are some of the last to complete development which would suggest that adolescents and young adults are still overcoming the limits to working memory.
Casey et al. (2000) explain that memory and inhibition work together to maintain relevant information while suppressing competing representations or memories. Likewise, attention and inhibition attend to relevant events while suppressing irrelevant events and attention and memory come together to represent a single construct in working memory. One common element these three constructs share is the presence of competing information. For instance, in the case of attention, if one is media multitasking during learning there is interference from simultaneous input/output. In the case of memory, there is interference from competing memories or representations. However, if there are no interferences than the process of inhibiting is not necessary.

The current study is designed to provide a better understanding of the cognitive demands required to media multitask and how this might impact the adolescent brain’s ability to adapt while still developing. An empirical investigation will explore relationships between media multitasking and student outcomes that require the ability to inhibit and organize information in working memory. Although prior studies (Hembrooke & Gay, 2003; Ophir et al., 2009) have addressed issues with media multitasking, the current study will examine the immediate consequences multitasking has on working memory. This is particularly important for adolescents as prior research suggests that working memory is associated with development (Atkins et al., 2012; Casey, 2000; Choudhury, 2006; Cycowitcz, 2000).

This review has examined the link between development and limits to working memory capacity. This development is necessary in order to inhibit and organize information into working memory for proper encoding and later retrieval. The goal of
the current study is to provide parents and educators with a better understanding of how experiences with technology affect the processes of working memory. Prior research has suggested that different environmental experiences are associated with differences in working memory capacity (Cantlon & Brannon, 2006). In addition, those who perform low on tasks of working memory tend to also do poorly on comprehension tasks according to Pike, Barnes and Barron (2010). The following study will compare difference between a multitasking group and a non-multitasking group to determine if multitasking affects memory for an academic lecture and if working memory helps explain those results.
This study examined the differences of student outcomes between a control group (non-media-multitasking) and a multi-tasking group. Groups together attended a brief lecture on the topic of the frustration that many students feel over the lack of technology in the classroom. The control group was simply asked to listen, whereas the multitasking group also engaged in text messaging and an internet search simultaneously. This chapter describes the methods used for this study.

**Design and Research Question**

In order to understand the difference between media multitasking and refraining from media multitasking during a lecture, the researcher conducted a study at California State University Sacramento. The study aimed to answer the following questions.

1. Are there differences between a control group and a multitasking group on post lecture assessment scores?

2. Does working memory contribute to memory of lecture content?

These questions have significance for parents and educators since media multitasking is a common behavior among adolescence. It was hypothesized that the control group will out-perform the treatment group on the post lecture assessment and that working memory will contribute to memory for the lecture as well.
Participants

There were 62 participants, 31 from two different university courses (57 female, 5 male). Approximately half of the participants (45%) were 20-22 years of age, a range considered emerging adulthood. The remainder were 18-19 years of age (n = 3, 5%), 23-27 years (n = 16, 26%), 28-35 years (n = 7, 11%) and 36 years or older (n = 8, 13%). The control group had 28 students, of which four were male, where as the multitasking group had a total of 34 students with only one being male. Almost half of the control group were 20-22 (n=12, 42%) while the remainder were 23-27 years (n=6, 22%), 28-35 years (n=4, 14%) and 36 or older (n=6, 22%). The majority of the multitasking group were also 20-22 years of age (n=16, 47%) while only 9% (n=3) were 18-19 and the remainder were 23-27 (n=10, 29%), 28-35 (n=3, 9%) and 36 or older (n=2, 6%).

Participants were also asked how often they use more than one form of media simultaneously, such as cell phone, computer and I-Pod. Nearly one-third of the sample (n = 19, 31%) claimed to frequently use multiple media simultaneously. Approximately one-fourth claimed to use multiple sources of media all of the time (n = 15, 24%) or often (n = 14, 23%). The remaining participants claimed to sometimes (n = 10, 16%) or rarely (n = 4, 6%) use multiple sources simultaneously. The control group had a relatively even split in multitasking behaviors with the majority reporting to use multiple sources of media some of the time (n = 8, 29%) while only 7% (n = 2) claimed to rarely media multitask. The remaining participants reported equally to engage in multiple sources either often, frequently or all of the time (n = 6, 21%). In contrast, 38% (n=13) of the multitasking group reported to frequently multitask while 26% (n = 9) reported to media
multitask all of the time and 24% (n = 8) engaged often. Only .06% (n=2) claimed to sometimes use multiple sources simultaneously as well as rarely.

