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Computer-Based Cognitive Training for Age-Related Cognitive Decline and Mild Cognitive Impairment

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COMPUTER-BASED COGNITIVE TRAINING FOR AGE-RELATED COGNITIVE DECLINE AND MILD COGNITIVE IMPAIRMENT

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Abstract

Cognitive Training has been shown to be an effective tool in enhancing cognitive functioning. Research has also shown video game playing can improve certain aspects of visual attention and cognitive processing speed. The purpose of this study was to evaluate the effectiveness of both a specific computer-based cognitive training program and non-specific video game playing in improving cognitive functioning for individuals with age-related cognitive decline and mild cognitive impairment. Twenty-nine older adults were recruited into the study and randomly assigned to either the cognitive training group or video-game playing group. Nineteen participants completed the study, engaging in either cognitive training or video game playing for 10-15 minutes a day, 4 days per week, for eight weeks. Multiple measures of neuropsychological functioning were administered both before and after training. The results showed no significant improvements in the cognitive training group, while the video game playing group improved on measures of auditory memory and processing speed. No significant differences were found between the two groups on any of the dependent variables. The electronic version of this dissertation is available free at Ohiolink ETD Center, www.ohiolink.edu/etd".

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Chapter I: Introduction

In the next 50 years, the proportion of older adults to the population as a whole will more than double, increasing from 7% in 2000 to 16% in 2050 (Cohen, 2003). Researchers point to the dramatic increase in Alzheimer's disease as the cause of death in older adults as evidence that neurocognitive decline is the biggest threat to successful aging in our society (Park & Reuter-Lorenz, 2009). Alzheimer's disease (AD), the most common etiology for dementia, is expected to quadruple from a 2006 global prevalence rate of 26.6 million to over 100 million individuals by 2050. In the United States, an estimated 5.3 million Americans have AD. Every 70 seconds, someone in America develops AD. This number is expected to decrease to every 33 seconds by 2050, and the prevalence rate in the US is estimated to grow to between 11 and 16 million people ("2009 Alzheimer's disease facts and figures," 2009). The direct (health care costs) and indirect (e.g., lost work productivity) costs of this dramatic shift are estimated at $148 billion annually. The tally of direct and indirect costs fail to include an additional $94 billion in unpaid services provided annually by caregivers ("2009 Alzheimer's disease facts and figures," 2009). Moreover, the numbers do not speak to the profound emotional toll exacted on individuals, their families and friends, and society as a whole when active lives and minds are lost to Alzheimer's disease.

For reasons both economic and intangible, identifying ways to combat neurocognitive frailty and delay or prevent the onset of cognitive decline and AD is well worth pursuing.

Chapter II: Literature Review

In order to provide the framework on which the current study is based, the following literature review is presented. The reason for the study rests on the idea that people experience decline in cognitive functioning as they age. While most often this decline is not pathological in nature and is simply a normal part of the aging process, a significant number of older adults experience a neurodegenerative process which impacts cognitive functioning to a much greater degree than expected in normal aging and can have significant repercussions on both those individual adults' health and quality of life as well as present significant financial costs in health care. As our population ages, effective treatments which halt this cognitive decline and regain some cognitive functioning, both in normal aging and more severe neurodegenerative processes, is therefore, imperative. The different interventions currently used to effective such change is discussed with particular attention to cognitive training and, more specifically, computer-based cognitive training which is the basis for this study.

Cognitive Decline

Age-Related cognitive decline. Cognitive decline is generally considered a normal part of aging. While the age of onset can vary dramatically, most adults experience age related cognitive decline (ARCD) which can negatively affect their quality of life (Mahncke et al., 2006). Still, debate exists as to what ARCD actually is, or what the underlying process is. While many older adults experience ARCD, a large number of individuals do not experience cognitive decline (Greenwood & Parasuraman, 2010). In addition, cognitive decline does not occur uniformly, with some research suggesting that cognitive processing speed declines more significantly than verbal abilities and domain knowledge (Finkel, Reynolds, McArdle, & Pedersen, 2005) and other studies concluding that memory impairment is more common (Bjørnebekk, Westlye, Walhovd, & Fjell, 2010). In contrast, Clay et al. (2009) posit that changes in memory and fluid intelligence are not significant after accounting for vision and processing speed declines. Mahncke et al. (2006) contend that, in addition to worsened sensory processing abilities, ARCD is the result of "a self-reinforcing downward spiral of degraded brain function" resulting from withdrawal from attention-demanding tasks and active learning, as well as physical deterioration in the brain itself (p. 12523).

Much debate also exists as to the extent to which ARCD affects functioning. While some maintain that ARCD does not compromise everyday functioning, other research suggests even slight changes in cognitive abilities can have a functional impact. For example, Tucker-Drob (2011) found that changes in neurocognitive performance "were strongly correlated with individual differences in changes in performance on… everyday tasks." (p. 368). Mahncke et al. (2006) wrote that ARCD "negatively impact[s] the quality of life, independence, frequency and quality of social interaction, and engagement in cognitively stimulating activities" (p. 12523). Moreover, these changes are related to increased risk for nursing home placement and negative health outcomes, including cardiovascular disease, dementia, and death(Clay et al., 2009; Morrison-Bogorad, Cahan, & Wagster, 2007; Smith et al., 2009; Tuokko, Garrett, McDowell, Silverberg, & Kristjansson, 2003). As Graham et al. (1997) noted patients with ARCD "were three times more likely to be living in institutions than were cognitively unimpaired patients" (p. 1793).

Neuroanatomy of ARCD. Neuroanatomical studies have thus far failed to definitively identify the underlying neurological correlates to the loss of cognitive functioning experienced in aging. Research has failed to consistently show a relationship between volumetric cortical loss and cognitive changes (Rodriguez &

Raz, 2004; Van Petten, 2004; Van Petten et al., 2004) There is also no significant neuron loss in old-age (Greenwood & Parasuraman, 2010). Synapse loss does occur, but only after age 65 or so (Greenwood & Parasuraman, 2010). Some research has shown cognitive aging is associated with losses in the grey and white matter in the medial-temporal, parietal, and frontal regions of the brain (Gordon et al., 2008); however, as Raz and Kennedy (2009) noted after an extensive review of the literature, "the search for the neuroanatomical basis of cognitive aging has so far yielded limited and somewhat contradictory results" (p. 59).

