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The Near and Far Transfer Effects of Multimedia Cognitive Training

Alison M. McGinnis
amm14f@acu.edu

ABSTRACT

The aim of this study was to determine the degree to which “brain games,” such as Lumosity, have an effect on the young adult population and their capabilities of near and far transfer. Previous research on this topic has displayed both positive and negative results, with some research suggesting that training has increased subjects’ cognitive abilities and showed signs of transfer, with other results showing no increase in cognitive ability for training. Participants for this study were 26 undergraduates. The study entailed an experimental group that played Lumosity, an active control group that played Bejeweled, and a passive control group that did not play a game. The participants performed a pre-test and post-test assessment consisting of various measures that evaluated working memory, selective and sustained attention, visual search, and fluid intelligence. It was hypothesized that the results would not show statistically significant increases in far transfer cognitive ability. Results supported this hypothesis with experimental subjects failing to show significantly improved cognitive ability evidencing far transfer in comparison to the other groups and no significant group differences on near transfer measures. The possibility that low observed statistical power from small sample size may partially account for observed results cannot be dismissed. Future research is warranted to address the limitations of this study; including a long-term trial with a larger sample. This would allow researchers to better understand how brain games and cognitive training effects and potentially may improve near and far transfer learning.

Keywords: cognitive ability, transfer, working memory, brain games

The Near and Far Transfer Effects of Multimedia Cognitive Training

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I would like to dedicate this thesis to my loving family, especially to my grandfather who suffered from Alzheimer's for a number of years. To all the individuals who suffer or are a caregiver of this disease, I hope this study will open doors for future research in the fields of neuroscience and psychology, in hopes that a cure is on its way.

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CHAPTER I

LITERATURE REVIEW

The advances in technology that society is seeing today have provided us with infinite possibilities and responsibilities. One of the most recent developments that has attracted hundreds of experts in the fields of psychology and medicine is the idea of what is known as “brain games” or “brain training” (Shipstead, Hicks, & Engle, 2012). These games were created with the idea of being able to increase a person’s working memory capacity. Companies such as Mindsparkle (2011), Lumosity (2011), Jungle Memory (2011), and Cogmed (2011a), claim that their games improve intelligence quotient (IQ), creativity, grades, or attention. In recent years, the rise in popularity of “brain games” could be a result of audiences such as parents or schools who wish for their child’s or student’s IQ to be above the norm, or senior citizens who wish to keep their mind sharp to offset the risk of dementia and Alzheimer’s (West, Cole, Goodkind, & He, 2014).

Two programs that are the most familiar and most widely used for working memory training include Cogmed and Lumosity (Shipstead et al., 2012). These two, to be discussed more in-depth later, were created and advertised to provide an example of correct working memory functions so that one can more adequately and successfully complete educational and professional tasks (Shipstead et al., 2012). Lumos Labs, Inc. has published a “brain game” that they claim increases working memory and cognitive abilities (Hardy et al., 2015). The game, Lumosity, has become a huge trend that users download on smart phones and tablets and can use to “train” daily. However, one important question remains: Do "brain games" actually benefit or improve day-to-day cognitive function? For example, a study by Finn and McDonald (2011) showed neither benefit nor significant effect on everyday memory performance in individuals who had recently undergone cognitive training. Logically, it seems obvious that before claims are made that a product increases working memory capacity, an adequate research foundation should be established to demonstrate such, particularly in terms of near and far transfer learning (Shipstead et al., 2012).

Research in working memory training, cognitive ability training, and the effects that video games have on users' cognitive abilities has increased recently due to the rising popularity of brain games. Most of these studies have included young school-aged children and older adults, but relatively little attention has been given to the college student age range to date (Basak, Boot, Voss, & Kramer, 2008; Borella, Carrietti, Riboldi, & De Beni, 2010; Holmes, Gathercole, & Dunning, 2009; Holmes et al., 2010b; Mackey, Hill, Stone, & Bunge, 2011; Rueda, Rothbabrt, McCandliss, Saccomanno, & Posner, 2005; St. Clair-Thompson, Stevens, Hunt, & Bolder, 2010; Thorell, Lindqvist, Bergman-Nutley, Bohlin, & Klingberg, 2009). Rueda and colleagues (2005) found that it was not difficult to modify cognitive abilities during young ages; specifically, the researchers mentioned that children around the age of 4 were most easily modified, whereas 6-year-olds were less likely to have cognitive abilities modified. The brain of younger children was more likely to be altered in regards to cognitive abilities due to the brain constantly growing and developing during this time frame. This is consistent with the findings of other researchers who in turn suggest that training should be performed when cognitive development or decline is more malleable (Borella et al., 2010; Fry &

Hale, 2000). The young ages between preschool and primary education are a period of time in which development and maturity could possibly be facilitated and accelerated (Rueda et al, 2005). Chooi and Thompson (2012) also report support for the hypothesis that working memory and cognitive training results in transfer effects. Traditionally, transfer effects are defined as the impact of previous learning on the acquisition of new information (Mayer, 2001). These results imply that it is possible for people to improve working memory and other cognitive abilities through training, and possibly even training on games such as Lumosity (Chooi & Thompson, 2012). Studies showing that it is possible to improve working memory and cognitive ability through training give support to the hypothesis that both working memory and cognitive ability training may have the potential to facilitate transfer of relevant material in academic and educational settings (Holmes & Gathercole, 2014).

If brain training is found to be effective and to produce significant gains in learning transfer of information, then it could conceivably be used inside and outside of classrooms to increase working memory and cognitive functioning in everyday life. It is easy to see some of the day-to-day benefits that training may have, but it can also be used for more precise and specific pursuits. Some of the longer-term purposes include boosting academic and intelligence performance and general cognitive abilities (Chooi & Thompson, 2012; Colom et al., 2010; Holmes & Gathercole, 2014; Kesler, Sheau, Koovakkattu, & Reiss, 2011; Redick et al., 2013), diagnosis of mental health conditions such as attention-deficit, hyperactivity disorder (ADHD) (Klingberg et al., 2005; Klingberg, Fossberg, & Westerberg, 2002a), and dementia/Alzheimer's (Clare, Wilson, Carter, Roth, & Hodges, 2002). Also, one very specific instance of training being beneficial in a long-term sense is its use to help pediatric cancer patients who do not have access to traditional cognitive learning modalities (Kesler, Lacayo, & Jo, 2013).

Cognitive Training

Cognitive training, or "brain training," has received increased attention in recent years. Brain training is defined as intensive training that focuses on improving targeted cognitive skills (Holmes & Gathercole, 2014). According to Shipstead and colleagues (2012), the logic of cognitive training lies in the efficiency of one's working memory. They also stated that working memory is the main factor underlying cognitive abilities, including reasoning, attention, and impulse control (Shipstead et al., 2012). One important aspect that creators of working memory training programs stress is that an individual's performance in different cognitive abilities can be predicted by working memory capacity. Examples of these cognitive abilities are multitasking (Buhner, König, Prick, & Krumm, 2006; Hambrick, Oswald, Darowski, Rench, & Brou, 2010), emotion regulation (Kleider, Parrott, & King, 2009; Schmeichel, Volokhov, & Demaree, 2008), and mind wandering (Kane et al., 2007). The rationale for working memory training is simple; if cognitive abilities are limited by an individual's working memory capacity, then training and increasing working memory capacity with a game or program should improve these abilities (Shipstead et al., 2012). Also, results suggest that cognitive training has greater potential efficacy for individuals with lower pretraining cognitive ability (Whitlock, McLaughlin, & Allaire, 2012).

Owen and colleagues (2010) found that brain training led to improvements in cognitive tasks that were targeted in training. On the other hand, cognitive tasks that were not specifically targeted in training demonstrated no transfer effects (Owen et al., 2010).

This brings up problematic programing in some cognitive training measures because the training measure lacks tasks for some particular cognitive abilities. For example, during training, it is assumed that advancement in different levels of the task will translate to improvement of some sort. But simply seeing improvements on a training task does not necessarily provide enough evidence that cognitive ability has increased per se. Chase and Ericsson (1982) state that improvements that are seen on a training task are direct results of practice that coordinates specifically with that task. However, these trained tasks do not generalize to other types of executive, reasoning, or academic tasks (Harrison et al., 2013; Melby-Lervag & Hulme, 2013). Therefore, it is important that researchers show that training will lead to parallel improvement on untrained tasks.

Transfer

Transfer is defined as "the effect of prior learning on new learning or performance" (Mayer, 2001, p. 20). Some researchers believe that transfer rarely occurs (Detterman, 1993), whereas others believe that it is a common occurrence (Dyson, 1999). Pan and Yang (2010) explain that we use transfer learning to utilize previously acquired knowledge to solve new, similar problems more quickly and efficiently. Any type of learning that we do requires some type of transfer (Perkins & Salomon, 1996) and is linked to how we live our lives through solving new obstacles we encounter every day (Leberman, McDonald, & Doyle, 2006). Desse (1958, p. 213) even goes so far as to say that "there is no more important topic in the whole psychology of learning than transfer."

Similar to Mayer's (2001, 2002) cognitive theory of multimedia learning (CTML), Austin (2009) notes retention to be a significant factor in learning, as well as the importance of being able to transfer, process, understand, and infer learned concepts to everyday situations. Retention is also a core concept that helps us learn by simplifying storing, remembering, and getting information (Leberman et al., 2006).

Austin (2009) also categorized different ways that we use transfer in terms of four categories of problem-solving questions: redesign, troubleshooting, prediction, and conceptual. Gertner (2011) later elaborated on this categorization of learning transfer processes, providing increased clarity regarding the focus of each category. Redesign questions focus on the changing of the design or function of something. For example, someone who was taking something apart would be able to show someone else how to put it back together, or put it back together with improvements. Troubleshooting questions have to do with one's ability to have a logical or systematic way of thinking when dealing with the source of a problem. An example of this is if a doctor or a physician is able to refer to symptoms a patient may be having and relay those certain symptoms back to a certain disease or organ that would be the potential source of the problem. Prediction transfer questions involve a person's knowledge of the potential that something may have to cause a reaction for something else. This may also be understood as cause and effect, or how to fix certain situations with appropriate changes. The final type of transfer problem-solving questions is conceptual. Conceptual questions refer to an overall knowledge of a certain concept or topic. For instance, everyone has a general knowledge of how the human body works but not an in-depth understanding of every cell and organ in the body and what it does. The purpose of each of these types of problem-solving questions, which are asked and answered by the internal dialogue of the individual, is to use them to help them understand the concept of transfer learning (Gertner, 2011).

Transfer Theories

Two main transfer theories are Effect Perspective: Positive vs. Negative Transfer (Cree & Macaulay, 2000; Osman, 2008) and Situation Perspective: Specific vs. General Transfer (Austin, 2009; Butterfield & Nelson, 1991; Mayer, 2001; Mayer & Wittrock, 1996; Pressley & Woloshyn, 1995). Positive transfer uses what is learned in one context to help learn something later in another context (Gertner, 2011). For instance, what we learn in basic algebra helps us in higher-level mathematics courses such as statistics (Leberman et al., 2006). Negative transfer is when something interferes with relevant knowledge being applied to certain tasks or goals (Osman, 2008). For example, if a native English speaker learned to speak Spanish as a second language, they may have trouble learning French as a third language because of what they have learned in Spanish.

The second theory mentioned above has to do with specific transfer vs. general transfer. Specific transfer is using what is learned in one task to do something in a task that is similar (Gertner, 2011). For example, once you learn how to cut your steak with a fork and a knife, you will be able to apply what you learned to cut chicken with a fork and knife. Lu and colleagues (2015) suggest that the next step in specific transfer learning is to extract knowledge from different source tasks so that we can apply the knowledge from those tasks and aim them at one specific target task. General transfer is quite the opposite. General transfer involves taking skills and abilities learned from one task and using that knowledge to complete an entirely different target task (Gertner, 2011).