Almost one-half (42%) of participants stated they engaged in multiple tasks such as typing a paper, Facebooking, and shopping on-line all the time on the computer. Out of the remaining half, one-fourth (n = 16, 26%) stated they engaged in multiple tasks on the computer frequently while the remainder stated doing multiple computer tasks often (n = 9, 15%), sometimes (n = 9, 15%) and rarely (n = 2, 3%). Forty four percent (n = 15) of the multitasking group claim to computer multitask all of the time compared to 39% (n = 11) of the control group. The multitasking group also reported to frequently computer multitask at 32% (n = 11) while only 21% (n = 6) of the control group reported frequent computer multitasking. Only one participant from each group claimed to rarely engage in multiple tasks on the computer.

**Measures**

Demographic information related to age, gender and experience with technology was collected using a survey created by the researcher (Appendix A). The survey also identified type and frequency of media multitasking. Using a five point likert scale and several yes or no questions, participants identified the amount and type of media they owned in the past and present, frequency of use and level of multitasking. Participants also identified their current age range using the five point likert scale.

The ability to manipulate information in working memory was measured using a backward digit span assessment from the Woodcock-Johnson III Tests of Cognitive
Abilities (WJ-III, Woodcock, McGrew & Mather, 2007). Participants were given a series of digits orally by the researcher that they then had to record in backward form on their papers. For instance, the researcher would say, “4…7…3…9…2” and participants would record the digits in backward order on their paper. Memory for lecture content was measured using a series of sequencing, true/false, fill in the blank, short answer and multiple choice questions created by the researcher (Appendix B). The assessment was based only on the information presented in the power point by the researcher.

**Procedure**

At the beginning of the study, the researcher obtained consent from Human Subjects to recruit participants from Child Development classes at California State University, Sacramento. These included entry level child development classes as well as classes that focus on research and methods. These classes are intended to provide future educators with an understanding of how cultural and environmental influences effect human development at the social, emotional and cognitive level. In addition, the research and design classes take students through the process of conducting research that is intended for the human population. Participants were recruited from these classes because most of the students were likely to range in age from 18 – 26, an age span considered to cover late adolescence and emerging adulthood. Student enrollment for the research and design class was approximately 38 however only 31 participated in the study. The entry level child development course had a student enrollment of approximately 43 however only 31 students participated from that course as well.
Once participants were recruited from two of the classes, the researcher obtained informed consent by explaining the nature of the study and providing consent letters for participants to sign. The consent letters (Appendix D) were collected and stored separately from data collection forms in order to maintain confidentiality. The researcher went back to the two participating classes at a later date for data collection at which time participants were assigned a number to ensure that data results would remain anonymous and confidential. Participants were then randomly divided into two groups and instructed to label all data collection forms with their individual number and group letter. The multitasking group was then informed that they would be text messaging with three friends while also searching for five local business addresses on the internet during a brief lecture presented by the researcher. Participants in the multitasking group were given a form with the name of the businesses in order to record the addresses as they found them. The control group was instructed to simply listen to the lecture while refraining from texting and the internet. Neither group was allowed to take notes on the lecture however the researcher moved the control group to the front of the room in order to minimize any distractions they may endure from the multitasking group. Participants in the multitasking group were also asked to silence any alerting sounds from their devices.