Mild Cognitive Impairment. It is important to distinguish between age-related cognitive decline which, as noted, is regarded as a normal part of the aging process, and more severe cognitive changes which may reflect a neurodegenerative process and have more profound impacts on one's health and functioning. During the end of the last century, much effort was expended in differentiating between normal, age-related cognitive decline and dementia by defining a transitional stage between the two. While as many as 11 distinct diagnoses were proposed, mild cognitive impairment (MCI) emerged as the most widely accepted term. In 1999 Peterson first proposed MCI as impairment in cognitive functioning exceeding what would be expected, but without severe declines in everyday functioning. Peterson outlined the criteria for diagnosing the condition which consisted of (1) subjective memory complaints, (2) the presence

of memory deficits on objective cognitive assessment, (3) normal general cognitive function, (4) intact activities of daily living, and (5) the absence of dementia (Petersen, et al., 1999). While originally the disorder focused on memory loss as the defining feature (single-domain, amnestic MCI), MCI has been further broken down into other subtypes, including (1) multi-domain, amnestic MCI, (2) single-domain, non-amnestic MCI, and (3) multi-domain, non-amnestic MCI (Peterson, 2004). Typically, 1.5 standard deviations below the mean on neuropsychological measures is considered the standard cut-off point for establishing cognitive deficits (Petersen et al., 2001; Petersen, 2004).

Prevalence rates and risk factors. Prevalence rates for ARCD range from 7.5% to 19.3% (Di Carlo et al., 2000; Ritchie, Artero &Touchon, 2001). Estimates of prevalence in MCI range vary even more, from 5.3% to 34%, with amnestic MCI accounting for approximately half the cases (Di Carlo et al., 2000; Ganguli, 2011; Graham et al., 1997; Hänninen, Hallikainen, Tuomainen, Vanhanen, &Soininen, 2002; Lopez, 2003a; Manly, 2005; R. C. Petersen, 2004; Ritchie et al., 2001; Schröder et al., 1998). These widely variable estimates likely reflect the difference in the operationalization of the MCI diagnosis through the selection of instruments, determination of cut-off scores, inclusion/exclusion of MCI subtypes, and other methodological disparities. Research has identified

several risk factors for cognitive decline, including older age, African-American ethnicity, less than high school education, low literacy level, smoking, lack of physical exercise, malnutrition, depression, the presence of the apolipoprotein E e4 allele (ApoE 4), diabetes, hypertension, hyperlipidemia, and vascular disease (Barnes, Alexopoulos, Lopez, Williamson, &Yaffe, 2006; Bordet &Deplanque, 2009; Buchman, Wilson, Leurgans, Bennett, & Boyle, 2009; Di Carlo et al., 2000; Fiocco et al., 2009; Geda, 2010; Hong, Cheong, Oh, & Lee, 2009; Kivipelto et al., 2001; Lopez, 2003b; Pavlik, Doody, Massman, & Chan, 2006; Tervo et al., 2004; Wiederkehr, Laurin, Simard, Verreault, & Lindsay, 2009).

Conversion to Alzheimer's disease and effects. The estimates of yearly conversion rates from MCI to Alzheimer's Disease, the most common etiology of dementia, range from 10% to 28% (Bowen et al., 1997; Ronald C. Petersen et al., 1999; Schmidtke & Hermeneit, 2007; Tierney et al., 1996), while in one study, upwards of 80% of MCI patients developed dementia after 6 years (R. C. Petersen et al., 2001). Individuals diagnosed with multi-domain amnestic MCI and amnestic MCI are at the greatest risk for developing dementia.

In 2006, the worldwide prevalence of Alzheimer's Disease was 26.6 million. It is estimated that by the year 2050, that number will quadruple to over 100 million. Brookmeyer, Johnson, Ziegler-Graham, and Arrighi (2007) estimate

that approximately 43% of AD patients will require a high level of care, equivalent of that to a nursing home. Their research indicates that treatment programs that delay the onset of AD by an average of two years would decrease the worldwide prevalence rate by 22.8 million cases, saving billions of dollars. Not only Alzheimer's disease is associated with significant negative effects. Graham et al. (1997) found that individuals with ARCD were three times more likely to be living in an institutionalized setting than were cognitively intact individuals. Additionally, older individuals' worries about memory problems are common and are associated with depression and anxiety (Mol et al., 2007; Reese, Cherry, & Norris, 1999). Given the costs associated with cognitive decline, not just financial, but personal, emotional, and societal, finding effective methods of preventing the progression to MCI or AD or even recuperating lost cognitive abilities in healthy adults is clearly important. As Mowszowski, Batchelor, and Naismith (2010) point out, "with the rapidly aging population,...interventions aimed at decreasing the social and financial costs of declining cognitive function are irrefutably worth pursuing" (p. 537).

Treatments

Currently, research has explored several avenues for finding suitable methods for treating or preventing cognitive decline. These have included

changes in behavior, including diet, exercise, and engagement in cognitively stimulating activities, as well as pharmacological interventions. One way to reduce the risk of cognitive decline is, of course, to eliminate the risk factors associated with MCI and AD. For example, research has shown that cognitive decline is less likely once cardiovascular event risks are ameliorated through the treatment of hypertension, hypercholesterolemia, diabetes and implementation of weight reduction and smoking cessation programs. A review of the current treatment methods follows.

Exercise. The cognitive benefits of exercise are generally well accepted (Colcombe& Kramer, 2003; Gordon et al., 2008; Ratey & Loehr, 2011). Research indicates that even low levels of physical activity can improve cognitive function (Hayashi et al., 2009). Other research suggests that high intensity aerobic exercise is required to counteract atrophy in the medial temporal lobe and increase grey and white matter volume (Erickson et al., 2006; Head & Bugg, 2011). In a review of the relevant literature, Colcombe and Kramer (2003) found that "fitness training increased performance 0.5 [standard deviations] on average [on cognitive tests], regardless of the type of cognitive task, the training method, or participants' characteristics" (p. 128). For individuals already diagnosed with Alzheimer's disease, research suggests that physical activity does not slow the

rate of cognitive deterioration, but does, however, significantly reduce the mortality risk (Scarmeas, 2011).

Diet. In addition to exercise, a healthy diet has been associated with promoting cognitive health. Navqui et al. (2011) found that a diet high in mono-unsaturated fat was associated with a slower rate of cognitive decline in women. Research has shown that adhering to the Mediterranean diet (vegetable oils, fish, non-starchy vegetables, low glycemic index fruits, and moderate wine intake) is associated with a number of cognitive benefits, including slowed cognitive decline, reduced risk of conversion from MCI to AD, reduced overall risk of developing AD, and decreased all-cause mortality in AD patients" (Sofi, Abbate, Gensini, & Casini, 2010; Solfrizzi et al., 2011). Research has also found that the use of ascorbic acid combined with use of metabolic precursor to uric acid, like inosine or hypoxanthine could be helpful in maintain cognitive health (Waugh, 2008).