Variables That Affect Transfer

Just like there are ways for transfer to help us do things, there are variables that inhibit transfer from occurring. For instance, Austin (2009) states that individual differences such as working memory, multimedia comprehension skill, and fluid intelligence can affect one's transfer ability and performance on transfer tests. Three variables that affect transfer are working memory capacity, mental model construction, and comprehension (Gertner, 2011). Working memory capacity is the ability to maintain information that is relevant at an active state of mind (Meinz & Hambrick, 2010). There is a limit for a human's working memory capacity, and it is easy for working memory to become overloaded (Baddeley, 1999). Working memory tasks focus on short-term memory, which allows for people to process, dispose, and retrieve information (Mayer, 2001). This is why people who have a higher working memory capacity perform better on transfer tests.

Another variable that can affect transfer from occurring is mental models. A mental model is "an internal mental representation of some domain or situation that supports understanding, problem solving, reasoning, and prediction in knowledge-rich domains" (Azevedo, Guthrie, & Seibert, 2004, p. 95). The status of mental models has to do with how well someone understands how much of what they are learning. Transfer is affected by an individual's ability to understand the different aspects of and associations between ideas (Gertner, 2011).

The third variable that may affect transfer is comprehension. Comprehension focuses on the variables that represent how well a subject understands the literal message contained in communication (Bloom, 1956). For example, if a mechanic does not understand what a supervisor is saying when the supervisor says to mount an engine into a car, there is no way that the mechanic could mount an engine into a car. To understand how to do something, you must be able to understand the literal meaning behind the original message.

One other variable that may affect someone's transfer ability, or test scores, is the design of the multimedia on a test. Austin (2009) found that the positioning and motion of text can distract a participant and cause the participant to lose focus on the task at hand, resulting in smaller comprehension levels and less overall transfer.

Near and Far Transfer

Earlier research (Belmont & Butterfield, 1997; Ferrara, Brown, & Campione, 1986) indicated that instructional steps accompanied by repeated training on a specific task resulted in improved performance on that task, but rarely demonstrated transfer and improved general cognitive abilities. Transfer can be categorized into two sections: near transfer, referring to "changes in a domain caused by changes in another similar domain due to comparable ability or process," and far transfer, referring to "changes in domains caused by changes in a separate domain of different processes" (Chooi & Thompson, 2012, p. 532). Multiple studies have reported observing near transfer as a result of cognitive training in the areas of working memory, executive functioning, attention control, fluid reasoning, and task switching (Basak et al., 2008; Borella et al., 2010; Chooi & Thompson, 2012; Holmes et al., 2009; Holmes et al., 2010b; Karbach & Kray, 2009; Kesler et al., 2013; Mackey et al., 2011; Rueda et al., 2005; Schmiedek, Lovden, & Lindenberger, 2010; St. Clair-Thompson et al., 2010; Thorell et al., 2009). Some studies have reported observing far transfer occurring as a result of cognitive training programs (Buschkuel et al., 2008; Mahncke et al., 2006; Richmond, Morrison, Chein, & Olson, 2011; Schmiedek et al., 2010), and others have reported finding significant evidence of far transfer effects (Dahlin, Neely, Larsson, Backman, & Nyberg, 2008a; Dahlin, Nyberg, Backman, & Neely, 2008b; Li et al., 2008). One of the studies reporting evidence of far transfer effects was done by Klingberg, Fossberg, and Westerberg (2002a), who found improved performance on a far transfer test after subjects participated in a trained visuospatial working memory task. The far transfer task was not closely similar to the trained task in terms of the process and procedures.

Transfer in Relation to Age

Another topic of discussion in near and far transfer is that of age. The results of the studies mentioned above suggest that the effects of far transfer may be dependent on the subject's age. These results showed that far transfer effects were more profound in young adults and less potent in older adults (Richmond et al., 2011). This parallels the findings of other studies reporting that adults showed more significant signs of far transfer (Baltes & Kliegl, 1992; Dahlin et al., 2008a; Jaeggi, Buschkuel, Jonides, & Perrig, 2008; Jones et al., 2006; Klingberg et al., 2002a; Kray & Epplinger, 2006; Westerberg & Klingberg, 2007). However, Dahlin, Nyberg, Backman, and Neely (2008b) reported observing significant improvements among both young and older adults on a letter memory test, suggesting that working memory capacity can be increased through early and older adulthood. In fact, some of the older adults participating in this study showed greater improvement than the young adults in the study (Dahlin et al., 2008b). Chein and Morrison (2010) also found working memory training gains to be similar between young adult and older adult subjects. Their data showed evidence of significant transfer from working memory to untrained tasks throughout the entire group of subjects (Chein & Morrison, 2010). Substantial research on the association between working memory training and far transfer effects among adults and children is available; however, markedly fewer studies have examined this question among young adults of college age (Basak et al., 2008; Borella et al., 2010; Holmes et al., 2009; Holmes et al., 2010; Mackey et al., 2011; Rueda et al., 2005; St. Clair-Thompson et al., 2010; Thorell et al., 2009).

Working Memory

Working memory has been deemed one of the most significant current theoretical constructs in cognitive psychology today (Melby-Lervag & Hulme, 2012). Working memory is generally defined as an important short-term memory system that works to constantly alternate attention among multiple sources of information. It is a cognitive system that provides temporary storage for completion of cognitive tasks (Baddeley, 1992) and affects how well higher-order cognitive functions are performed (Ang, Lee, Cheam, Poon, & Koh, 2015). Working memory is operationally defined and measured in terms of an individual's working memory capacity. A person's working memory capacity is important because it reflects active cognitive mechanisms as well as the ability to retrieve and use critical information (Cowan, 2001; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Unsworth & Engle, 2007). More specifically, to differentiate working memory from short-term memory, which sometimes are interchangeably used, for the purposes of the current study working memory will be recognized as the central system that allows individuals to retrieve information, perform various cognitive attributes, and revise past memories based on new and pertinent information that has been obtained (Bull, Espy, & Wiebe, 2008). When accessing working memory, experimental task measures are typically used to test the individual's executive control to access their ability to process and store new information. (Bull et al., 2008). Working memory capacity is also important because working memory is closely related to components of a person's fluid intelligence, such as concentration, problem solving, and impulse control, and can serve as an indication of increased potential for academic and professional success (Shipstead, Hicks, & Engle, 2012). Ideally, working memory or working memory capacity could be increased through daily training. However, recent research has shown that working memory training does not necessarily lead to significant improvement in working memory or working memory capacity (Redick et al., 2013).

As mentioned before, working memory capacity has been suggested to be a strong indicator of academic or professional success; however, one controlled study found little evidence of improved academic performance following training of working memory (Wass, Scerif, & Johnson, 2012). Another study reported no improvement between pre-test and post-test performance after subjects had gone through working memory capacity training (Chooi & Thompson, 2012). It has also been noted that no current theory argues that working memory capacity should change from training (Gibson, Gondoli, Johnson, Steeger, & Morissey, 2012). Melby-Lervag and Hulme (2013) concluded from their meta-analysis that the new working memory training programs and training games are not based on any clear process or task analysis. Rather, it seems that these games and programs are based on a simple idea that working memory can be trained and improved the same way that muscles are strengthened by working out (Chein & Morrison, 2010; Schmiedek et al., 2010; Thorell et al., 2009).

Although a majority of the studies reviewed describe negative results for significant improvement following training, Klingberg and colleagues (2005) did report that performance on untrained working memory tasks could be significantly increased through working memory training. However, similar to the findings regarding near and far transfer, research on working memory and working memory capacity training seems to be inconclusive at present, with slightly more findings indicating that training does not result in observably improved performance.

Attention

Attention is a part of the foundation of cognitive functioning and is a significant component of many other mental functions that continually progress slowly through developmental stages (Davidson, Amso, Cruess-Anderson, & Diamond, 2006; Mayas, Parmentier, Andres, & Ballesteros, 2014). One aspect of attention relevant to this discussion is selective attention, which is defined as the ability of an individual to focus on a specific item while ignoring distractions (Green & Bavelier, 2012). Working memory capacity works simultaneously with attention. Thus, it has been proposed that an increased working memory capacity results in an improved ability to perform tasks involving distracting information due to selective attention (Melby-Lervag & Hulme, 2013).

Fluid Intelligence

Jaeggi et al.'s (2008) hypothesis holds that fluid intelligence can be improved by training working memory as a result of engaging the neural circuits that are shared by working memory and fluid intelligence. However, both Chein and Morrison (2010) and Richmond and colleagues (2011) found little evidence of transfer to measures of general fluid intelligence. Specifically examining the relationship between working memory and fluid intelligence, Halford, Cowan, and Andrews (2007) reasoned that capacity limits might be similar between working memory and reasoning skills. It was found that the relation between fluid intelligence and working memory was facilitated by activity "in the lateral prefrontal and parietal regions" (Gray, Chabris, & Braver, 2003, p. 316). It was also found that the dorsolateral prefrontal cortex of the brain could be significantly involved in working memory processes, especially when focusing on attentional control (Kane & Engle, 2002). There have been multiple hypotheses related to the neural mechanisms involved in working memory. One hypothesis is that working memory tasks engage the prefrontal cortex regions of the brain when it is necessary to disregard outside distractions while maintaining and manipulating information (Conway, Kane, & Engle, 2003; Gray et al., 2003).

Visual Search

The location to which attention is focused often determines what information is noticed about an environment (Scanlon, Drescher, & Sarkar, 2007). This has been demonstrated most visibly in the field of perceptual learning. One example suggests that the retinal position is relevant to learning and improving perceptual skills such as visual search (Karni & Sagi, 1991). For instance, subjects that were trained to specify the position of an object in one area of their field of vision showed signs of improved learning. These improvements were evident for a period of time ranging from a couple of days, to months, and even years. However, when the object is moved to a different, untrained area, there were no signs of improvement. The subject's performance levels began at the bottom again, and the subject had to learn the new area as they previously did (Green & Bavelier, 2012). Oei and Patterson (2013) demonstrated that visual search and spatial working memory showed significant improvements following hidden-object and memory matrix training, whereas visual search showed improvement following training using the game match-3. Oei and Patterson's (2013) research, as well as a study by Wu and Spence (2013), provide support for the hypothesis that training games which utilize frequent search will lead to increases in visual search performance.

Plasticity and Training

As recent studies have shown, working memory is no longer viewed as a constant trait, but rather a capacity that can be improved by flexible and extensive training. Klingberg (2010) states that this type of training often parallels shifts in brain activity in the frontal and parietal cortex, the basal ganglia, and dopamine receptor density. Transfer of the training effects to non-trained working memory tasks "is consistent with the notion of training-induced plasticity in a common neural network for working memory" (Klingberg, 2010, p. 319). This is also consistent with research by Buonomano and Merzenich (1998), who found improved performances in a vast majority of functions linked with neural changes from the intracellular level to functional organization of the cortex. Neuroimaging studies have also indicated that people have located activity connected with working memory in sensory association cortices and the prefrontal cortex (Curtis & D'Esposito, 2003; Linden, 2007). Psychological representations of working memory differentiate sensory-specific storage from a coordinating or governing function, also known as the central executive (Baddeley, 2003). This suggests that working memory training may lead to improvement in performance in non-trained tasks that rely on working memory and attentional control (Engle, Kane, & Tuholski, 1999). Thus, this transfer effect is consistent with training induced plasticity in an intraparietal-prefrontal network that is common for working memory and control of attention (Corbetta & Shulman, 2002; Klingberg, 2010).

Adaptive training focusing on attentional control could have similar effects, and some studies have reported promising results (Rueda et al., 2005). It is anticipated that training in a specific cortical region with specific tasks and functions will result in transfer to various other tasks and functions that use the same neural network (Olesen, Westerberg, & Klingberg, 2004). However, the same would not be expected for training that affects sensory association areas. This training would be expected to have more of a general effect because it would affect higher associated cortices (Klingberg, 2010). The majority of studies report a positive correlation between working memory capacity and brain activity in task-relevant areas (Gray et al., 2003; Lee et al., 2006; McNab & Klingberg, 2008; Todd & Marois, 2004; Vogel, & Machizawa, 2004).