The researcher then proceeded with a brief power point lecture (Appendix C) summarizing “Why Tweens and Teens Hate School” (Rosen, 2010, chapter 1). This chapter centers on the frustration that many adolescents feel due to the lack of technology in the classroom, which was an appropriate topic for the participants as they may become
future educators. The lecture highlighted key points in the chapter that the researcher briefly explained within ten minutes. Participants were not allowed to ask questions or comment on the lecture in order to maintain consistency between the two classes from which data was collected. The purpose for this was to minimize the chance that one class would receive more clarification about the lecture over the other class.

During the lecture, participants in the multitasking group were verbally asked to text message with three friends while also doing an internet search for the addresses of five local businesses. These individuals were given a form made by the researcher to record the addresses of the businesses as well as the minutes they spent text messaging. The control group simply listened to the lecture and neither group was able to take notes.

Once the lecture ended, the multitasking group was asked to put all electronic devices away while everyone completed the backward digit span task adapted from the WJ -III Tests of Cognitive Abilities (WJ-III, Woodcock et al., 2007). In addition, participants were asked to refrain from recording their responses until the researcher sounded a buzzer. Participants were required to record their responses on paper.

After the working memory assessment, participants completed a brief post lecture assessment and survey intended to gather information about their use of technology. The lecture assessment, made by the researcher, included four multiple choice questions, five true/false questions and five fill - in -the blank. As data collection concluded, all forms were collected by the researcher and stored for later analysis.
Chapter 4

RESULTS

This chapter reviews the results of a quantitative study that analyzed how media multitasking during a lecture and student working memory processes may impact student learning. This study was conducted to take a closer look at the ability to selectively attend to a target stimuli (i.e., lecture) while engaging in multiple tasks simultaneously. This chapter summarizes results of t-tests. Additional descriptive statistics, and ANCOVA designed to test the hypotheses are reported.

A series of independent samples t-tests were conducted to ensure multitasking groups were equivalent. As shown in Table 1, groups were relatively similar. However, some significant differences existed between groups. First, analyses showed a significant difference when comparing the control group to the multitasking group on age receiving first cell phone, such that the multitasking group received cell phones between 11 to 13 years of age whereas the control group at 14 to 16 years. In addition, there was a significant difference in average age at participation: Control: 23 to 27 years versus Multitasking: 20 to 22 years. Importantly, there was no difference between the two groups when comparing results of the digit span assessment.
Table 1

*Media use and age differences among multitasking and control groups*

| Source              | Control Group | | | Multitasking Group | | |
|---------------------|--------------|---|---|------------------|---|---|---|---|---|---|
|                     | \( M \) | \( SE \) | \( M \) | \( SE \) | \( t \) | \( N \) | \( p \) | \( d \) |
| Cell phone age      | 4.11 | .16 | 3.62 | .14 | 2.33* | 62 | .023 | .60 |
| Current age         | 3.14 | .23 | 2.56 | .17 | 2.09* | 62 | .041 | .54 |
| Digit span          | 3.39 | .63 | 3.65 | .45 | -.34 | 62 | .74 | 0.09 |
| Daily texts         | 2.14 | .23 | 2.59 | .23 | -1.35 | 62 | .18 | -0.35 |
| Hours on-line       | 4.04 | .19 | 3.88 | .19 | .57 | 62 | .57 | .15 |
| Computer multi      | 3.68 | .25 | 4.06 | .19 | -1.25 | 62 | .22 | -0.31 |
| Media multi         | 3.21 | .24 | 3.74 | .19 | -1.71 | 62 | .09 | -0.43 |

*Note. Cell phone age = age acquired first cell phone, 1= 6 or younger, 2= 7-10, 3= 11-13, 4= 14-16, 5= 17 or older; daily texts = amount of text messages sent/received daily, 1= 30 or less, 2= 31-75, 3= 76-150, 4= 151-300, 5= 301-500, 6= 501 or more; computer multi= frequency of engaging in multiple tasks simultaneously on the computer, (ie. E-mail, Facebook, internet search) 1= rarely, 2= sometimes, 3= often, 4= frequently, 5= all the time; media multi = frequency of using more than one media simultaneously, (ie. television, cell phone, computer) 1= rarely, 2= sometimes, 3= often, 4= frequently, 5= all the time. *\( p < .05 \)
Because of the significant difference in age, this was included as a covariate in the hypothesis test. An ANCOVA was conducted with multitasking group (yes versus no) as the independent variable and memory for the lecture as the dependent variable. Cell phone age and age of participation were covaried. As shown in Table 2, results indicated that although cell phone age was still significantly different between multitasking groups, there was a main effect of multitasking. Figure 1 displays the multitasking group performed significantly worse than the control group on the memory test (control: $M = 11.29, SD = 1.29$; multitasking: $M = 9.26, SD = 1.73$).