Pharmacological Interventions. Extensive research has been conducted to find pharmacological interventions to treat mild cognitive impairment and Alzheimer's disease, with mixed results. The most common class of drug studied for the treatment of AD has been Acetylcholinesterase inhibitors (AChEI). Based on the finding that cholinergic deficits in the cerebral cortex and basal forebrain

are associated with cognitive impairment in AD, AChEI chemicals were developed to inhibit the breakdown of acetylcholine, thus increasing both the level and duration of action of the acetylcholine neurotransmitter (McGleenon, Dynan, & Passmore, 1999). While research has shown modest effectiveness of AChEI in treating moderate to severe AD, several studies have been unable to find significant benefits in using the chemicals to treat MCI and mild AD (Allain, Bentué-Ferrer, & Akwa, 2007). Other studies have demonstrated the potential of these agents to slow the conversion rate from MCI to dementia, but only at the cost of increased "adverse effects," including vomiting and nausea, which resulted in significantly more people dropping out of the treatment groups as compared to placebo groups (Diniz et al., 2009; Sobów & Kłoszewska, 2007; Takeda et al., 2006). As Sobów & Kłoszewska (2007) wrote: "Because of the questionable efficacy: risk ratio, we believe that it is too early to recommend ChEI in MCI" (p. 11). Additionally, while the AChEI Galantamine has been shown to be efficacious at treating MCI and mild AD, it is not a recommended form of treatment as is been shown to increase death rates (Loy & Schneider, 2006; Sobów & Kłoszewska, 2007). Memantine has also been studied as a potential agent to treat AD; however, a meta-analysis reveals a lack of evidence to support its effectiveness in treating mild AD, and scant evidence for its benefit in moderate AD (Schneider, Dagerman, Higgins, & McShane, 2011). Moreover, no

pharmacological interventions exist for the treatment of non-pathological age-related cognitive decline.

Cognitive Intervention. In addition to changes in diet, adding an exercise program, and psychopharmacological intervention, research has shown cognitive interventions to be effective in staving off cognitive decline and regaining cognitive functioning already lost.

Cognitive remediation refers to "intervention strategies [used] to mediate deterioration" in cognitive functioning (Mowszowski et al., 2010). Often the terms "cognitive training", "cognitive rehabilitation" and "cognitive stimulation" are used interchangeably, masking important differences between the varied approaches. Clare & Woods (2004) sought to remedy the situation by utilizing a literature review to outline the differences in the three approaches. A summary of their suggested nomenclature follows.

Cognitive Stimulation. Cognitive stimulation and reality orientation approaches use group activities to enhance cognitive and social functioning. The approach does not employ the structured or directed tasks associated with a training or rehabilitation program (Clare & Woods, 2004). Instead, cognitive stimulation may involve activities such as listening to music, baking, or engaging in a discussion. This method has primarily been used for people who have already

progressed to a moderate degree of dementia, since research has shown global cognitive stimulation to be more effective for that population than programs that target specific cognitive functions. Spector et al. (2003) in one of the largest randomized controlled trials, found improvements in cognition and quality of life in patients with moderate dementia using this approach. However, as is the case with much of the research in this area, since the comparison group was a no-contact control group, it cannot be determined whether the benefits derive mainly, or at least partly, from the increased social interaction participation inherent in the intervention assigned to the stimulation group.

Cognitive rehabilitation and cognitive training. Cognitive rehabilitation is the "systematic use of instruction and structured experience to manipulate the functioning of cognitive systems to improve the quality or quantity of cognitive processing in a particular domain" (Robertson, 1999, p. 704). Both cognitive rehabilitation and training involve structured activities designed to improve cognitive and/or daily functioning. More specifically, cognitive training involves tasks intended to stimulate mental activity in several different domains including visual spatial skills, memory, problem solving, and attention (Sitzer, Twamley, & Jeste, 2006). While cognitive training involves a standardized training protocol, rehabilitation employs "individually tailor[ed] programs" (Belleville, 2008, p. 58). Research has shown that cognitive training can yield significant improvements in

cognitive abilities in both MCI and normal aging populations (Belleville et al., 2006; Belleville, 2008; Hampstead, Sathian, Moore, Nalisnick, & Stringer, 2008; Londos et al., 2008; Valenzuela &Sachdev, 2009). However, Papp, Walsh, & Snyder (2009), in a meta-analysis of the cognitive training literature, found only a weighted mean effect size (Cohen's d) of .16 across 10 randomized controlled trials, concluding that "the existing literature is limited by a lack of consensus on what constitutes the most effective type of cognitive training, insufficient follow-up times, a lack of matched active controls, and few outcome measures showing changes in daily functioning, global cognitive skills, or progression to early AD" (p. 50).

Computer-based cognitive training. Computer based cognitive training, as the name suggests, utilizes a computer for the delivery of the training module. There are several advantages to administering a cognitive training module via computer (Gunther, Haller, Holzner, & Kryspin-Exner, 1997; Hofmann, Hock, & Müller-Spahn, 1996). Cognitive training via a computer is likely to facilitate motivation as it can directly measure progress and provide immediate feedback. Additionally, it can easily customize the difficulty of the training and is "flexible and comprehensive enough to allow systematic training of specific aspects of cognition that may be problematic" (Günther, Schäfer, Holzner, & Kemmler, 2003, p. 201).

The adaptability of computer-based cognitive training becomes an important benefit when we find that research shows variability on how people respond to different forms of treatment based on their level of functioning. Research (Kasten et al., 2007) indicates that individuals with MCI or dementia benefit from cognitive interventions that focus on repetitive training tasks rather than the explicit teaching of memory strategies. Kasten et al. (2007) hypothesizes that this suggests that an intact hippocampal-medial temporal lobe network may not be required to show gains from training that doesn't rely on declarative memory. Echkroth-Bucher & Siberski (2009) found that training via repetitive practice exercises versus teaching training strategies showed results for mci but not non impaired (ARCD). However, the researchers themselves suggest that these results may in fact reflect the ceiling effects found in the measures they used. That is to say, the Dementia Rating Scale and MMSE were likely insufficiently sensitive enough to detect any improvement in non-impaired individuals. In fact, ACTIVE study found that non-impaired individuals benefitted from repetitive speed of processing training via computer training. Moreover, while participants experience cognitive gains in all domains trained (memory, reasoning, processing speed) they showed the greatest improvement in the domain of processing speed, the one domain that was trained solely via

implicit training rather than the teaching of strategies combined with practice exercises.

The ACTIVE study's use of computer-training on the domain of processing speed, like most computer-based cognitive training and rehabilitation, is based on the principles of neural plasticity. Contrary to the long held belief that the brain is an immutable organ, neural plasticity describes the way in which the brain's neural pathways and synapse change as the result of learning, changes in behavior, or brain injury (Greenwood & Parasuraman, 2010). Typically neural plasticity can be broken down into positive neural plasticity, which results in increased neuronal transmission as a result of engaging in cognitive enhancing activities, and negative plasticity, which can result when individuals withdraw from social and cognitive experiences. Research suggests that age-related cognitive decline is the result of negative plasticity as it is characterized by worsened processing through the peripheral and central sensory systems ("2009 Alzheimer's disease facts and figures," 2009; Clay et al., 2009). Consequently, unlike traditional cognitive training methods, which rely on the teaching of putative strategies, computer-based cognitive training programs typically focus on practicing perceptual speed and accuracy and implicit memory and attention

training (Cipriani, Bianchetti, & Trabucchi, 2006; Rozzini et al., 2007; Smith et al., 2009).