Another factor that affects working memory capacity is age. Researchers report an increase in working memory capacity related to brain activity in task-related areas of the intraparietal sulcus and prefrontal cortex of the brain during childhood (Ciesielski, Lesnik, Savoy, Grant, & Ahlfors, 2006; Crone et al., 2006; Klingberg et al., 2002; Kwon, Reiss, & Menon, 2002; Olesen et al., 2007; Scherf et al., 2006). However, the opposite seems to occur with aging. Working memory is seen to decline with age, which potentially may be related to a decrease in activity (Persson & Nyberg, 2006). It may also be because of different activity patterns that have been found in other prefrontal areas of the brain (Rajah & D'Esposito, 2005). The results mentioned above suggest that better working memory capacity can be linked with higher levels of activity (Edin, Macoveanu, Olesen, Tegner, & Klingberg, 2007; Edin et al. 2009; Macoveanu, Klingberg, & Tegner, 2006). It may be that cognitive and brain plasticity leads to adaptation through compensating neural activity (Greenwood & Parasuraman, 2010; Hertzog, Kramer, Wilson, & Lindenberger, 2009; Park & Reuter-Lorenz, 2009).

The dominant idea in the field of neuroscience over the past century was that the brain is fairly plastic in infancy, childhood, and adolescence, but becomes fixed and immovable during adulthood and older ages. As a result, it was thought that large changes in learning and plasticity were only available early in life (Green & Bavelier, 2012). However, current research has shown that the adult brain has much more capacity for plasticity, given proper activity and training, than previously understood (Bavelier, Levi, Li, Dan, & Hensch, 2010; Morishita & Hensch, 2008).

Short- and Long-Term Memory

Short-term memory tasks involve minimal amounts of information that are kept and repeated in sequential order without requiring resources from the subject's long-term memory and other cognitive demands to understand the task (as required by working memory) (Bull et al., 2008). Near transfer on short-term memory tasks has previously been observed in young adults (Chein & Morrison, 2010). Dunning and colleagues (2013) found that working memory training did not enhance performance on tests of verbal short-term memory. This was consistent with results from studies by Holmes and colleagues (Holmes et al., 2009; Holmes, Gathercole, & Dunning, 2010). Researchers have also concluded that verbal working memory tasks require an important component of working memory that does not involve much from the executive control of working memory (Baddeley, Gathercole, & Papagno, 1998).

However, training programs currently in use apparently can provide short-term improvements on verbal and nonverbal working memory tasks. For example, Richmond and colleagues (2011) found that training led to improvements on tasks that were trained and resulted in near transfer on short-term and working memory tasks as well. Unfortunately, it has been found that trainees do not sustain the short-term near transfer effects of verbal working memory after a span of about 9 months (Melby-Lervåg & Hulme, 2013). Wass, Scerif, and Johnson (2012) reported that the effects of one period of working memory training appear to progressively weaken over time. More importantly, Melby-Lervåg and Hulme (2013) found no evidence that working memory training produced gains in generalized tasks and skills such as verbal ability, word decoding, or arithmetic, even when assessed immediately after training occurred. Contrary to what Melby-Lervåg and Hulme (2013) reported, Dahlin and colleagues (2008b), along with previous researchers (Erickson et al., 2007; Kramer, Hahn, & Gopher, 1999; Stigsdotter-Neely & Backman, 1993; Willis et al., 2006), demonstrated that the training program constantly being updated resulted in gains being maintained over a longer period of time.

“Brain Games”

There has been a growth in popularity of “brain games” in recent years. Brain games are games that target working memory training and have been developed to be commercialized and sold via computer or mobile applications. The two leading brain games are Cogmed (http://www/ Cogmed.com/) and Lumosity (http://www.lumosity.com/). Cogmed, now available in 30 countries, is based on eight different exercises that use visuospatial and verbal working memory tasks that adaptively vary in difficulty level during training. Cogmed is now used in many schools and clinics throughout the world. The Cogmed website claims that their training program can be used as a solution for those who are restricted by working memory capacity, such as individuals who have deficiencies in attention or other learning disorders (Cogmed, 2011a). Cogmed's website also states that their training program will improve an individual's fluid IQ, which in turn will help the individual "pay attention, resist distractions, self-manage, and learn" (Cogmed, 2011b, para. 5). Lumosity also claims that mental abilities like working memory can be increased through mental exercises (Richmond et al., 2011).

It is important to understand that these training games allegedly targeting working memory give participants adaptive tasks to perform that are above their capacity when played. It is also important to note that these games are not based on task analysis or theoretical postulation that these types of training will improve working memory capacity (Gibson, Gondolli, Johnson, Streeger, & Morrissey, 2012; Melby-Lervag & Hulme, 2013). If efficacy could be established, approaches like these would provide a cost-effective way to address cognitive deficits that are linked with poor educational processes (Holmes & Gathercole, 2014).

Lumosity

Although a number of studies have reported near transfer effects and improved performances using both programs, far transfer and long-term results, as well as academic performance gains, have yet to be confirmed. Lumosity was selected for this study because Lumosity is a commercial product that recently has appealed to the public more broadly when marketed as a "freemium" app/game on IOS and Android devices. Many of these commercials and marketing ploys seem suspicious, appearing to appeal to consumers by claiming that playing this game will improve the memory and cognitive functions used in everyday life.

Lumosity, founded in March 2005, is a commercial computerized cognitive brain training game that is widely advertised as leading to improved core cognitive processes and skills such as problem solving, memory, attention, processing speed, mental flexibility, spatial orientation, and logical reasoning (Shute, Ventura, & Ke, 2015). Lumosity's website seems to be dedicated to press releases and has "About Lumosity" on every document stating:

> Lumosity is committed to pioneering the understanding and enhancement of the human brain to give each person the power to unlock their full potential. Lumosity's online and mobile programs train core cognitive abilities such as memory and attention. Founded in 2005 and launched in 2007, Lumosity now has more than 40 games, 50 million members, and paying subscribers from 180 countries. Lumosity's games are based on the latest discoveries in neuroscience, with continuing independent third-party studies being conducted by researchers at Harvard, Stanford, and other academic institutions. (Lumosity, 2013a, para. 5)

When you first play Lumosity, you have to log on to the Lumosity website and play a sequence of training games that claims to have been personalized for you. These personalized sequences of games consist of five games that last approximately 5-6 minutes each. Each sequence of games is categorized under a certain cognitive skill (e.g., memory, attention, processing speed, mental flexibility). The Lumosity website describes many studies that support and promote the effectiveness of Lumosity on the cognitive skills that the games target.

A user's performance in Lumosity is judged by their "brain power index" (BPI), which is the total score of all of the Lumosity activities. The "Brain Performance Test" (BPT) is used to generate a user's BPI (Shute et al., 2015). The goal of the BPT, released in 2013, is to allow researchers from Lumosity to improve upon the way they measure transfer effects to similar cognitive tasks, as well as everyday life tasks (Lumosity, 2013b). Results suggest that the more training an individual performs, the larger the expected gains in performance observed (Sternberg, Hardy, Ballard, & Scanlon, 2013).

Lumosity's reported recent milestones (Lumosity, 2015b) include launching an iPhone mobile application in January 2010. Lumosity reached 50 million members by October 2013 (Lumosity, 2013c). Lumosity later went on to introduce the Human Cognition Project. The goal of the Human Cognition Project is "to rapidly and efficiently advance our understanding of the brain." Lumosity claimed that they are "particularly interested in applying the knowledge we gain from this research in real-world settings where they can help people live better, fuller lives" (Lumosity, 2013e, para. 6). Lumosity has launched multiple programs including the Lumosity Education Access Program (LEAP) for students (Lumosity, 2014a) and the Clinical Access Research and Education (CARE) program, and they are currently working on different versions of the Lumosity program such as "LumiKids," a children's version of Lumosity (Lumosity, 2015a). Lumosity has received millions of dollars through funding (Angel funding, Series B, C, D funding), been named to the INC. 500 list, and had publications in *Brain Injury*, *Neuropsychological Rehabilitation*, *Mensa*, *Brain Impairment*, *Clinical Breast Cancer*, and *Frontiers in Neuroscience* (Lumosity, 2015b).

In a paper published on the Lumosity website titled "The Science Behind Lumosity" (Hardy, Farzin, & Scanlon, 2013, p. 5), the authors state that, "taken together, the entire suite of exercises in Lumosity represents a comprehensive brain training system – an entire gym for the brain." Hardy and colleagues (2015) report that people who regularly played Lumosity showed greater improvements than the control group when comparing cognitive skills including speed of processing, short-term memory, working memory, problem solving, and fluid reasoning. Lumosity's press releases each speak of different studies that are being conducted to document support for their product.

One Lumosity study examined cognitive training tasks and found them to accelerate learning rates (Lumosity, 2013a). This study reported that changing different psychophysical task parameters that increase the difficulty of tasks led to different learning rates of said tasks. These same results also provided evidence that effects were dose-dependent, and relied upon how much time was required to make cognitive changes, and that the group whose training tasks had been changed showed improved spatial recall and attention (Anguera & Gazzaley, 2015; Lumosity, 2013a). Kaluska, the lead researcher on this project, reported that the results of this study were very interesting because they showed that any changes, no matter the size, could result in differences to learning rates (Lumosity, 2013a). He also stated that understanding the changes could help us better understand and develop tasks that help individuals learn faster (Lumosity, 2013a).

Another study, titled "Optimizing Cognitive Task Designs to Improve Learning Rates in a Large Online Population" (Lumosity, 2014b), had two stated goals. The first goal of the study was to facilitate online studies involving thousands of participants so that the researchers could get a better understanding of how people learn. The second stated goal of the research was to apply the findings of the research so that they could improve their product. After analyzing 99,022 participants' game play, the researchers found that players who began playing closer to their performance threshold on a cognitive task tended to have a faster learning rate; this was especially apparent at higher difficulty levels of game play (Lumosity, 2014b).

Lumosity also has reported results from a study examining lifestyle effects on cognitive training ("Estimating Sleep, Mood and Time of Day Effects in a Large Database of Human Cognitive Performance"; Lumosity, 2014c). The study "analyzed over 60 million data points from 61,407 participants and found that memory, speed, and flexibility task peaked in the morning, while crystalized knowledge tasks such as arithmetic and verbal fluency peaked in the afternoon" (Lumosity, 2014c, para. 1). Results of the study showed that the best game performances occurred after the user had seven hours of sleep and played the game with a positive mood (Lumosity, 2014c).

Sternberg, the lead researcher, also led a study that was part of the Human Cognition Project (Lumosity, 2013e). Part of the study examined how learning ability changes over the lifespan and how aging might affect learning across distinct cognitive abilities. He reported that, as age increased, improvements began to decrease. Specifically, results on tasks that had to do with fluid intelligence decreased more quickly than on tasks related to crystalized intelligence (Lumosity, 2013e). These findings support the claim that cognitive performance is at its highest during young adulthood, and that humans accumulate knowledge throughout life so that older adults are still capable of performing at a high level.

Another analysis that showed improvements associated with training included 1,300 students who trained with Lumosity (Lumosity, 2013d). These students showed greater improvement on a battery of cognitive assessments than controls. Specifically, students who played Lumosity improved their scores on a group of online cognitive assessments in comparison to a group of students who participated in a traditional academic schedule. It is also worth noting that the effects of the study were dose-dependent in the sense that students who trained more than 9 hours nearly doubled improvements compared to students who did not train (Lumosity, 2013d).

Another study funded by Lumos Labs, Inc. reported that it was possible to improve cognitive abilities through training outside of a laboratory setting with web-based applications (Scanlon, Drescher, & Sarkar, 2007). Results of improved cognitive abilities were mainly seen on visual attention and working memory tasks for the training group, whereas the control group showed no significant improvements (Scanlon et al., 2007).