Table 2

*Main Effect of Multitasking on Memory*

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multitasking</td>
<td>49.16</td>
<td>1</td>
<td>49.16</td>
<td>15.79*</td>
<td>.000</td>
<td>.217</td>
</tr>
<tr>
<td>Cell Phone Age</td>
<td>18.09</td>
<td>1</td>
<td>18.09</td>
<td>5.81*</td>
<td>.019</td>
<td>.093</td>
</tr>
<tr>
<td>Current Age</td>
<td>10.22</td>
<td>1</td>
<td>10.22</td>
<td>3.28</td>
<td>.075</td>
<td>.054</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.354</td>
<td>1</td>
<td>.354</td>
<td>.114</td>
<td>.737</td>
<td>.002</td>
</tr>
<tr>
<td>Error</td>
<td>177.45</td>
<td>57</td>
<td>3.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6681</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* $p < .05$
Figure 1. Memory for lecture content by multitasking group.
Chapter 5

DISCUSSION

This study of media multitasking set out to determine whether media multitasking and working memory played a role in memory for an academic lecture. This chapter discusses results of the study, describes suggestions for homework practices and provides suggestions for future research.

Major Findings of the Study

In both the control group and multitasking group participants attended to the same lecture provided by the researcher in order to answer the following questions: Are there differences in post lecture assessment scores between a multitasking group and a control group? Does working memory influence memory of an academic lecture for those that are multitasking during the lecture? It was hypothesized that the control group would out-perform the multitasking group on both the post lecture assessment and the backward digit span task to assess working memory. Results demonstrated that participants in the control group performed significantly better on memory of lecture content than the multitasking group. Working memory did not influence memory for lecture content with the multitasking group. In addition to these findings, the analysis
revealed significant differences between the two groups’ current age and age of their first cell phone.

**Assessment for Memory of Lecture Content**

A major finding in the results was that participants in the control group out–performed participants in the multitasking group on the post lecture assessment with the control group scoring, on average, two points higher than those multitasking. These results demonstrate the negative consequences of becoming distracted with digital multitasking during moments of learning. Furthermore, results support the assumption that there are limits to the amount of information processing that can be done simultaneously (Seigler & Alibali, 2005). In this study, the behavior of multitasking likely affected the students’ ability to actively monitor and manipulate information while facing interfering distractions. In other words, their ability to hold information needed for comprehension and learning in working memory was distorted. According to Rosen (2012), texting along with other media sites are some of the most common distractions during student learning which draw from the same mental resources required for learning in the first place. This is because media multitasking is the same as attention shifting. According to Medina (2008), the brain is naturally designed to focus on concepts sequentially; however media multitasking requires one to shift attention from one task to another.

In this study, both texting and internet searching were demanding tasks competing with learning lecture information. Media multitasking affected both the essential and generative processes of the multitasking group. According to Clark and Mayer (2008)
these processes are necessary in order to integrate working memory with prior knowledge. For instance, essential processing, the ability to select relevant information from the lecture, was more difficult for the multitasking group as was generative processing, their ability to maintain motivation to learn. These findings also support Posner and Rothbart’s (2007) Theory of Attentional Network. Accordingly, participants in the multitasking group had more difficulty orienting their attention toward the lecture than the control group because their alerting network maintained sensitivity to the media distractions. Finally, the results of this study support claims of prior research in that cognitive demands of media multitasking can have a negative effect on measures of memory (Hembrooke & Gay, 2003; Ophir et al., 2009).