In order to be capable in effecting positive neural plasticity, researchers argue that the cognitive training intervention must target specific areas of cognitive functioning. Rozzini et al. (2007) highlights the importance of training specific areas: "Current researchers maintain that the efficacy of the rehabilitation depends on the specificity of the training used. The aim of the particular treatment is to modify the structure or the capability of specific cognitive functions through the repeated administration of exercises" (p. 259). Similarly, Cipriani et al. (2006) emphasizes the importance of cognitive training programs to incorporate intensive practice on perceptual speed and accuracy while utilizing adaptive algorithms and emphasizing attention and reward.

In contrast to the abundance of research on traditional cognitive training and despite a basis in cognitive plasticity theory, only limited research exists showing the effectiveness of computer-based cognitive training (Cipriani et al., 2006; Hofmann, Hock, Kühler, & Müller-Spahn, 1996). While studies have shown that computer-based cognitive training can be effective in improving cognitive functioning in domains such as processing speed, memory, and attention, many studies suffer from methodological concerns and limitations.

Most of the studies on computer-based cognitive training either failed to include a treatment control group (Cipriani et al., 2006; Günther et al., 2003) or utilized a simple wait-list or no-contact control group (Belleville et al., 2006; Eckroth-Bucher &Siberski, 2009; Faucounau, Wu, Boulay, De Rotrou, &Rigaud, 2010; Rozzini et al., 2007). Some studies did include an active control group, but often the groups did not involve utilizing a computer (Galante, Venturini, &Fiaccadori, 2007; Schreiber, 1999; Talassi et al., 2007) or were passive in their treatment style (e.g., watching an educational DVD on the computer) (Mahncke et al., 2006; Smith et al., 2009). Even less well-designed research exists on the effective use of computer-based cognitive training for healthy older adults with ARCD.

One study that did require participants in the active control, at least in part, to use the computer in an interactive fashion was conducted by Barnes et al. (2009). Specifically, the study, which evaluated computer-based cognitive training in MCI patients, utilized an active control group which involved participants using the computer for both interactive and passive activities (i.e., listening to audio books, reading an online newspaper, and playing the video game "Myst"). While they found improvement on their primary outcome measure, this difference was nonsignificant when compared to the active control group.

In addition to limited use of appropriate control groups, one of the issues the current research on computer-based cognitive training faces is its ability to show training effects that generalize to neuropsychological measures. Many studies have shown that people improve in performance on the tasks on which they are trained during the cognitive training program; however, fewer studies have been able to show this improved performance transferring to non-trained tasks as measured by neuropsychological instruments. This may be due to a number of factors. Firstly, it is possible that the cognitive training program does not sufficiently improve abilities such that they can be measured by neuropsychological testing. Alternatively, the selection of neuropsychological measures may limit the likelihood that any generalizable effects can be found. For example, some studies fail to include measures that correspond to the domains on which subjects train. In addition, some measures used in the research have been shown to have significant ceiling effects, meaning that relatively unimpaired individuals will not be able to improve significantly on the test given their high pre-training level of functioning. Therefore it is imperative that the instruments selected for such research purposes include measures that cover all the relevant cognitive domains being trained and have demonstrated sufficient sensitivity to reveal changes in normal functioning adults.

Beyond generalizability to neuropsychological measures, cognitive training has yet to reveal consistent effects on everyday functioning. While research has shown improvement in the activities of daily living in a dementia population, most studies fail to find changes in everyday functioning with the normal or mildly cognitive impaired population. This is likely due to the fact that individuals experiencing MCI and ARCD, by definition are not significantly impaired in their ADLs and therefore have no room for significant improvement.

Clearly the effectiveness of computer-based cognitive training still remains largely unproven. And, even if computer-based cognitive training does work, the question remains whether playing video games can be as effective.

Video Games. Research examining changes in cognitive functioning as a result of video game playing dates back to 1989. Mane & Donchin (1989) developed the "Space Fortress Game" to study complex skill acquisition. Specifically, they endeavored "(1) to create a complex task that is representative of real-life tasks, (2) to incorporate dimensions of difficulty that are of interest based on existing research on skill and its acquisition, and (3) to keep the task interesting and challenging for the subjects during extended practice" (p. 17). Studies conducted by Gopher, Weil & Bareket (1994)and Hart & Battiste (1992) using the space fortress game showed that skills trained during the playing of the

game could transfer to “real life” tasks including piloting an aircraft. As Mouck (2010) noted:

> This research showed for the first time that practice on a complex videogame could improve performance not only on the practiced video game task, but could also generalize to improved performance on other tasks. This generalized learning suggests that the improvements in performance were not only due to specialized learning of stimuli-response pairings associated with the specific game, but were more likely caused by changes in the general cognitive processes required by the video game, leading to the possibility of improved performance on any other task that relies on the same cognitive processes. (p. 4).

While several studies have shown a relationship between playing action video games and improved attention and other cognitive abilities, many of these studies have methodological limitations. Many of the studies are of a correlational design wherein participants are categorized as either video game users or nonusers based on self-report of their video game playing experience. The performances on cognitive and neuropsychological measures are then compared between the two groups. Consequently, these studies fail to provide evidence for causation, as it is possible that self-identified video game users play video games precisely because of their pre-existing relative strengths in attention and processing speed, whereas non video game users avoid playing video games due

to their relative weaknesses in the same cognitive domains. To rule out these potential confounds, Green and Bavelier (2003)included as a part of their larger study a video-game-training component. Non video game users played the action video game *Medal of Honor* for one hour a day for ten consecutive days. A control group played the Tetris video game over the same time span. The researchers hypothesized that visual attention would improve in the action video game group because it "require[s] that attention is distributed and/or switched around the field [of view]", whereas "Tetris demands focus on one object at a time" (p. 536). Their hypothesis was confirmed as they found significant improvements on the three dependent variables they measured and concluded that"10 days of training on an action game is sufficient to increase the capacity of visual attention, its spatial distribution and its temporal resolution" (p. 536).

A cognitive training study inadvertently found similar results. While studying the effects of computer-based cognitive training, Barnes et al.(2009) found that their active control group, which was assigned to play the video game "Myst", improved significantly on visual-spatial abilities and approached significance when compared to the cognitive training group.