Contrary to Lumosity's claims, several studies conducted by outside researchers have failed to observed support for the claims Lumosity makes on their website. These researchers conclude that games such as Lumosity do not promote transfer or generalization beyond the actual tasks used in the games during the training (Ackerman, Kanfer, & Calderwood, 2010; Boot et al., 2013; Redick et al., 2013; Zickefoose, Hux, Brown, & Wulf, 2013).

Shute and colleagues (2015) reported that training exposes each user to gradually increasing levels of challenges, adapting to task difficulty, but observed no significant improvement from pre-test to post-test for Lumosity participants. Zickefoose and colleagues' (2013) results were discouraging to Lumosity because participation in the programs showed only limited or no apparent generalization benefits. The results of the study also confirmed a popular speculation of researchers that there is a certain ease for the company to demonstrate significant improvements on certain tasks but not to provide evidence of conversion of these improvements to everyday tasks (George & Whitehouse, 2011; Owen et al., 2010; Papp, Walsh, & Snyder, 2009; Zickefoose et al., 2013). Another study (Cruz et al., 2009) reported inconclusive evidence of improved cognitive capabilities in a training group that played Lumosity when compared to a control group that did not play Lumosity. The small improvements that they did see were only in the memory of letter and number test, and the participants had to have played Lumosity for 10 sessions during 3 weeks (Cruz et al., 2009).

Video Games

In addition to research on brain games, there has also been significant research on video games and their relation to cognitive abilities. The two main objectives behind playing video games are enjoyment and continued player engagement (Anguera & Gazzaley, 2015). The goal of cognition exercises is to challenge users' various neural systems, or their cognitive abilities through a targeted approach without a primary focus on entertainment that traditionally characterizes video games (Anguera & Gazzaley, 2015). Current research has delineated a relationship between action video games and improved visual and attentional skills (Green & Bavelier, 2006, 2008; Green, Lim, & Bavelier, 2010). However, other researchers disagree, arguing that cognitive improvements are due to the action of video games (Oei & Patterson, 2013). Some researchers have gone so far as to say that playing video games can improve basic skills that may be applied to various tasks and stimuli (Feng, Spence, & Pratt, 2007). More importantly, transfer appears to occur when the game played is similar to the task performed. A recent study suggested that video games possibly can be effective in improving the cognitive functioning of older adults depending on variables such as video game difficulty, the participant's age, the amount of time spent training, and the cognitive process being assessed (Toril, Reales, & Ballesteros, 2014). Similarly, Oei and Patterson (2013, 2015) concluded that training with video games on an iPhone or iPad led to improvements in attention abilities and working memory abilities.

One problem with studies that have shown improvement from pre-test to post-test performance for subjects playing action video games is that they did not have a proper control group. The best solution to this potential confound is to introduce a well-planned active control group, where the amount time spent in training is equated (Green & Bavelier, 2012). One effect that is seen on subjects who play action video games is that they show more substantial improvement between pre-test and post-test performances than control group subjects do. In contrast to earlier experiments that failed to include contact controls, it has recently become more common to include an active control (Klingberg, 2010). The purpose of including active control and non-active control conditions is to ensure that the effects that are observed in trained groups are not plausibly due to test-retest effects. It is common for participants to perform better on a test the second time it is taken within a relatively short time; therefore, comparing the scores of all three groups would provide a check on the simple effects of recent test exposure. Including active control groups also makes less likely factors such as the Hawthorne effect, that is, the idea that subjects who are shown more attention perform better on the tests compared to the subjects who are shown little attention. The majority of studies conducted on the cognitive effects of action video game play show the greatest impact on areas where a user's performance is restricted by top-down attention or the procedures that govern attentional allocation and resource management (Green & Bavelier, 2012).

In a study previously described, Oei and Patterson (2013) found that groups that played a match-3 game and an action video game showed increases in higher-level executive processes. These higher-level executive processes are important for carrying out difficult attention-span tasks (Oei & Patterson, 2013). However, Boot, Kramer, Simons, Fabiani, and Gratton (2008) reported contradictory findings. Boot and colleagues (2008) studied the effects of non-video-game players playing 20 hours of video games on working memory, task switching, and reasoning, reporting negative results. The difference between these two studies indicates that using these platforms does not appear to conclusively lead to verifiable cognitive enhancement (Unsworth et al., 2015), and also suggests that not every type of video game has the same effect.

The growing literature in this area suggests several speculative reasons regarding why video games might be effective, including improvements in processing speed, executive control, and attentional control. These improvements also lead to the ability to observe and distinguish between objects and events. Video games also provide other benefits such as engagement, motivation, arousal, and enjoyment (Belchior et al., 2013).

Casual Games

One type of video game receiving attention with regard to cognitive training is casual games. Casual games appeal to people who do not consider themselves gamers, and consist of simple rules that allow the user to complete the game in a fairly short amount of time (Baniqued et al., 2013). Casual games are available in a variety of platforms, including via the Internet, gaming consoles, mobile devices, and other platforms. Although these games are considered casual, they may require players to utilize many different cognitive skills, and they usually have different levels that increase in difficulty, which has been found to be an important part of improving training (Brehmer, Westerberg, & Backman, 2012; Holmes et al., 2009). Casual games tend to engage people more often than games that are founded on psychological tasks. This tends to lead more frequent game play, and in turn, greater exposure to cognitive training (Baniqued et al., 2013).

Several factors may affect a player's gaming experience. One of these factors is motivation. One aspect of video games that causes an increase in motivation is the reward structure that is found in many video games (Anguera & Gazzaley, 2015). Dorrenbacher and colleagues (2014) claimed that the motivational environment might lead to a positive influence on near transfer. However, the motivation environment was not seen to lead to positive effects on abilities that were not directly trained (Dorrenbacher, Muller, Troger, & Kray, 2014). Motivation can also lead to players training more on their own and having better scores than players with low motivation, which would appear likely to impact their performance in the game and resulting potential transfer effects.

Conversely, Katz and colleagues (2014) claim that certain types of motivational elements, such as real-time scoring, can lead to poor cognitive training effects. Another factor that is implemented in video games that enhances the gaming experience and may lead to positive training effects is the employment of varying difficulty levels. This is referred to as additivity, and modifies the stimuli presented to game players (Katz, Jaeggi, Bushkuehl, Stegman, & Shah, 2014).

Current Study

Researchers studying cognitive abilities and the impact of training on cognitive performance have delineated several influential factors. However, several interesting questions remain unanswered. For example, we do not yet know for certain whether cognitive training interventions, such as Lumosity, benefit day-to-day cognitive functions. The multiple studies mentioned above failed to show consistent, replicated results when examined together. More studies completed with conclusive, replicable results are needed before being able to state unequivocally that training interventions such as Lumosity lead to increased cognitive performance. Also, a number of the studies reviewed did not include a control group, which can result in misleading conclusions. Researchers need to compare the game or treatment with a similar active control group with the same expectations of improvements as their experimental group, primarily to allow results to be cleanly attributed to the effects of the treatment (Shute, Ventura, & Ke, 2014). It has been seen that some video games can motivate people to learn valuable knowledge and skills, (Coller & Scott, 2009; Tobias & Fletcher, 2011; Ventura et al., 2013; Wilson et al., 2009; Young et al., 2012), but the degree to which Lumosity leads to enhanced motivation and, in turn, to improved performance remains to be documented.

One of the major trends in brain games is the mini-task approach. Green and Bavelier (2012) described the mini-task approach as when the individual completes a small set of tasks repeatedly. These tasks are fairly simple models that are filled with visual effects and sounds or music so that they will be more attractive to the user. Users are able to tell that they are getting better at the task, or the mini-game in this instance, because they will continue to beat their high score (Green & Bavelier, 2012). The question that needs to be answered is whether or not these tasks help to enhance the individual's performance on the untrained tasks they encounter in settings outside of training. Green and Bavelier (2012) state that the main goal of the training programs should be to benefit users outside of training settings in day-to-day tasks. If the objective was to train a specific skill that needs to be done repeatedly without error, then it is easy to see how this could be beneficial to the user. However, if the objective were to produce an increase in performance across a wide range of day-to-day tasks, then the proper training program would include fewer training games of a single task, and a broad exposure to a variety of tasks (Schmidt & Bjork, 1992). A broader selection of tasks in a training program could lead to more general learning. Variety is critical to training programs and can lead to transfer of learning as tasks share common components and processes (Kemp, Goodman & Tenebaum, 2010). Some tasks will include identical components as other tasks; however, if two or more tasks share similar processing elements, then learning one of the tasks should benefit performance on the other.

One controversial trend in the literature to date regards the use of digital media to provide cognitive training and in turn enhance cognitive performance (Ferguson, 2013). Digital media programs continue to be developed and continue to claim that they allow the user to improve cognitive control and goal management (Anguera & Gaazaley, 2015). Research has examined claims that training games improve working memory and cognitive skills (Holmes & Gathercole, 2014). Different training games that specifically target working memory provide significant evidence that it may be possible to enhance memory (Holmes & Gathercole, 2014). Unfortunately, these studies also suggest that training and practice on a task only improve performance on that task, failing to demonstrate transfer of performance gains to other cognitive abilities (Belmont & Butterfield, 1977; Ferrara, Brown, & Campione, 1986).

There are several factors that need to be taken into consideration when examining cognitive improvements through video game play. Some factors include time training, dose effects, number of video games played, and the age of participants. Boot and colleagues (2008) showed that missing one or more of the training effects mentioned above was related with the idea that playing a certain video game would not lead to cognitive improvements. This is also in relation to the idea of dose effects; some researchers believe video game training may require more hours of game play to see any cognitive improvements. However, the data shown by Owen and colleagues (2010) suggest that a multiple video game approach has not steadily shown effective results of transfer past a control group, no matter the amount of time that was spent training (Ackerman et al., 2010; Nouchi et al., 2012). Along the same lines, Smith, Stibric, and Smithson (2013) demonstrated how very restricted transfer effects could be on college-age participants. These researches concluded by suggesting caution in the overgeneralization of cognitive training systems (Smith et al., 2013).

It is more likely for people to show improvements in cognitive abilities when their training program focuses on tasks that the user is more likely to participate in during everyday life. Using a more focused and strategic plan of cognitive tasks to train is more likely to be superior for users who are training with a cognitive training program. Angurea and Gazzaley (2015) suggest that, based on the evidence documented by Shute and colleagues (2015), and the recent meta-analysis study by Toril and colleagues (2014), training with a smaller group of tasks is possibly more beneficial in regards to transfer effects than training with a broad group of tasks. Therefore, this study utilized a group of tasks including visual search, working memory span task, sustained attention, selective attention, and fluid intelligence. It is still unknown if younger adults that train using cognitive training games will show comparable cognitive improvements. Consistent with the claim that transfer of learning depends on the similarities between learning and transfer task; I hypothesized that near transfer effects would be more apparent in tasks that shared similar properties with the training game. Thus, when individuals frequently train with games that share skills with outside behavioral tasks, the user will improve in that certain task. As a result, it was proposed that participants would not see far-transfer effects, meaning individuals would not improve to the same degree on tasks that were dissimilar to the tasks trained in the games. Therefore, it was generally hypothesized that Lumosity's brain training program would not show significant results for far transfer in regard to cognitive functions.

A strict definition of transfer was developed specifically for this review. Rather than judging the efficiency of training of single concepts, this study focused on whether or not improvements were generalized to other cognitive functions. One of the main questions being addressed here was the degree to which cognitive training aimed towards a younger adult population could demonstrate a broader transfer of effects.