Despite use of random assignment for this study, both current age and age of first cell phone were significantly different between groups. The average age of participants in the multitasking group was a few years younger than the control group. This demonstrates that the control group may have had a slight advantage as structural growth in some regions of the brain still occur throughout emerging adulthood. In other words, if participants in the control group were also multitasking, they may still have outperformed participants in the multitasking group. Contrarily, the control group may still have demonstrated better memory of the lecture if neither group were multitasking.

In addition to the control group’s slight age advantage, results also found that most participants in the multitasking group received their first cell phones at a significantly younger age than participants in the control group. This may reflect a cohort effect with younger cohorts being exposed to more media at a younger age which
is inconsistent with research that has suggested that adolescents lack the capacity to meet the cognitive demands required for proper cell phone use due to still developing attentional networks (Casey, 2000; Kumari & Ahuja, 2010). However, a cohort effect is consistent to other research that has suggested that those who receive cell phones at a younger age actually perform better on standard measures of comprehension, fluency and vocabulary (Plester et al., 2009). Importantly, when these differences were statistically controlled, the significant difference in multitasking remained.

**Backward Digit Span Task**

According to the results of the digit span task, working memory did not contribute to memory of lecture content. Given how poorly both groups did, it is unclear how working memory may have contributed to either group’s memory of the lecture. Because of the adaptations to the Woodcock-Johnson III Tests of Cognitive Abilities (WJ-III, Woodcock et al., 2007) for the current study, time needed to complete this task may have exceeded the duration of working memory, thus providing an invalid measure of working memory. However, past studies have shown that media multitasking has affected the processing of working memory. For instance, Ophir et al.’s (2009) study demonstrated a difference between self-proclaimed media multitaskers and non-media multitaskers in terms of inhibiting irrelevant environmental information in working memory. Results showed that the media multitaskers had more difficulty task switching and organizing information than the non-media multitaskers. According to Hembrooke and Gay (2003), unconscious mechanisms play a role in selecting information for encoding. Therefore,
new incoming information in working memory is intended to be linked with relevant aspects of prior knowledge and the act of multitasking can disrupt this process.

On the other hand, it is possible these results suggest digit span performance is not predictive of long term memory. One explanation may be that the digit span task is numeric, whereas the primary dependent measure in the current study was memory for verbal information. In a learning environment, students must select words and images to process in working memory. This information is then integrated with prior knowledge into long term memory (Sweller, 1988). However, the students in the current study may have experienced what Clark and Mayer (2008) refer to as extraneous load. In other words, working memory may have had an overload of information to process since numeric and verbal information were not integrated together in the lecture. Rather, the students were set up to process verbal information alone for long term storage.

**Limitations**

The findings in this study demonstrate that media multitasking during the process of learning can have negative consequences on student performance however some limitations to this study should be noted. To begin with, participants were all 18 years of or older. Many of these participants are in a developmental category considered emerging adulthood therefore results may generalize well to an older high school population over a younger population. Another limitation was that analysis was limited to comparing differences among groups. The results therefore only reflect which group
out-performed another and lacked showing individuals how they performed under both
conditions. In addition, the control was placed at the front of the class in order to
minimize distractions from the multitasking group. Some students in the control group
may have had a slight advantage by sitting towards the front of the classroom. Also,
participants performed relatively poorly, averaging 3 out of 12 correct on the backward
digit span task. One reason both groups may have done poorly is that the original digit
span task is intended to be administered individually and participants are required to
respond orally. For this study, however, the measure was administered to the whole
class, with participants recording responses on paper. Time may have succeeded working
memory duration. Furthermore, the items were administered out of order to minimize the
participants’ chances of pattern seeking. The original task starts with four digits and
continually increases but for this study the task started with eight digits and continued to
vary in the amount of digits, which may have been too extreme of a modification. As a
result, participants may have had difficulty encoding a mental image of the digits in their
backward form. Finally, the groups were different in both their current age and age of
first cell phone. Although these differences were unintentional and lend to sampling bias,
analysis still showed a significant difference in memory once those two variables were
controlled.
Suggestions for Practice

Results in this study have some important suggestions for parents, educators and students in the use of multi-media during learning. These findings suggest that in order for deeper understanding and memorization to occur, learning should occur as a single task rather than shared with multiple tasks. The following sections discuss ideas for parents, educators and students to implement into the process of learning in order to minimize distractions from digital surroundings.