Similar to the dearth of quality research on computer-based cognitive training, there is only limited methodologically robust research on the effectiveness of video games in improving cognitive abilities.

Chapter III: Methods

Rationale for Study

Although it is well established that cognitive training can have positive effects on cognitive functioning, less research exists examining the effectiveness of computer-based cognitive training. The first hypothesis addresses this question, stating that functioning across neuropsychological domains will improve with the use of the computer-based cognitive training program. While some research has shown correlations between video game playing and improved visual attention and processing speed, little experimental evidence exists to show a causal relationship between the two. The second hypothesis addresses this, stating that functioning across neuropsychological domains will improve with the use of participant-selected video games. No research in the literature has sought to compare the effects of using a computer-based cognitive training program specifically designed to target and train various cognitive domains with the effects of using participant-chosen video games. As such, it is unclear whether utilizing the cognitive training program will be more effective at improving cognitive abilities than video games. Nevertheless, our third hypothesis addresses this, stating that the cognitive training group will improve cognitive functioning across domains significantly more than the video game control group.

Study Design and Methodology

The study utilized a single-blind controlled trial with randomized parallel groups. The study consisted of two groups. One group utilized the computer-based cognitive training software Lumosity, while the second group played computerized video games. The Lumosity intervention group accessed the web-based Lumosity cognitive training software's "Basic Training" program, which includes exercises designed to target specific cognitive domains including memory, attention, processing speed, mental flexibility, and visual processing. The video game control group accessed web-based video games from the website "www.play.vg" and were free to choose the number and type of games they played. Both intervention groups were assigned the same treatment schedule: 10-15 minutes a day, 4 days a week, for 8 weeks. The experimental and control groups both received the same type, frequency, and duration of researcher attention, including interactions for assessments, explanation of procedures and informed consent. All participants followed similar timelines of assessment, time commitment, and computer exposure. Effectively, the distinguishing factor between the two groups was that the experimental group spent their time engaged in a comprehensive cognitive training program whereas the active control group utilized computer video games. This active control group was selected

specifically to address the nonspecific factors of video game use and research participation.

In this study, the independent variable was treatment type, either Lumosity cognitive training or video games. The dependent variables included measures of neuropsychological functioning in the domains of visual and verbal memory, processing speed, attention, mental flexibility, and visuospatial abilities.

Hypotheses

1) Utilizing computer-based cognitive training (Lumosity) improves cognitive functioning across neuropsychological domains in older adults.
2) Playing computer-based video games improves cognitive functioning across neuropsychological domains in older adults.
3) Computer-based cognitive training is more effective at improving cognitive functioning than playing video games across neuropsychological domains in older adults.

Procedures

Participants. Twenty-nine participants in the Santa Barbara, Ventura, and Los Angeles area were recruited via informational flyers and word of mouth, as well as through brief informational presentations conducted at the Center for Successful Aging, S+AGE (Specialized Ambulatory Geriatric Evaluation at Sherman Oaks Hospital) and older-adult social groups. Eleven participants

withdrew or were excluded from the study, leaving the actual sample size as 18. The inclusion criteria for the study limited participation to adults aged between 60 to 85 years with access to a computer and with a score greater than or equal to 23 on the Montreal Cognitive Assessment. Participants with MoCA scores lower than 23 were excluded from the study because that level of impairment was not the focus of this study. In addition, excluding those participants significantly minimized the risk of including participants in the study who would be unable to understand the risks and benefits of the experiment and, therefore, could not ethically give informed consent. No inducement was given to participate other than the possibility of furthering research on the benefits of cognitive training in older adults like themselves, free access to cognitive training for the duration of the study, and access to a summary of the results and findings of the research at the conclusion of the study.

The only potential risk faced by participants in this study was the possibility of emotional discomfort associated with contemplating their cognitive status. In particular, participation in the study held the potential of revealing cognitive deficits that participants might find distressing. Referrals were made available for any patient who felt they required counseling to aid in the processing of emotions that arose as a result of participation in the study. Specifically, the contact information for licensed mental health service providers was included in

the informed consent form. In addition, contact information for the graduate student research assistant and dissertation chair was provided. Both individuals were prepared to facilitate additional community mental health referrals to any participant who expressed discomfort associated with participation in the study.

Description of measures. Assessment tools that measure abilities in the domains of visual and verbal memory, processing speed, attention, mental flexibility, and visual spatial abilities were used. Given that the participant sample included people with no measurable cognitive deficits, the assessment battery was selected to minimize ceiling effects.

Memory. Verbal memory was measured using the Rey Auditory Verbal Learning Test (RAVLT), while visual memory was assessed with the Rey-Osterrieth Complex Figure Test (ROCF) and Modified Taylor Complex Figure (MTCF). The RAVLT is word-list memory test in which the test administrator read aloud a list of 15 nouns "for five consecutive trials, each trial followed by a free-recall test" (Strauss, Sherman, & Spreen, 2006, p. 776). The RAVLT has several different word lists. In order to minimize practice effects, a different list of nouns was used at each evaluation. Both the ROCF and MTCF involved the participant copying a complex figure and then drawing it from memory (Strauss et al., 2006). In order to minimize practice effects, half the participants took the

ROCF test during the first assessment and the MTCF during the second assessment, and the other half of the participants took them in the reverse order.

Attention/Working memory. Attention and working memory was primarily measured using the Wechsler Adult Intelligence Scale – Fourth Edition (WAIS-IV) Digit Span subtest. This test is comprised of three separate tasks (Digit Span Forward, Digit Span Backward, and Digit Span Sequencing) which required individuals to listen to a string of digits and repeat back the numbers in the same order, reverse order, or ascending numerical order, respectively(Wechsler, 2008).

Processing Speed. Two types of processing speed, psychomotor speed and verbal fluency, were measured. Psychomotor speed was assessed by both Trail Making Test part A and the WAIS-IV Coding subtest. The Trail Making Test part A, constructed in 1938 and adapted by Reitan in 1955, required the participant to "connect, by making pencil lines, 25 encircled numbers randomly arranged on a page in proper order"(Strauss et al., 2006, p. 655). The WAIS-IV Coding subtest is a "core Processing Speed subtest" in which the "examinee copie[d] symbols that [were] paired with numbers within a specified time limit" (Wechsler, 2008, p. 16). Verbal fluency was measured by both phonemic and semantic fluency tasks. For the phonemic fluency test participants were given three trials of one minute

each in which to generate as many words as possible that began with a specific letter. Semantic fluency asked the participant to generate in one minute as many words as possible within a specific category (e.g., animals or vegetables)(Strauss et al., 2006).