CHAPTER II

METHODS

Participants

The current study began with 32 students enrolled at Abilene Christian University in undergraduate psychology courses (e.g., Cognition and Learning, Health Psychology) volunteering to participate, but due to scheduling conflicts and failure to complete both assessment sessions, the study concluded with 26 participants. Participants were 18 females and 8 males with an average age of 20.88 years. Participation in this study required students to have access to either a smart phone or a computer. After providing consent to participate, subjects completed a demographic questionnaire and scheduled an individual assessment session. During this assessment session, participants completed a series of assessments relating to working memory, selective and sustained attention, visual search, and fluid intelligence. After pre-assessment participants were randomly assigned to one of three training conditions, the experimental group, the active control group, or the control group. At the completion of the study the experimental group contained 10 participants, the active control contained 9 participants, and the passive control group contained 7 participants.

Course-specific extra credit was awarded to participants in this study. At the discretion of individual instructors, alternative routes to obtaining equivalent course-specific extra credit were made available to non-participants.

Measures

Rey Auditory Verbal Learning Test (RAVLT)

According to Statistics Solution (2015), the Rey Auditory Verbal Learning Test (RAVLT) is used to evaluate a wide variety of cognitive functions, including short-term auditory-verbal memory, rate of learning, learning strategies, retroactive and proactive interference, presence of confabulation of confusion in memory processes, retention of information, and differences between learning and retrieval. During the RAVLT, participants are given a list of 15 unrelated nouns that are repeated over five sequential trials; participants are then asked to list these nouns following each presentation. Next, participants are presented with a second list of 15 unrelated nouns, followed by a similar free recall period. Finally, participants are asked to repeat the original list of 15 nouns, with the process repeated following a 30-minute delay. Approximately, the RAVLT requires 10-15 minutes, not including the 30-minute delay, resulting in a total elapsed time of 40-45 minutes to complete the task.

The score is composed of the sum of the number of correctly recalled words from the list. Then, a total score is calculated from the sum of the 1 through 5, and 7 trial scores. Words that are either repeated or not on the list are noted as errors but do not affect the participant’s score. Student normative data were gathered and showed a response of an average of 8.9 words recalled for trial 1, 12.7 for trial 2, 12.8 for trial 3, 13.5 for trial 4, and 14.5 for trial 5, resulting in an overall mean of 12.5 words recalled by students during the RAVLT, and a mean of 14.8 during the recognition trial for the RAVLT (Berg, Granzen, & Wedding, 1987). Normative data has also been complied for the clinical population as well as healthy individuals (Lezak, 1995; Schmidt, 1996).

A study by Magalhaes, Malloy-Diniz, and Hamdan (2012) found RAVLT test-retest correlations to range from .36 to .68. The weakest correlation (r = .28) was found in the A2 measure, with stronger correlations found for A1 through A5 (r = 0.68). The other measures included moderate correlations. Internal consistency of the RAVLT was reported to be moderately strong (Cronbach's Alpha of .80) and evidence of divergent and convergent validity deemed sufficient (Magalhaes et al., 2012). Thus, the RAVLT is considered a valid and dependable psychometric instrument for assessment of cognitive function (De Paula et al., 2012; Fichman et al., 2010; Magalhaes et al., 2012; Messinis, Tsakona, Malefaki, & Papathanasopoulos, 2007).

Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV)

The Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV) is a clinical instrument that assesses cognitive abilities of adolescents and adults between the age of 16 years and 90 years 11 months (Wechsler, 2008a). Completion of the WAIS-IV provides a composite score that shows the individual's intellectual functioning and general intellectual ability in certain cognitive areas. The working memory index is compiled using the Digit Span and Arithmetic portion of the WAIS-IV. One subtest of the WAIS-IV is the digit span forward test. During this portion, the test taker is asked to recall a series of numbers in the same order that they were orally presented (Wechsler, 2008a). For example, the test administrator says, "7, 8, 9," and then asks the test taker to repeat the numbers back to them in the exact same order. For the digit span backward portion of the test, the test administrator reads aloud a series of numbers and then asks the test taker to say them back but in reverse order. For example, the test administrator says, "2, 3, 4," and the test taker has to answer, "4, 3, 2." Another portion of the test is the digit span-sequencing task. During this part of the test, another series of numbers is orally presented and respondents are asked to read back the numbers that the test administrator read but in ascending order. Each one of these portions of the test is comprised of two separate trials. After both trials of each portion, discontinuation takes place. The instructor is responsible for making sure the participant's responses match the correct response listed in the manual. For each correct response, the participant receives 1 point; no point is given if the participant responds with the incorrect answer, states he/she does not know the answer, or does not respond within 30 seconds. The item score is the sum of points within that trial.

The fourth part of the test is the arithmetic portion. In this portion of the test, subjects have to mentally solve a sequence of arithmetic problems. One example of an arithmetic problem similar to those on the subtest is: "Jeffrey has eight flowers, if he loses three, how many flowers will Jeffrey have?" Each question has a 30-second time limit. Discontinuation of presented items takes place after 3 successive scores of 0 (Wechsler, 2008a). The instructor is responsible for making sure the participant's responses match the correct response listed in the manual. For each correct response the participant receives 1 point; no point is given if the participant responds with the incorrect answer, states he/she does not know the answer, or does not respond within 30 seconds. Correct answers consist of numerically correct responses, even if the unit is not provided. The maximum total raw score is 22 points (Wechsler, 2008a).

For digit span, the raw scores from the forward, backward, and sequencing total are added together (maximum total raw score = 48 points), and then converted to a scaled score. The arithmetic raw score is equal to the number of correct responses on the subtest (maximum total raw score = 22) and then converted to a scaled score. Then the two scaled scores are added together to create the sum of scaled scores for working memory, which is then converted to the composite score based on the norms of equivalent composite scores (Wechsler, 2008a).

According to the *WAIS-IV: Technical and Interpretive Manual*, the Digit Span and Arithmetic subtests show strong internal consistency reliability (Wechsler, 2008b). Reliability coefficients for the Digit Span subtest for subjects aged 18-29 years old range from .91-.94, with a composite mean of all ages of .94. The internal consistency reliability of the Arithmetic subtest is reported to range from .84-.89, with a composite mean of all ages of .89 (Wechsler, 2008b).

The Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV) was also utilized to compile an index score that represented the individual's intellectual capabilities in processing speed. The processing speed index complies the individual's intellectual capabilities in processing speed by using the Symbol Search and Coding portion of the WAIS-IV. For the Symbol Search portion there is a time limit; during this time the test taker examines a search group and has to determine whether the symbols in the group match. After 120 seconds, discontinuation occurs. Each item of the test has two symbols and a search group that is comprised of five symbols. When scoring the Symbol Search portion of the test, the test giver has to record the amount of time it takes the test taker to complete the test; the maximum amount of time that will be given is 120 seconds. The Symbol Search Scoring Key is used to score the participant's responses. If the response of the participant appears in bold on the scoring key then the answer is correct; any other response should be counted as incorrect. If the participant skips or does not reach a question, then that question should will not be counted as correct or incorrect towards their total score. Correct answers will be recorded in the space labeled “C” on the bottom of page 2, and all incorrect answers will be recorded on the space labeled “I” on the same page. After scoring page 2, search group symbols for page 3 are to be used with the keys aligning properly. The number of correct and incorrect scores are then recorded in the spaces labeled “C,” for correct, and “I,” for incorrect at the bottom of page 3. Then the same will be done for pages 4, 5, 6, and 7. Then the total number of correct and incorrect responses will be summed on all pages of the answer key and transferred to the Record Form. The raw score is the number of correct answers minus the number of incorrect answers. Test administrators are instructed to mark the total score as 0 if the total score is 0 or less than 0 (Wechsler, 2008a). Subjects will also be given a key to copy symbols that are partnered with different numbers in a designated time limit. After 120 seconds, discontinuation occurs again. To score the coding portion of the subtest, the test administrator records the amount of time it takes the participant to complete the test. To score the coding portion, the test administrator will use the Coding Scoring Template and compare it to the participant’s scores. To count a participant’s answer as correct, the answer has to be drawn correctly, or it can be drawn incorrectly but easily identified as the symbol. One point will be given to the participant if he or she draws the symbol correctly within the given time limit, or if he or she realizes a mistake has been made and draws the correct symbol on top of or next to the originally drawn symbol. Any items on the test that are skipped are not counted in the score and are counted as a raw score of 0. The final score of the participant is the number of symbols that are drawn correctly within the given 120 seconds or less (Wechsler, 2008a).

For symbol search, the raw score is calculated by subtracting the number of incorrect responses from the number of correct responses (maximum total raw score = 60), and then translated to a scaled score. The coding raw score is equal to the number of correct responses (maximum total raw score = 135) and then translated to a scaled score. Then the two scaled scores are added together to create the sum of scaled scores for processing speed, which is then converted to the composite scores based on the norms of equivalent composite scores. (Wechsler, 2008a).

According to the *WAIS-IV: Technical and Interpretive Manual*, Symbol Search and Coding reliability is shown through the internal consistency composite scores (Wechsler, 2008b). The Symbol Search portion of the test for ages 18-29 has an overall reliability coefficient of .81 and a composite mean of .81 for all age groups. Coding reliability coefficient is .85 with a composite mean of .86 for all ages (Wechsler, 2008b). Wechsler (2008b), with the support of Benson, Hulac, and Kranzler (2010), shows an average internal consistency reliability of .90 for the Processing Speed Index.

Overall, the WAIS-IV "features a normative sample of 2,200 adults and was stratified by age, gender, education level, ethnicity, and region to provide the highest reliability of results" (Pearson, 2008, para. 4). The WAIS-IV provides evidence of both exploratory and confirmatory factor analysis for each different age subgroup (Canivez & Watkins, 2010; Wechsler, 2008b). Results from previous studies suggest supporting evidence of construct validity as well as this study's results supporting the idea that the WAIS-IV measures identical constructs across all age groups (Benson et al., 2010; Bodin, Pardini, Burns, & Stevens, 2009; Keith, Fine, Taub, Reynolds, & Kranzler, 2006).

Conners Continuous Performance Test, 2nd Edition (CCPT-II)

Sustained attention, as well as the subject's inattentiveness, impulsivity, and vigilance are measured by using the Conners Continuous Performance Test, 2nd Edition (CPT-II). The Conners CPT is "a task-oriented computerized assessment of attention-related problems in individuals aged 8 years and older" (Conners, 2015, "Description," para. 1). First administration of a short practice test is given to each participant. During the 14-minute administration, participants are required to push the spacebar when any letter except "X" appeared (Conners, 2015). The CPT-2 is scored using the computerized software. Sustained attention is the ability to keep focus as the task continues. A drop in sustained attention can usually be caught by a decrease in the participant's Hit Reaction Time (HRT) as well as a growth in their Omissions, failure to respond to non-X's, and Commissions, an unwanted response to the X's. The HRT Block Change is the degree of change that takes place in the HRT throughout all six portions of the test. A positive degree of change indicates a slower reaction time as the test progresses. A negative change shows a faster rate of reaction time. When the test-taker has a higher HRT Block Change score, then they have a decrease in their reaction time which translates to a decrease in efficiency of their information processing and loss of focus (Multi-Health System, Inc., 2014). There are 6 blocks that contain 20 trials in which the stimuli (i.e. non-X's) are presented at either 1, 2, or 4 second intervals. It should be noted that guidelines in the CPT-II manual point toward administering the CPT twice before analysis of the report, for establishing baseline purposes (Conners, 2000). For this study in particular, this guideline was not followed due to this being neither an assessment nor a treatment of ADHD.

The Conners CPT-II scales of inattentiveness, impulsivity, sustained attention, and vigilance have all been calculated for both normative and clinical sample populations. Conners CPT normative sample population contains 1,400 persons and is arranged by either gender, race, geographical region, or parental education level (Conners, 2015).