Suggestions for Parents

A few of the findings in this study suggest that media multitasking can distract from the deeper learning that homework is intended to support. Results demonstrate that student memory of learning content is better if digital distractions are not at hand. This does not mean that adolescents and teen-agers should not be allowed such devices, however it is important monitor their digital activities in order to maximize academic performance. Children in this age group are concerned with missing out on the latest and greatest in their social environment. Cell phones and internet not only provide an outlet for this type of concern but they also provide quick resources to assist with homework. Therefore, it might be better to insist that all devices are off for 20 – 30 minutes at a time followed by brief breaks for 10 -15 minutes (Rosen, 2012). Also, there are times when the internet is needed for research. The main point is for parents to be proactive during homework time and decide which compromise is the best fit for their family.
Another interesting result of this study was the difference in age of first cell phone. Carrying a cell phone around requires the ability to divide attention among multiple tasks at once. Cognitive processes required to share attention like this are still developing in young children and adolescents. According to Casey (2000), cognitive development is more vulnerable to external stressors during this time. This vulnerability may impact the development of attentional control required for learning. However, as children get older their ability to shift attention between tasks improves as working memory capacity increases. Therefore, it is reasonable to allow for privileges such as owning a cell phone as children mature.

**Suggestions for Teachers and Students**

Results of this study also have implications that both teachers and students may find useful. Most elementary and high school classrooms already have a zero tolerance policy for cell phone and internet use during learning time. However, to illustrate the consequences that digital distractions have on memory, teachers can easily simulate this study by allowing students to have cell phones on and text while they are either reading a text book or listening to a lecture (Nass, 2012). Then, compare assessment results to a similar lesson in which there were no digital distractions.

Some classroom environments are interactive and come equipped with internet access to encourage research. Students may also be expected to submit assignments and lecture notes on-line rather than bringing a hard copy up to the teacher’s desk. Such learning environments need to be monitored carefully to ensure a deeper understanding of
the material, especially in novice learning situations (Carr, 2011; Clark & Mayer, 2008). Finally, students need to take responsibility for their learning through self-monitoring (Rosen, 2012).

**Future Directions for Research**

The current study provides useful information about the effects of media multitasking on student learning however questions remain for future research. This study demonstrated that using the internet and text messaging during a lecture had a significant impact on students in emerging adulthood. Future research may want to investigate students at the junior high, high school and even elementary level. In addition, this study took place in a classroom setting, future research in the home environment may provide insight to the effects that media multitasking during homework has on student outcomes. Such an approach could bring about self-awareness to individual participants and their parents. A final suggestion for future research would be to examine the effects of media multitasking in a lab setting. This would provide researchers with the latest fMRI technology to track cognitive activity as participants engage in media multitasking. Also, results from such a study would demonstrate the cognitive demands and limitations of various age ranges, thereby supporting past theories of development.
Conclusion

The present studies investigation of how media multitasking during learning can affect student outcomes has shown that there is a significant difference in performance when comparing results of those that were multitasking to those that were not. Findings suggest that the cognitive demands required for internet searching, text messaging and learning result in an overload of information that interferes with deeper learning. In addition, the average age of participants in the treatment group was significantly younger than the control group, which suggests future comparison in differences between the cognitive demands of emerging adults to older adults. Finally, the findings in this study raise implications for how parents should monitor their children’s level of multitasking, especially with younger children due to their shorter attention span.
Appendix A

DEMOGRAPHIC SURVEY

Number____________

Group:    A   or   B

Please answer the following questions and don’t forget to circle your group number and write your participant number at the top of this page.