Mental Flexibility. Mental flexibility was measured by both the Golden Stroop task and Trail Making Test B (TMT B). The Golden Stroop test required participants to "suppress a habitual response in favor of a less familiar one" (Strauss et al., 2006, p.477). More specifically, in the target task, participants were shown cards with rows of color names (blue, green, red) printed in colored ink different than the word itself (e.g., the word "blue" would be printed in red or green ink) and asked to name the color of the ink rather than read the word. TMT B required the participant to connect, as quickly as possible, "25 encircled numbers and letters in alternating order" using a pencil (Strauss et al., 2006, p. 655).

Visualspatial Abilities. Visualspatial abilities were measured by the copy portion of the Rey-Osterrieth Complex Figure Test (ROCF) and Modified Taylor Complex Figure (MTCF).

Mental Status. The Montreal Cognitive Assessment (MoCA), a brief mental status exam, was used as a screening tool to rule out participants who

exhibited signs of dementia or serious cognitive impairment. The test measures abilities in several cognitive domains, as outlined by Nasreddine et al.(2005):

> The short-term memory recall task (5 points) involves two learning trials of five nouns and delayed recall after approximately 5 minutes. Visuospatial abilities are assessed using a clock-drawing task (3 points) and a three-dimensional cube copy (1 point). Multiple aspects of executive functions are assessed using an alternation task adapted from the Trail Making B task (1 point), a phonemic fluency task (1 point), and a two-item verbal abstraction task (2points). Attention, concentration, and working memory are evaluated using a sustained attention task (target detection using tapping; 1 point), a serial subtraction task (3 points), and digits forward and backward (1 point each). Language is assessed using a three-item confrontation naming task with low-familiarity animals (lion, camel, rhinoceros; 3points), repetition of two syntactically complex sentences (2 points), and the aforementioned fluency task. Finally, orientation to time and place is evaluated (6 points).

Test Batteries. Two Batteries (Battery A and Battery B) were developed using alternate forms of some tests in order to minimize practice effects. Battery A consisted of RAVLT List 1, Phonemic Fluency FAS, Semantic fluency Animals, the Digit Span subtest, the Coding subtest, TMT A and B, the Stroop,

and the Rey Complex Figure. Battery B consisted of RAVLT List 2, Phonemic fluency CFL, Semantic Fluency Vegetables, the Digit Span subtest, the Coding subtest, TMT A and B, the Stroop, and the Modified Taylor Complex Figure. The first 12 participants recruited were administered Battery A at time 1. Participants numbered 13 through 26 received Battery B at time 1. The final 3 participants completed Battery A at time 1. All participants who completed testing at time 2 received the alternate battery at that time.

Research Team. The research team included two supervising licensed psychologists, one post-doctoral fellow, and two graduate students (one of whom was the primary investigator). The post-doctoral fellow and two graduate students conducted all the neuropsychological assessments.

Step-Wise Procedures.

Step 1- Prior to meeting with the participant, in order to prepare the correct paperwork, the participant was assigned to one of the two experimental groups via the toss of a coin, with results as follows: “heads” = cognitive training group, “tails” = video game group.

Step 2- Upon meeting with the participant, informed consent was explained, including the risks and benefits of the study and how the results would be kept confidential. The only identifying piece of information on each questionnaire and

test result was a code number, linked to the participant's name only through their signed informed consent form, which was kept in a secured location.

Step 3- Once the participant signed the consent form, the Montreal Cognitive Assessment was administered. All participants met inclusion criteria of MoCA score >23 and accordingly no participants were excluded from the study at this point.

Step 4- The neuropsychological instruments (Battery A or Battery B)were administered to the participant in a quiet room free from distractions.

Step 5 – The participant was given the printed instructions specific to their group assignment (see appendix), along with two record sheets. Participants were shown how to record the date and time of their sessions, along with the specific activities or games they utilized.

Step 6- Participants engaged in the 8-week intervention specific to their experimental group during which time support was available via telephone or email. Participants accessed the cognitive training software or video game software from their personal computers. Two participants contacted the researchers via email with questions about "logging in" to the cognitive training website. One participant requested instruction in using the video games. In-person instruction was provided to this participant.

Step 5- The participant underwent a second battery of neuropsychological tests following completion of the intervention period.

Participants who completed fewer than eight sessions in the first four weeks or skipped eight consecutive sessions thereafter were discontinued from the study. In addition, participants were free to withdraw consent at any time during the study. As noted, 11 participants were excluded from the final analysis, as 5 explicitly withdrew from the study and 5 failed to complete a sufficient number of training sessions to be included in the study. The remaining individual was not included in the final analysis as he/she was not able to complete all trials of the Stroop test due to color-blindness.

Chapter IV: Results

Data was analyzed using the SPSS version 20.0 for Windows. All procedures were approved by Antioch University Santa Barbara's Institutional Review Board for Human Use. Data was stripped of identifying information to protect the privacy of study participants.

Descriptive statistics for all cognitive measures are displayed in Table 1. Sixteen of the 29 participants were assigned to the cognitive training group and the remaining 13 were assigned to the video game group. Of the twenty-nine individuals who participated in the study, 10 either withdrew from the study or did not complete enough training sessions to be included in the statistical analysis, while one was excluded for not completing all measures administered in the test battery, making a final sample of 18 individuals. The sample of 18 individuals had a mean age of 70.33±6.30 years, four reported some college education, five were college graduates, two reported some post-graduate education and 7 reported post-graduate degrees. There were 16 females and 2 males. Four individuals scored below normal on the MoCa (<26) and the mean MoCA score was 27.00±2.08. These characteristics are consistent with the full sample of 29 individuals. There were no significant differences between the final sample of 18 individuals and the 11 individuals excluded from the analysis. Of the eleven

Table 1

Demographic Characteristics

N=18	Frequency	Percent
Gender		
Female	16	88.9
Male	2	11.1
Education		
Some college	4	22.2
College graduate	3	16.7
Some graduate school	2	11.1
Graduate degree	7	38.9
Occupation		
Executive/Professional	13	72.2
Skilled/Technical	3	16.7

Table 2

Multivariate Analysis by Intervention Group

Treatment Group	Measure	Time 1	Time 2	F value	p value
Cognitive Training (N=9)					
	RAVLT Total Score	105.11 (14.56)	118.22(14.41)	0.26	0.63
	RAVLT ImmRecall[a]	104.44(17.76)	116.11(12.69)	0.96	0.37
	RAVLT Delay Recall	109.44(17.76)	116.11(14.53)	0.22	0.66
	CFT Copy	99.33(8.59)	105.56(8.83)	3.13	0.13
	CFT ImmRecall[b]	107.00(25.71)	110.89(28.05)	1.22	0.31
	CFT Delay Recall	109.22(27.51)	107.44(27.44)	1.99	0.21
	Phonemic Fluency	107.67(14.36)	110.67(9.22)	0.59	0.48
	Semantic Fluency	90.33(19.63)	95.22(11.19)	0.17	0.69
	Digit-Span Forward	98.89(16.35)	96.67(8.67)	3.36	0.12
	Digit-Span Backward	103.33(10.90)	107.78(7.55)	3.53	0.11
	Digit-Span Sequence	105(11.46)	103.89(7.82)	0.52	0.50
	Digit-Span Total	101.11(13.64)	103.89(9.28)	4.65	0.07
	Coding	112.22(11.76)	117.22(11.21)	0.40	0.55
	Trail Making Test A	93.11(15.54)	100.33(11.15)	0.67	0.44
	Trail Making Test B	98.44(11.01)	102.00(7.81)	0.74	0.42
	Stroop CW Inter[c]	102.22(8.80)	107.22(8.66)	0.17	0.70