Across all scores, split-half reliability estimates a range from 0.66 to 0.95. The CPT-II has also suggested a good level of test-retest reliability with the inclusion of the d' and Beta measurements (Conners, 2000; Homack & Riccio, 2006). Llorente and colleagues (2001) then demonstrated a rather strong internal consistency and reinforced the intra-individual test-retest reliability. Both discriminative validity and incremental validity were assessed and found to differentiate between groups and to show positive correlations with other measures of similar constructs (McGee, Clark, & Symons, 2000). Substantial differences were found when the ADHD sample was compared to the general population on many measures that had a small or moderate effect size (Conners, 2000). One important aspect of the Conners CPT is that it provides a validity check based off of the number of errors that are committed. The Conners CPT-II also gives a self-diagnostic check with regard to the accuracy of the time for test administration. If the Conners CPT-II finds an inadequate number of hits (correct responses), or if the number of omission errors is above 25%, then a note is given about the errors and re-administration is then recommended.

Stroop Color and Word Test (STROOP)

Selective attention was assessed by using the Stroop Color and Word Test (STROOP) (Wass, Scerif, & Johnson, 2012). The Stroop procedure is designed so that individuals who have brain damage could be distinguished from individuals without brain damage. The test procedure requires only 5 minutes, and has been normed for individuals from 15 to 90 years of age. The test was designed to assess cognitive processing while also providing diagnostic information on factors such as brain “dysfunction, cognition, and psychopathology” (Golden, 2015, "Description," para. 1). The Stroop Color and Word Test is based on the concept that participants read words faster than they are able to recognize and name colors (Golden, 2015).

The latest version of the STROOP consists of three 8.5x11 pages. The first page randomly places the word red, green, or blue 100 times in black ink. The participant is asked to read down the column as quickly as possible the words printed. The second page also has 100 marks of XXXX on the page, but this time the XXXX is printed in either the color red, green, or blue. The participant is then asked to name the color in which the XXXX is printed. Lastly, the third page consists of 100 randomly placed words red, green, and blue, but the color of the text does not match the word itself; that is, the word green is printed in either the color red or blue and so on. The participant is then asked to name the color rather than the actual word printed on that page. Participants are given 45 seconds per page to get as many as they can correct. The score consists of the number of correct answers they can provide to the instructor within the time limit on each page. These scores are then converted into standardized *t*-scores using tables in the test manual (Berg, Franzen, & Wedding, 1987).

The Stroop procedure is reported to have strong reliability across different versions of the test. Test-retest reliability for periods ranging from 1 minute to 10 days is reported to be strong, with Jensen (1965) reporting test-retest reliability scores of .88, .79, and .71. Similarly, Golden (1975) reports reliability scores of .89, .84, and .73 ($N = 450$) in regards to the group version, and reliability scores of .86, .82, and .73 ($N = 30$) for individual. According to Strauss, Allen, Jorgensen, and Cramer (2005), “findings suggest that RTs for congruent and incongruent were highly reliable” (p. 334). The consistency of these reliability scores suggests that the Stroop is a reliable psychometric procedure across forms of use (Golden & Freshwater, 2002). Multiple studies suggest that performance on the Stroop can differentiate between samples of clinical and non-clinical populations, resulting in good discriminant validity as well (Golden, 1976; Guise, Thompson, Greve, Bianchini, & West, 2014; Lavoie & Charlebois, 1994).

Raven Progressive Matrices (RPM)

The Raven Progressive matrices (RPM) is used to measure the educative ability of an individual. Educative ability is the ability to develop high-level paradigms that make thinking about complex situations easier (Raven, Raven, & Court, 2000). Carpenter, Just, and Shell (1990) noted that the RPM serves as a test of analytical or diagnostic intelligence. RPM had the subject decipher a pattern of a missing piece from another pattern given to them. RPM is most commonly used as an intelligence test. Raven (2000) showed that the test focuses on two different cognitive processes: educative skill and reproductive skill. As mentioned before, educative skill is the ability to think clearly during complex situations and to be able to make sense out of chaotic dilemmas. Reproductive skill is the ability to remember and duplicate information that has been explained previously. The Raven Progressive Matrices involves 60 different items, each arranged by level of difficulty (Shute et al., 2015). The assessment does not require a time limit but generally takes about 40 minutes to an hour to complete. Each item consists of a pattern in which a piece is missing. The participant needs to select the missing piece from a range of 4 to 8 different inserts. After all the items have been completed, using the *Manual for Raven's Progressive Matrices and Vocabulary Scales*, the scoring key is used to identify correct responses (Raven, Court, & Raven, 1893). The sum of correct responses equals the raw score (maximum raw score = 60), and is then converted into percentiles. The higher the percentile, the less likely there will be a presence of dysfunction in a participant's fluid intelligence, and vice versa (Berg et al., 1987).

The estimated reliability for the Raven Progressive Matrices is .88 (n = 793), which is adequate internal reliability (Wechsler, 2007). Previous studies also reported adequate convergent (O'Leary, Rusch, and Guastello, 1991; Raven, Raven, & Court, 2000) and content validities (Carpenter, Just, and Shell, 1990). Another study (Gonzalez, Thomas, & Vanyukov, 2005) provided evidence of its criterion-related validity by showing a positive correlation with scores in decision-making tasks (Wechsler, 2007). Concurrent validity of the RPM has shown to have a moderate to strong correlation with other intelligence measures (WAIS) (Raven et al., 1983).

Enjoyment Survey

The enjoyment survey was created to allow participants to report on the degree to which they enjoyed playing their assigned game. They were asked to answer a single question on a scale of 1-10 (1 being the lowest, 10 being the highest) and were also asked to provide a short explanation for their rating.

Procedure

The study consisted of a three by two (training conditions [Lumosity, active control (bejeweled), passive control]; assessment time [pretest, immediate posttest]) experimental design. At the beginning of the pre-assessment phase, students were briefed about the requirements of the study and had the consent reviewed. No other information pertaining to the experiment was provided at this time. They were then asked to read and sign the informed consent form. The participants were randomly assigned into one of the conditions: experimental group, active control, or passive control. Each participant was scheduled to complete the pretest assessment, consisting of the battery of cognitive tests (RAVLT; WechWM; CPT-3; STROOP; WechPSI; RPM). Participants proceeded with prescribed instruction depending on which group they were randomly assigned to. The experimental group was asked to download the application *Lumosity* on their smart phone or to create an account using the computer interface. They then played Lumosity for the next 10 days for 30 minutes a day whenever they preferred. This amounted to 5 hours of "brain training" on Lumosity. The active control group was asked to download the application *Bejeweled Classic* on their smart phone and play for 30 minutes a day for 10 days whenever they preferred. This also amounted to 5 hours of playing a casual video game. To keep track of their game playing, participants were sent friendly automatic reminders via e-mail reminding them to play the application for 30 minutes if they had not already for the day. The passive control group was asked to take the pre-test and post-test when needed and no other contact was made. After the prescribed game playing, students took an immediate post-test consisting of the same battery of testing as the pre-test. At the end of the post-test battery of assessments, the experimental and active control group were asked to complete a self-report survey rating how much they enjoyed playing their game on a scale of 1-10 and to provide a short explanation for their rating.

Data Analysis

It is still unknown if younger adults that train using cognitive training games show comparable cognitive improvements when compared to children and older adults. Consistent with the claim that transfer of learning depends on the similarities between the learning and transfer tasks, I hypothesized that near transfer effects were more likely in tasks that share similar properties as the training game played. Thus, when individuals frequently train with games that share skills with outside behavioral tasks, the user will improve in that certain task. As a result, I hypothesized that the participants would not show far-transfer effects, meaning individuals would not improve on tasks that were not similar to the tasks they trained in the games. Therefore, I hypothesized that Lumosity's brain training program would not be able to show significant results for far transfer in regards to cognitive functions. The independent variables were the three groups (experimental, active control, and passive control), and the dependent variables were the measures in which were assessed (RAVLT, CPT-3, STROOP, WAIS IV [WMI and PSI], RPM). In order to test these variables, after measures had been taken, a multivariate analysis of variance (MANOVA) was computed to evaluate if there was an overall significance between measures taken at the pre-test to post-test; if so, separate analyses of variances (ANOVAs) were computed to identify specific areas in which differences occur.

CHAPTER III

RESULTS

Participants were recruited from the undergraduate psychology courses previously described and were randomly assigned to one of three conditions: experimental (Lumosity), active control (Bejeweled), and passive control (no game-playing assignment). To examine participants' performances on the cognitive tasks before and after playing their assigned game, a series of cognitive assessment measures were administered as pre- and post-experiment batteries. Before completing the second round of assessments, participants were requested to play either Lumosity or Bejeweled or play no assigned game for 10 consecutive days. Group means for each cognitive performance measure were compiled, and change scores for each instrument were computed by subtracting pretest from posttest scores.

As an initial analysis, paired *t*-tests were calculated to investigate differences between pre-assessment and post-assessment scores for all subjects (experimental groups collapsed). Statistically significant improvement was noted from pre-to post-assessment for the RAVLT, PSI, CPT number correct, and STROOP color mean scores. Similar differences were observed for the WMI, CPT detectability, STROOP word, and STROOP color word scores; however, the magnitude of these differences did not reach the level of statistical significance with observed probabilities of less than $p = .1$. Only the RAVEN and CPT response time measures showed no evidence of change across time for all subjects. Dependent *t*-test results are presented in Table 1.

Table 1

Post-Test Minus Pre-Test for All Subjects

	Observed Mean Difference	*t*	Sig. (2-tailed)
RAVLT2- RAVLT1	12.15	9.61	.00
WMI2-WMI1	3.04	2.05	.05
PSI2-PSI1	11.00	8.40	.00
CPTcorr2-CPTcorr1	3.50	3.23	.00
CPTHRT2-CPTHRT1	5.02	.78	.44
CPTd2-CPTd1	.17	1.99	.06
RAVEN2-RAVEN1	.04	.07	.94
STRword2-STRword1	4.92	1.96	.06
STRcolor2-STRcolor1	2.23	2.43	.02
STRcw2-STRcw1	2.35	1.79	.09

$n = 26$

Hypotheses

The first stated hypothesis proposed that near transfer effects would be more apparent in tasks sharing similar properties with the training game. As previously explained, for near transfer the measures utilized in this study included the RAVLT, CPT, WMI, PSI, and STROOP scores. Change scores for each instrument were computed by subtracting pretest from posttest scores. Mean comparison of group change scores was calculated by the use of a MANOVA, resulting in no significant findings of between-group differences across cognitive performance measures (Wilks' $\lambda = .38$, $F = .87$, $p =$

.62). Table 2 presents group means and one-way analysis data for each dependent measure. Visual inspection of change score group means suggests that the Lumosity group achieved greater improvement for RAVLT and STROOP than did both the Bejeweled and control groups. Due to concern over small experimental group sizes, power analyses were computed for change scores and resulting values ranged from .052 to .445, suggesting that detection of statistically significant differences between groups was unlikely to be observed.

The second stated hypothesis proposed that the Lumosity training program would not show significant evidence of far transfer effects in cognitive functions. As previously detailed, this hypothesis was assessed with performance on the Raven's Progressive Matrices test (RAVEN). Change scores for each instrument were computed by subtracting pretest from posttest scores. Mean comparison of group change scores was calculated by the use of an ANOVA, resulting in no significant findings ($F(2,26) = .20$, $p = .82$). Observed power for this analysis was .077, again suggesting that detection of statistical significant differences between groups was unlikely. These results are also presented in Table 2.

Table 2

Post-Test –Pre-Test Group Mean Comparisons

	Control	Bejeweled	Lumosity	*F*	Sig.
N	7	9	10		
RAVLTchange	10.00	10.78	14.90	1.57	.23
WMchange	3.57	1.11	4.40	.45	.64
PSIchange	14.43	10.67	8.90	1.49	.25
CPTcorrchange	4.29	4.67	1.90	.67	.52
CPTHRTchange	-10.45	22.64	.00	2.47	.11
CPTdchange	.18	.18	.15	.02	.98
RAVENchange	.43	.22	-.40	.20	.82
STRwordchange	5.14	-1.33	10.40	2.17	.14
STRcolorchange	.86	2.44	3.00	.43	.66
STRcwchange	4.43	.22	2.80	.81	.46

Additional Analyses

In order to explore additional factors potentially affecting participants' cognitive performance, several additional analyses were computed. First, participants' reports of compliance to daily training with the assigned game were compared. The Bejeweled group reported playing an average of 9.67 days, while the Lumosity group reported playing 8.75 days. This disparity was not statistically significantly different (t = 1.59, p = .13). Similarly, subjects' responses to the enjoyment survey question revealed no statistically significant group mean difference (Bejeweled mean: 7.33, Lumosity mean:

7.60; *t* = -.48, *p* = .63). Change scores were also compared across subject gender (18 female, 8 male participants). No significant differences were observed for the majority of cognitive measures. Statistically significant difference in change scores was observed for the CPT on the Hit-Rate Response Time score (*t* = 3.06, *p* = .005), where females showed improved performance (change score mean of 16.34) and males showed a decrease in performance (change score mean of -20.43). These results are presented in Table 3.