1. How many television sets were in the house you grew up in?
   0    1    2    3    4    5 or more

2. How many televisions do you have now?
   0    1    2    3    4    5 or more

3. How many computers were in the house you grew up in?
   0    1    2    3    4    5 or more

4. How many computers do you have now?
   0    1    2    3    4    5 or more

5. Do you own a cell phone? If so, what type?

6. How old were you when you owned your first cell phone?
   6 or younger   7-10   11-13   14-16   17 or older   N/A

7. Do you have an I-pod or some type of MP3 player? If so what type?

8. How old were you when you owned your first I-Pod?
9. Do you own a laptop? If so what type?

10. How old were you when you owned your first laptop?
   6 or younger  7-10  11-13  14-16  17 or older  N/A

11. Do you own an iPad or tablet?

12. How old were you when you owned your first iPad or tablet?
   6 or younger  7-10  11-13  14-16  17 or older  N/A

13. What is your current age?  18-19  20-22  23-27  28-35  36 or older
14. What is your gender?  M  F

15. How often do you talk on your cell phone each day?
   Less than an hour  at least an hour but less than two  at least two hours but less than three
   At least three but less than four  four or more hours

16. How many text messages do you send/receive each day?
   30 or less  31-75  76-150  151-300  301-500  501 or more

17. How many hours a day do you watch TV?
   Less than an hour  at least an hour but less than two  at least two hours but less than three
   At least three but less than four  four or more hours

18. How many hours a day are you on-line for either homework, personal or business use?
   Less than an hour  at least an hour but less than two  at least two hours but less than three
   At least three but less than four  four or more hours
19. How often do you use more than one media at the same time? (ex. Texting, online, watching TV, listening to I-Pod)

   Rarely     sometimes    often    frequently    all the time

20. Do you typically engage in more than one task at the same time on the computer? (ex. Type a paper, check e-mail, face-book, google search or shop)

   Rarely     sometimes    often    frequently    all the time
Appendix B

MEMORY OF LECTURE ASSESSMENT

Group __________
Number#__________

According to the lecture you just heard, answer the following questions. Answers should be based on the information from the presentation only.

1. What problem did the girl in the beginning have with pictures in books?
   a. They are lacking in quality of color
   b. They are one-dimensional
   c. They are too silent

2. The iGeneration spends their day immersed in any form of electronic media because___________.
   a. They were born surrounded by technology
   b. They aren’t challenged enough by parents and teachers
   c. It helps them focus better

3. iGeners hate school because education has not caught up with them, they learn differently, they have adapted to technology that didn’t exist a decade ago and _________.
   a. Classroom peers make it difficult to focus if they are always texting
   b. Most teachers don’t know how to use technology correctly
   c. They need a more interactive approach from instruction

4. Future homework should take place in a __________instead of having students___________.
   a. lab setting; read in books
   b. virtual classroom; use paper and pencils
   c. multitasking form; write essays by hand
5. The pace of technology has not accelerated in the past 20 years.  T  F

6. According to the graph, cell phones took between 10 to 15 years to reach their benchmark.  T  F

7. iGeners mostly uses their cellphones for something other than texting and talking.  T  F

8. Older generations are often influenced by the iGeners to advance in their use of technology.  T  F

9. It is difficult for parents and teachers to draw in the attention of iGeners because they seem to have a high rate of ADD (attention deficit disorder).  T  F

10. Most preteens and teens are constantly connected to technology from the moment they __________ until they go to sleep.

11. Children today are growing up in an environment where technology is everywhere and it can even be ______________.

12. The iGeneration has never used a __________________ and often use dictionary.com or Wikipedia instead of a real dictionary or encyclopedia.

13. Teens and tweens awaken in the night to respond to a ____________.

14. The ____________________ is the largest storehouse of information available.
Appendix C

POWER POINT SLIDES

11/11/2013

Why Tweens and Teens Hate School!!
Adapted from Rosen, L. D. (2010).
Rowland, New York, NY: Palgrave Macmillan

"I absolutely hate school. They make me sit and listen as some old, stuffy teacher drones on and on about stuff from a book written in the dark ages. We have to read pages of facts and then harp them up on tests that will make or break whether we get into a good college or not. They have pictures on all the pages but books are so one-dimensional. Don't they know anything about video and what kids like to do? We get to go to the computer lab once a week for like an hour and even then most of what I do is blocked. I can't wait until I am out of this place and go to college where they let us bring computers to class and know how to treat wired kids like me."