Table 2 Continued
Video Games (N=9)

RAVLT Total Score	98.0 (8.43)	114.0 (14.05)	14.76	<0.01**
RAVLT ImmRecall[a]	105.55(12.61)	111.67(18.20)	9.86	0.02*
RAVLT Delay Recall	105.00(12.99)	110.00(14.58)	16.55	<0.01**
CFT Copy	101.78(6.28)	100.44(14.01)	0.04	0.84
CFT ImmRecall[b]	114.67(10.36)	122.44(14.05)	0.02	0.89
CFT Delay Recall	119.67(6.91)	122.00(14.05)	0.18	0.70
Phonemic Fluency	106.00(12.35)	105.78(20.11)	0.22	0.65
Semantic Fluency	98.78(20.12)	97.33(16.76)	1.97	0.21
Digit-Span Forward	98.33(11.99)	96.11(7.82)	1.50	0.27
Digit-Span Backward	102.22(7.12)	104.44(16.67)	0.70	0.44
Digit-Span Sequence	102.78(13.02)	105.00(8.29)	0.16	0.70
Digit-Span Total	101.11(9.93)	102.78(10.03)	0.20	0.67
Coding	109.44(7.27)	114.44(10.74)	8.40	0.03*
Trail Making Test A	90.89(15.85)	104.56(10.93)	2.88	0.14
Trail Making Test B	92.89(12.61)	99.56(11.81)	3.24	0.12
Stroop CW Inter[c]	108.00(9.35)	110.11(10.50)	1.42	0.28

* p<0.05 ** p<0.01
a=RAVLT Immediate Recall b=Complex Figure Test Immediate Recall c=Stroop Color-Word Interference

individuals excluded from the analysis, seven were in the cognitive training group and four in the video game group. The 11 participants excluded from the sample had a mean age of 65.50+4.04, one reported some college, one was a college graduate, and were five reported earning post-graduate degrees. Education information was unavailable for the remaining four.

Statistical Procedures

Hypothesis 1 tested whether utilizing the structured cognitive training program Lumosity improved the participants' performance on the neuropsychological measures administered. To test whether these changes in performance were significant, a multivariate analysis with repeated measures was

conducted. The results are presented in Table 2. No significant differences were found on any of the dependent variables.

Hypothesis 2 tested whether utilizing freely available video games in an unstructured, participant-selected manner improved the participants' performance on neuropsychological measures. To test whether these changes in performance were significant, a multivariate analysis with repeated measures was conducted. The results are presented in Table 2. Significant improvement in scores were noted on memory measures including the RAVLT total recall score ($F(1,16) = 14.76$, $p < .01$), RAVLT Immediate Recall ($F(1,16) = 9.86$, $p = .02$), RAVLT Delayed Recall ($F(1,16) = 16.55$, $p < .01$), and WAIS-IV Coding subtest ($F(1,16) = 8.40$, $p = .03$). No significant differences were found on the remaining dependent variables.

Hypothesis 3 tested whether using the cognitive training program improved participants' performance on neuropsychological measures more so than using video games. First, to test whether the intervention in general (both cognitive training and video games) significantly improved performance on neuropsychological measures a multivariate analysis with repeated measures was conducted. Overall, no significant improvement was found, while examining individual measures revealed improvements in RAVLT Total Score ($F(1,16) = 29.38$, $p < .001$) Immediate Recall ($F(1,16)=8.46$, $p=0.01$), Coding

(F(1,16)=14.40, p =0.002), Trail Making Test Part A (F(1,16)=11.05, p=0.004), and Trail Making Test Part B (F(1,16)=4.71, p=0.05). The complete results are presented in Table 3. Analysis did not yield a significant interaction between intervention nor were significant interaction effects found on any of the dependent variables. The results are presented in Table 3.

Table 3

Multivariate Analysis of Combined Treatment and By Group Comparison

	Measure	Mean		Combined Treatment		By Group	
N=18		Time 1	Time 2	F	Sig.	F	Sig.
	RAVLT Total Score	101.56(12.10)	116.11(13.98)	29.38	<.001***	.29	.60
	RAVLT ImmRecall[a]	105.00(14.95)	113.89(15.40)	8.46	<.01**	.83	.38
	RAVLT Delay Recall	107.22(15.27)	113.06(14.47)	2.31	.15	.05	.83
	CFT Copy	100.56(7.40)	103.00(11.71)	.81	.38	1.92	.19
	CFT ImmRecall[b]	110.83(19.41)	116.67(22.33)	1.08	.32	.12	.73
	CFT Delay Recall	114.44(20.20)	114.72(22.43)	.002	.96	.13	.73
	Phonemic Fluency	106.83(12.02)	108.22(15.39)	.19	.67	.25	.62
	Semantic Fluency	94.57(19.77)	96.28(13.87)	.34	.57	1.13	.30
	Digit-Span Forward	98.61(13.91)	96.39(8.00)	.86	.37	0	1
	Digit-Span Backward	102.78(8.95)	106.11(12.67)	1.85	.19	.21	.66
	Digit-Span Sequence	103.90(11.95)	104.44(7.84)	.04	.84	.37	.55
	Digit-Span Total	101.11(11.58)	103.33(9.40)	1.77	.20	.11	.74
	Coding	110.83(9.56)	115.83(10.74)	14.40	.002**	0	1
	Trail Making Test A	92.00(15.27)	102.44(10.93)	11.05	.004**	1.05	.32
	Trail Making Test B	95.67(11.84)	100.78(9.80)	4.71	.05*	.44	.52
	Stroop CW Inter[c]	105.11(9.29)	108.67(9.45)	1.64	.22	.27	.61

* p<.05. ** p<.01. *** p<.001.

a=RAVLT Immediate Recall b=Complex Figure Test Immediate Recall c=Stroop Color-Word Interference

Chapter V: Discussion and Conclusions

The goal of this study was to evaluate the effectiveness of a computer-based cognitive training program compared to the use of non-specific video game playing. We utilized the cognitive training program Lumosity for the experimental treatment group since it contained a specific training program designed to target the cognitive domains of attention, memory, visual spatial abilities and mental flexibility. This condition was compared to our active control group, which consisted of participant-selected video games from the "play.vg" web site.