Table 3

Group Statistics

	Gender	*N*	Mean	*T*	Sig. (2-tailed)
RAVLTchange	Female	18	11.72	-.50	.62
	Male	8	13.13		
WMIchange	Female	18	2.39	-.65	.52
	Male	8	4.50		
PSIchange	Female	18	10.78	-.25	.80
	Male	8	11.50		
CPTcorrchange	Female	18	3.94	.61	.55
	Male	8	2.50		
CPTHRTchange	Female	18	16.34	3.06	.01
	Male	8	-20.43		
CPTdchange	Female	18	.25	1.45	.16
	Male	8	-.01		
RAVENchange	Female	18	-.06	-.25	.80
	Male	8	.25		
STRwordchange	Female	18	5.11	.11	.91
	Male	8	4.50		
STRcolorchange	Female	18	3.00	1.27	.22
	Male	8	.50		
STRcwchange	Female	18	2.61	.298	.77
	Male	8	1.75		

Finally, correlations were computed to investigate the possibility that participants' age might be significantly related to change in cognitive performance. Only the Raven Progressive Matrices measure was found to be statistically, significantly related to self-reported age (r = -.426, p = .03, n = 26).

CHAPTER IV

DISCUSSION

Importance of Question

The idea of cognitive training games being able to improve and support transfer effects is an important and promising idea because of the new technologies that are constantly being released in our society today. Imagine what the possibilities would be if everyone with a smart phone, tablet, computer, or multiple other devices could be able to constantly train and enhance their ability on the fly. These programs could be used for adults to use during their down time in a productive manner; children with ADHD could train to improve their symptoms and their situation; and older adults could use the programs to slow down the effects of Alzheimer's, dementia, and other cognitive disabilities that are constantly troubling their age group. For example, traditional treatment may not always be available to children with ADHD due to issues with money, timing, or various other reasons. However, if the technology and effective programing existed, the child would be able to work at home, or at school, on their own time and on their own schedule. Technology such as this may also be able to find its way into the classroom and school systems to help children of young ages improve their scholastic abilities and better improve their capabilities moving forward. It would be possible to improve the potential to facilitate transfer of relevant materials in academic and educational settings if improving working memory and cognitive ability through the electronic training programs were found to be plausible. The introduction of a training program on electronic devices that are so easily accessible to everyone can be very enticing, and could make a difference to many people in many different situations.

Just recently, with the rise in popularity of brain games, psychologists have begun looking at determining whether or not brain games produced by major companies will benefit and improve users' day-to-day cognitive function. Most of the studies reviewed that psychologists have done on this topic involve younger school-aged children whose brains are still in the early stages of development or older adults whose brains have begun to deteriorate. Due to these findings, it is easy to see why bringing cognitive training into the classroom, or making it readily available to children with tablets and computers, would be extremely beneficial for children of this generation and future generations. Psychologists have also found that it is best to administer training when the cognitive development is declining and when the brain is more malleable. This supports the idea of introducing cognitive training and technology to older adults who have begun to suffer from symptoms of Alzheimer's and dementia. Because cognitive training is more effective when the brain is in this state, it is possible that cognitive training in older adults could help delay the onset of these illnesses and could even keep them in a better, happier state of mind than if they were not introduced to cognitive training. Similar to schools, it would be an easier, and most likely less expensive, way for assisted living centers and rehabilitation centers to provide training to older adults so that they can live more satisfying lives for a longer period of time.

Research Foundation

The rationale for working memory training is simple; if cognitive abilities are limited by an individual's working memory capacity, then training and increasing working memory capacity with a game or program should improve these abilities. That is why psychologists are studying whether or not these brain games are effective. Owen and colleagues (2010) found that brain training led to improvements in individuals when tasks were targeted in the training program. However, cognitive tasks that were not targeted in the training program did not show any transfer effects (Owen et al., 2010). This can prove to be problematic because some training measures lack tasks for certain cognitive abilities.

When examining training programs and cognitive abilities, Melby-Lervåg and Hulme (2013) concluded that the training programs are not based on any clear process. Melby-Lervåg and Hulme (2013) also stated that the training games treat working memory as a simplistic idea and try to train working memory like a muscle, something that can be strengthened by working out (Chein & Morrison, 2010; Schmiedek et al., 2010; Thorell et al., 2009). Although Melby-Lervåg and Hulme (2013) stated this about training programs, other psychologists have been more successful in finding positive results with training programs. Multiple studies observed near transfer occurring because of cognitive training programs in areas such as working memory, executive functioning, attention control, fluid reasoning, and task switching (Basak et al., 2008; Borella et al., 2010; Chooi & Thompson, 2012; Holmes et al., 2009; Holmes et al., 2010; Karbach & Kray, 2009; Kesler et al., 2013; Mackey et al., 2011; Rueda et al., 2005; Schmiedek et al., 2010; St. Clair-Thompson et al., 2010; Thorell et al., 2009). Other studies have also shown far transfer occurring and evidence of far transfer effects as a result of cognitive training programs (Buschkuel et al., 2008; Dahlin et al., 2008a; Dahlin et al., 2008b; Li et al., 2008; Mahnacke et al., 2006; Richmond et al., 2011; Schmiedek et al., 2010). One major study included 1,300 students who trained over 9 hours with Lumosity and showed improvements in a variety of cognitive assessments when compared to students on a traditional academic schedule (Lumosity, 2013d). However, another study done by Shulte and colleagues (2015) did not observe any significant improvements from pre-test to post-test for subjects that trained with Lumosity. These results are discouraging because they did not show apparent generalization benefits when using the program. Another problem that was highlighted by the study is a common concern for many psychologists; it is easy for companies to demonstrate significant improvements on certain tasks without evidence of conversion of these improvements to everyday tasks (George & Whitehouse, 2011; Owen et al., 2010; Papp et al., 2009; Zickefoose et al., 2013). This means that companies can show evidence that users have improved their scores in games, but what is really important and what really needs to be shown is improvements in cognitive abilities and how the improvements in the training program transfers to improvements in day-to-day cognitive abilities and functions. All of these findings are important for psychologists so that they can determine what works and what does not work, or if any of it works at all. If the game seems like it is working because the user shows improvements in their scores in the game, what good is it if it does not improve their ability in their daily tasks?

Current Findings

The aim of this study was to determine to what degree cognitive training by means of multimedia "brain games" (i.e. Lumosity) could elicit a broader transfer effect in a younger adult population. Due to the extensive research done on younger children and adults in later stages of life, we focused on the young-adult population. The 26 participants were randomly assigned to either the experimental, active control, or passive control group, and partook in both a pre- and post-cognitive assessment that include the RAVLT, CPT-3, WMI and PSI from the WAIS-IV, STROOP, and RPM.

The hypothesis suggesting that near transfer effects will be more apparent in tasks that share similar properties with the training game Lumosity was found not to be consistent with results found. The MANOVA showed no significant differences between group change scores. Although non-significant, a trend in the direction of a possible increase in cognitive function was seen by the greater improvement in change score mean for the experiment group over the active and passive control for the RAVLT and STROOP.

The hypothesis suggesting that participants will fail to show statistically significant results for far-transfers effects to cognitive functions after playing Lumosity for a total of 5 hours of game play was confirmed. Through the use of the ANOVA, findings resulted in no significant differences.

Paired *t*-tests were calculated in order to compose an initial analysis regarding all 26 participants showing the differences between pre-assessment and post-assessment scores. These *t*-tests showed that there was a statistically significant improvement from pre-to post-assessment for the RAVLT, PSI, CPT corrections, and the STROOP color mean scores. In comparison, the WMI, CPT, STROOP word, and STROOP color word showed non-significant results.

As a matter of interest, we further analyzed other potential factors that may contribute to the findings, and found that there were significant differences in change scores of age and gender. In addition, the daily training compliance report and the enjoyment of training response report was also assessed. No significant difference was observed for either the report of compliance to daily training or the response of enjoyment for either the experimental or active control group. In contrast, a statistically significant difference was observed when looking at the CCPT score for the Hit Rate Response Time. Females showed improved performance change score compared to the males who showed a decrease change score, implying that on the CPT males may show a degree inattention or impulsivity with repeated administration, as seen by their increase in commissions. Lastly, only the Raven Progressive Matrices measure a showed statistically significant relation to age.

Limitations

The fact that Lumosity group did not show statistically significant (greater) change on assessment measures may be due to multiple factors. One idea behind this is that the games in Lumosity might not transfer to cognitive abilities, but instead train the user in tasks inside the game. The fact that Lumosity gives the user a score for a particular task in the game after playing can be misleading. For instance, after a user plays a task for the first time they may receive a score of 500, after playing the game three more times their score may increase to 700; this can be misleading and make the user think that they are improving their cognitive abilities, whereas they might truly be only increasing their capabilities of playing that certain task in the game. It may also be a factor that the users in this study used the free trial version of Lumosity rather than the paid, subscribed version of the brain game. The paid version of Lumosity contains more games and content compared to the free trial version; this may lead to a smaller variety of games that the user will train with and a smaller number of cognitive abilities the user trains.

In contrast to our hypothesis, the results showing no significant interaction with improving post-assessment after playing Bejeweled may be due to the lack of increase in the number of objects shown on the screen at a period of time. Although, the farther the participant progresses, the time pressure increased, the objects (i.e. jewels) remained in the same position unless moved due to the participant's decision. This prevents game players from using flexible strategies that could result in general improvement in cognitive functions. Both of these can be possible explanations leading to the lack of increase in participants' working memory capacity.

The findings of this study can be applied to understand better ways of conducting research and to find different subjects to research. As mentioned before, it seemed as if Bejeweled did not result in any significant differences when comparing the pre-test to the post-test. However, if the hypothesis is true and that this is caused by a lack of flexible strategies, then future researchers should acknowledge the idea that faster paced and more strategic games should be used when studying the effects of video games on cognition.

Due to the lack of time and limited resources, this study potentially may not have provided enough time to induce cognitive training, providing more supporting evidence that suggests there is still room for improvement in training methodologies. It is also suggested to avoid short time frames of training, small study groups, and an honor system based playing schedule. It is possible that the findings may be inadequate due to the fact that the subjects only played their game for a matter of 10 days or less. We were unable to find any significant research that stated how long a game or program must be played to show significant increases in cognitive abilities or signs of transfer; therefore it may be necessary for future research to have their subjects play the games for longer periods of time.

Also, the subject experimental group conditions were fairly small. This led to a smaller set of data, fewer people playing the game, and less information to utilize when comparing results. It would be ideal to have a larger group of subjects as long as it can be well controlled and maintained. And finally, having the users play their game on an honor system based schedule may lead to faults in the study. It would be easy for subjects to come into the study thinking that all they will have to do is take the pre-test and the post-test without even having to download the game. Future studies should find a way to be able to observe the subjects playing the game for the allotted amount of time required by them every day. If any number of the subjects chose not to play their game for the entire duration that was required, then data would be misleading. However, finding a way for researchers to observe every subject daily playing their game for the assigned 30 minutes was not feasible in this project.