-Venzo, age 12, New York City

What is the iGeneration?
- The iGeneration is children and teens in elementary, middle, and high school.
- They spend their days immersed in a "media diet" (entertainment, communication and any form of electronic media.)
- They were born surrounded by technology.

Why hate school?
- Education has not caught up with iGeneration.
- They learn differently.
- With all the technology they consume they need a more interactive approach from instruction.
- They have adapted to technologies that didn't exist a decade ago.

Rapid Pace of Technology
- Future homework should take place in a virtual classroom instead of a flat, two-dimensional piece of paper.
- The pace of technology has accelerated in the past two decades.
- The following graph reflects the bench marks of technology:
Communication

- iGener own own cell phones but mostly text with them
- They blog, vlog, video chat, share photos, etc.
- This influences older generations to follow suit
- iGeneration is constantly connected which makes it difficult for parents and teachers to draw in their time and attention

- Most preteens and teens are constantly connected to technology from the moment they wake up until they go to sleep.
- They often keep their phones on vibration at night and awaken to respond to a text.
- 8 out of 10 teens say they can't imagine a day without technology according to National Consumer Electronic Association.

Raised by Technology

- Children today are growing up in an environment where technology is everywhere and can even be invisible.
- They have grown up with the internet which is the largest storehouse of information available.
- They have learned at an early age how to play video/computer games, send e-mail, google search, etc.

- Most of the iGeneration use the library simply as a place to study as opposed to checking out books.
- They have never used a card catalog and often use dictionary.com or Wikipedia instead of a real dictionary or encyclopedia.

Conclusion

- The iGeneration might find flipping through text books, thesauruses, dictionaries and card catalogs just as challenging as a baby boomer might find learning to use an iphone.
- As a result, school can become boring and time consuming as they try to adapt to the learning tools of past generations.
- Instead, they are wired to learn with modern day technology.
Appendix D

CONSENT TO PARTICIPATE

Consent to Participate in Research

You are being asked to participate in research which will be conducted by Cynthia Davidson, a graduate student in Child Development at California State University, Sacramento. The study will investigate the impact media multitasking has on cognitive processing.

If you elect to participate you will be randomly divided into two groups and asked to complete a short questionnaire, then sit through a brief lecture about media use (or the lack of) in classroom settings. Afterwards, you will do a post lecture assessment, survey and memory task. Your total participation time required for participation will be 30-40 minutes.

The items on the questionnaire ask about you and your access to and use of technology. You may skip any questions you do not want to answer or stop your participation at any time. You may withdraw from the study up to the end of the Spring semester when the data will be analyzed for my thesis. Choosing not to participate will not affect your standing in the class.

It is possible that you may not benefit directly from participating in this research. It is hoped that the results of the study will be beneficial for parents and educators of students in high tech societies.

To preserve your confidentiality throughout this research, you will be assigned a participant number under which all data will be recorded and stored. Your responses to the questionnaires and assessments are strictly confidential. Your surveys will be kept separate from consent forms in a secure location. Data will be destroyed at the end of the study no later than December, 2013. Again, data will remain anonymous since it will not be able to be removed from the study. When complete, the results will be reported in summary form, no individuals will be identified.

You may contact Cyndi Davidson by e-mail at xxxxxxxxxxxxxxxxxx or Kristen Alexander at xxxxxxxxxxxxxxxxxx if you have any questions about the research.

Your participation in this research is entirely voluntary. Your signature below indicates that you have read this page and agree to participate in the research.
☐ yes, I choose to participate (saclink e-mail_______________________)

☐ no, I do not wish to participate

__________________________________________  ____________________________
Signature of Participant                          Date
References