Other confounding factors that may have played a role in the study's outcomes include the participants' busy college schedules and lack of motivation and challenges produced by said games, and a possible expectancy effect formed by the participant to expect gains just by playing. On the other hand, this study did not take into account participant's video game usage before or during the pre-and post-assessment periods. These effects of high gaming experience or expertise may have influenced the cognitive control of the participant already.

In hindsight, there were limitations that may have reduced the internal validity of the study. As previously stated, due to limitations of availability and scheduling, the subjects trained with their required game for only 10 days. It is not known yet how long it takes for lasting transfer of cognitive abilities to take place, therefore the small amount of time of training may have resulted in poor statistical evidence between the pre-test and post-test. Limited availability and scheduling conflicts also resulted in what can potentially be seen as too short of a period of time between the pre-test and the post-test. It would be ideal to have a larger amount of time between the pre-test and post-test and also to have a delayed post-test several months after the study was complete. Including the delayed post-test would also give insight into whether or not transfer of abilities stayed with individuals over time resulting in an increase in long-term memory.

The testing groups were also fairly small. There were originally 10 people in the passive control group, the active control group, and the experimental group. It would be beneficial to the study to have more subjects in each group in order to offer a better wealth of data to compile results and identify different trends in the data. Another limitation to the pre-test and post-test is the fact that not every subject had the same administrator of tests when they went in for their assessments. The administrator varied based on availability and did not always coincide with the original schedule or the test taker. This can be an issue of standardization and affect the mindset of the subject taking the test.

The lack of a screening for neurocognitive disorders or learning disabilities is another limitation that should be noted. This is an important factor because if participants have either a neurocognitive disorder or a learning disability then training and assessment scores could be affected without our knowledge of why. This could also potentially be a factor that inhibits the participant from completing the study at an equal standard as the other participants. Finally, as mentioned before, the Lumosity and Bejeweled games that were played by the users were the free trial versions of the applications. The free trial versions of the applications do not provide as many options as the paid versions do. For Lumosity, the free trial version does not include as many games as the paid version and does not offer the online tracking that the paid version does. The difference in the paid Bejeweled application and the free trial application is the number of levels that are offered in the game. This does not seem to be as much of a limitation with Bejeweled in this situation because of the short amount of time the game was played; however it may be more of a limitation in a longer study.

Implications for Future Research

Much work still remains to be seen on the controversial topic of whether training games can lead to improvement in cognitive tasks, and which task will lead to generalizable benefits for fundamental aspects of an individual's cognition. It is important that companies continue to improve upon the already existing games as well as increase the number of games, which could lead to improved cognitive abilities and control and allow for individuals to choose their preferred style of play. The results of this study have led us to believe that more time and materials should be invested into researching the actual cognitive training behind the games and less time on the effects that the games have on people. A wide range of results with varying findings in regards to whether or not "brain games" work has been reported to date. We believe that the focus should not only be on what parts of the cognitive training exercises are most effective and what parts are the least effective but also on how training exercises and brain games can lead to transfer effects so that psychologists and programmers can create the most effective brain game or training program for the benefit of society. No matter how many studies are done trying to decide whether or not brain games are effective, their impact will be limited if we do not know if the actual cognitive exercises in them are effective or not. Understanding the actual exercises and tasks that are in the programs, and how these tasks programs work, will lead us to developing the best possible software and programs for cognitive abilities, near transfer effects, and far transfer effects.

In closing, our results combined with previous findings reported earlier evidence little support for the claim that brain games demonstrably increase cognitive abilities. These results also show that various types of games may affect cognitive skills differently. If so, there may be other benefits as varying video games could be selected based upon what cognitive skill needs to be improved (Oei & Patterson, 2013). Training programs should not be discouraged by the results of this study, but these findings should be used as a challenge to further additional and more sophisticated research. Further investigations should look into examining a more detailed training regime that ensures both near and far transfer, and the actual tasks that are being used in the brain games should be specified in order to determine which attributes of the games are most effective in training and transfer. The more studies that are done on cognitive training and transfer the more findings will hopefully lead to concrete evidence and methods that will improve individuals' cognitive abilities and positive findings of transfer effects. The possibilities that can manifest if these findings are positive are abundant and could result in many beneficial outcomes such as; cognitive training in the educational settings, delay of Alzheimer's in older adults, and possibly even the increase of cognitive abilities and transfer effects in young adults. Desse (1958) described it best when he said “that there is no more important topic in the whole psychology of learning than transfer” (p. 213).

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APPENDIX A

IRB APPROVAL LETTER

ABILENE CHRISTIAN UNIVERSITY

Educating Students for Christian Service and Leadership Throughout the World

Office of Research and Sponsored Programs
320 Hardin Administration Building, ACU Box 29103, Abilene, Texas 79699-9103
325-674-2885

2/26/2016

Alison McGinnis
Department of Psychology
ACU Box 28011
Abilene Christian University

Dear **Ms. McGinnis:**

On behalf of the Institutional Review Board, I am pleased to inform you that your project titled **The Near and Far Transfer Effects of Multimedia Cognitive Training**

was approved by expedited review (46.110(b)(1) category **7**) on **2/22/2016** for a period of **one year** (IRB # **16-003**). The expiration date for this study is **2/22/2017** . If you intend to continue the study beyond this date, please submit the Continuing Review Form at least 30 days, but no more than 45 days, prior to the expiration date. Upon completion of this study, please submit the Inactivation Request Form within 30 days of study completion.

If you wish to make **any** changes to this study, including but not limited to changes in study personnel, number of participants recruited, changes to the consent form or process, and/or changes in overall methodology, please complete the Study Amendment Request Form.

If any problems develop with the study, including any unanticipated events that may change the risk profile of your study or if there were any unapproved changes in your protocol, please inform the Office of Research and Sponsored Programs and the IRB promptly using the Unanticipated Events/Noncompliance Form.

I wish you well with your work.

Sincerely,

Megan Roth

Megan Roth, Ph.D.
Director of Research and Sponsored Programs

Our Promise: ACU is a vibrant, innovative, Christ-centered community that engages students in authentic spiritual and intellectual growth, equipping them to make a real difference in the world.

APPENDIX B

ENJOYMENT SURVEY

Please indicate and rate the enjoyment you experienced while playing your game by circling a number on the scale below (1 being the lowest, did not enjoying playing required game, 10 being the highest, very much enjoyed playing required game).

1	2	3	4	5	6	7	8	9	10
Did not enjoy at all				It was ok					Very much enjoyed

Why is this your answer? Please briefly explain below.

How many days played: ___________ out of 10.

APPENDIX C

INFORMED CONSENT

Title of Study: The Near and Far Transfer Effects of Multimedia Cognitive Training

You are invited to take part in a research study. This form provides important information about the study, including the risks and benefits to you, as a potential participant. Please read this information carefully and ask any questions that you may have regarding the procedures, your involvement, and any risks or benefits you may experience. You may also wish to discuss your participation with other people, such as your family doctor or a family member.
Please let the researchers know if you are currently participating in any other research studies.

Also, please note that your participation is entirely voluntary. You may decline to participate or withdraw from the study at any time or for any reason without penalty or loss of benefits to which you are otherwise entitled.

Please contact the Principal Investigator if you have any questions or concerns regarding this study, or if you wish to withdraw from this study at a later time. Contact information for the Principal Investigator is provided at the end of this form.

Purpose and Procedures

Purpose of the Research: The purpose of this study is to examine the relationship among a number of cognitive abilities, including memory, problem-solving, and information transfer. Information obtained in this study will help researchers and clinicians to better understand the processes underlying cognitive performance in the relationship between exposure and improved cognitive performance. This study has been specifically designed to examine these effects among young adult participants, as these individuals have not been heavily utilized previously in research focusing on these issues.

Expected Duration of participation: Participation will involve completion of two cognitive testing sessions with research assistants. These will be scheduled approximately three weeks apart and will each require 90-120 minutes of your time. Some participants will also be asked to engage in brief cognitive training exercises in between assessment sessions.

Description of the procedure: After agreeing to participate in this study, you will be randomly assigned to a study group. All participants will complete an initial cognitive assessment battery that includes computerized, oral, and handwritten portions. This is expected to require 90-120 minutes to complete. Secondly, depending on the study group to which you are assigned, you may be asked to download a free smart phone cognitive-training application and use it for 30 minutes a day for 10 days. Finally, at the end of the study all participants will again complete the cognitive assessment battery, including computerized, oral, and handwritten portions. The assessment batteries will consist of commonly used psychological testing procedures. The cognitive training applications are widely available free of charge.

No experimental procedures are being used utilized in this study. You may withdraw your participation at any point during the study. Researchers deserve the right to terminate your participation if they believe it is no longer in your best interest to continue in the study or if you fail to generally follow the instructions provided. Your participation may also end if the study is terminated early for any reason. In the event of termination, you will be contacted by the primary investigators and provided specific information regarding the status of the study and your participation.

Risks and Discomforts

There are risks to taking part in any research study. Below is a list of the foreseeable risks, including the seriousness of those risks and how likely they are to occur:

No specific risks or substantial discomfort are anticipated on the basis of participating in the study. It is possible that you may experience mild degree of frustration, as completing cognitive assessment procedures can be frustrating, primarily since these tests are designed to assess an individual's maximum ability to remember, process information, and apply knowledge. Thus, it is unlikely that participants will correctly answer all testing items.

The two assessment sessions will each require a commitment of up to two hours. The daily training sessions will require no more than 30 minutes per day. It is possible that involvement in the study may minimally challenge time normally spent in academic preparation. More likely, participation in the study will require planning and some possible reallocation of your study time.

No physical, social, legal, or economic risks anticipated from as a result of your participation in this study. In designing this study, the principal investigators have taken steps to minimize the risks associated with your participation. However, if you experience any problems you may contact either of the principal investigators, Alison McGinnis or Dr. Scott Perkins.

Potential Benefits

The researchers and ACU have no plan to pay for any injuries or difficulties experienced as a result of participating in the study. Counseling services for study participants are available through the ACU Psychology Clinic.

There are potential benefits to participating in this study. Such benefits may include receiving partial course credit, learning about areas of psychology, and obtaining exposure to possible careers of interest. The researchers cannot guarantee that you will experience any personal benefit from participating in this study. However, it is anticipated that the information gained from this study will help others in similar situations in the future.

Provisions for Confidentiality

Information collected about you will be handled in a completely confidential manner in accordance with the law. Some identifiable data may be shared with individuals outside of the study team, such as members of the ACU Institutional Review Board. Aside from these required disclosures, your confidentiality will be protected and your identity removed from data related to your performance. This will be achieved by participants being assigned a coded subject number and all permanent data recorded without any personally identifying information.

Compensation

Course-specific extra credit will be awarded to participants in this study. At the discretion of individual instructors alternative routes to obtaining equivalent course-specific extra credit will be made available to non-participants. Independent research activity will involve work in primary research journals on an instructor approved topic of the student choosing, requiring equivalent time commitments.

Contacts

You may ask any questions that you have at this time. However, if you have additional questions, concerns, or complaints in the future, you may contact the Principal Investigators of this study. The Principal Investigators are Alison McGinnis, B.S. (contact at 254-723-6263 or amm14f@acu.edu) and Scott Perkins, Ph.D. (325-674-2280, perkinss@acu.edu).

If you have concerns about this study or general questions about your rights as a research participant, you may contact ACU's Chair of the Institutional Review Board and Director of the Office of Research and Sponsored Programs, Megan Roth, Ph.D. Dr. Roth may be reached at

(325) 674-2885
megan.roth@acu.edu
320 Hardin Administration Bldg, ACU Box 29103
Abilene, TX 79699

Consent Signature Section

Please sign this form if you voluntarily agree to participate in this study. Sign only after you have read all of the information provided and your questions have been answered to your satisfaction. You should receive a copy of this signed consent form. You do not waive any legal rights by signing this form.

___________________________	___________________________	___________
Printed Name of Participant	Signature of Participant	Date
___________________________	___________________________	______________
Printed Name of Person Obtaining Consent	Signature of Person Obtaining Consent	Date