Hypothesis 1

Hypothesis 1 stated that utilizing the cognitive training program would improve cognitive functioning across neuropsychological domains. No support was found for this hypothesis as participants did not significantly improve on any of the measures.

Memory. The results are similar to those found by Eckroth-Bucker & Siberski (2009) and Cipriani et al. (2006) who failed to find improvements in auditory memory, specifically story memory, following computer-based training in unimpaired participants. Conversely, Mahncke et al. (2006) found

improvements in auditory memory in cognitively healthy participants who used a computer-based training program which "intensively exercise[d] aural language reception accuracy" and required individuals to "perform increasingly more difficult stimulus recognition, discrimination, sequencing, and memory tasks under conditions of close attentional control, high reward, and novelty" (p.12524). Similarly, Smith et al. (2009) and Belleville et al. (2006) found improved rote verbal memory and list learning ability in cognitively healthy older adults. Other research has found similar improvements in auditory memory with mild to moderately impaired individuals (Belleville et al., 2006; Günther et al., 2003; Rozzini et al., 2007).

Attention/Working memory. The current study's lack of significant improvement on a measure of attention/working memory (WAIS-IV Digit Span Backwards) is similar to Barnes et al. (2009), Belleville et al. (2006), and Eckroth-Bucker &Siberski (2009) who failed to find significant improvements in this domain in either cognitively healthy or mildly impaired individuals.. Conversely, Smith et al. (2009) found significant improvements on the same attention task, and Mahncke (2006) found improved digit span recall even after a 3 month no contact follow-up.

Processing Speed. The current study failed to find significant improvement in cognitive processing speed for the cognitive training group.

While this result is similar to research conducted by Barnes et al. (2009) and Cipriani et al. (2006), it is at odds with the large multi-site ACTIVE (Ball et al., 2002)study which utilized computers for "speed-of-processing" training. In their sample of healthy older adults significant improvement was found on a measure of cognitive processing speed. However, it should be noted that the neuropsychological instrument used to measure cognitive processing speed (The Useful Field of View test) is itself administered on the computer thus limiting the generalizability of their findings. In fact, on their measures of "everyday speed" they failed to find significant improvement following cognitive training. The current study's failure to find significant improvements in verbal fluency, both semantic and phonemic fluency, is consistent with previous research (Barnes et al., 2009; Cipriani et al., 2006; Rozzini et al., 2007).

Mental Flexibility. Similar to the current study, previous research has also failed to show significant improvements in performance on the Trail Making Test (Barnes et al., 2009; Cipriani et al., 2006; Günther et al., 2003).

Visual-Spatial Abilities. Similar to the results of Barnes et al. (2009) and Rozziniet al. (2007), cognitive training participants in this study failed improve significantly on measures of visuo-spatial functioning. Conversely, mildly impaired individuals in a study conducted by Talassi et al. (2007) showed

significant improvement in cognitive functioning only in the domains of visual construction.

Hypothesis 2

Hypothesis 2 stated that utilizing computer-based video games would improve cognitive functioning across neuropsychological domains. Partial support was found for this hypothesis as participants improved significantly on 4 of the 16 dependent variables measured, including in the domains of auditory memory, specifically rote verbal memory and list learning ability (RAVLT Total Score, Immediate Recall, &Delay Recall) and processing speed (WAIS-IV Coding). No significant improvement was found in the remaining domains.

Previous Research. Comparison to previous research is limited due to the lack of randomized clinical trials examining the effects of computer video games on cognitive abilities in older adults. Similar to the current study, previous research has shown increased cognitive processing speed to be associated with video game use (Green & Bavelier, 2003). Unlike the current study, prior research has shown utilizing video games can improve visual attention (Green 2003) and immediate visual memory (Green & Bavelier, 2003). A unique finding of the current study was the significant improvement on verbal memory tasks found in the video game group.

Hypothesis 3

Hypothesis 3 stated that utilizing computer-based cognitive training improves cognitive functioning more so than does playing video games. First it must be determined whether the intervention in general (both cognitive training and video games) significantly improved performance on neuropsychological measures. Overall, no significant improvement was found, whereas examining individual measures revealed improvements in RAVLT Total Score and Immediate Recall, Coding, and Trail Making Test Part A& B. On all the neuropsychological measures administered, no significant differences were found between the cognitive training group and video game group. Consequently, no evidence was found to support hypothesis 3.

Strengths

The current study contains several strengths. The current study utilized a blinded randomized trial with pre-test and post-test measures. Unlike many previous studies, an active control group which engaged in interactive software on a computer was utilized. The study also measured functioning in all the cognitive domains on which training occurred and included measures sensitive enough to show improvements even in cognitive healthy adults.

Limitations

Several limitations of the current study prevent further generalization of the results. This study had a small number of participants (n=29) initially, and a 35% dropout rate, resulting in a statistical sample of only 19 individuals. The study was a single, not double-blind study. While participants were blind to their group participation, the study assessors were aware of the participants' group membership. The training schedule was only for 8 weeks. Perhaps a longer treatment schedule would have resulted in more significant results. The participant sample on the whole was rather homogenous group. Only 3 participants were male. Participants were also highly educated; 13 of the 19 participants had college degrees or above, including 8 participants having earned graduate degrees. Fourteen participants identified as having worked as a professional or executive, three reported being skilled workers, and two declined to answer. The significant improvements found in both the experimental and active control group could be interpreted as practice effects since only a comparison with a wait-list or no-contact control group could definitively rule out this possibility.

Implications of results and further study

The current study suggests that utilizing a computer for interactive software, either video games or cognitive training, can positively affect cognitive

functioning, specifically auditory memory, processing speed, visual attention, and mental flexibility. Moreover, the results indicate that computer based cognitive training does not provide significantly greater improvement than non-specific video game playing, suggesting that interactively using a computer for cognitively engaging exercises is adequate for producing some positive cognitive effects. As noted above, cognitive decline can lead to higher rates of depression and anxiety; consequently, computer-based interactive activities represent another avenue of intervention for clinicians who treat older adults experiencing cognitive decline and the associated negative emotional consequences.

As noted above, the current study suffers from several limitations which future research should seek to remedy. Further research would benefit from the inclusion of a no-contact control group to account for the possibility of practice effects. As previous research has shown passive use of a computer to be ineffective in promoting cognitive growth, it would be interesting to utilize various treatment groups with different levels and types of computer interaction in order to parse out what specific aspects of interactivity are essential in effecting cognitive change. Utilization of a double-blind study design would also add to the methodological robustness of the study. Follow-up testing after 6 months to one year after the conclusion of cognitive training would provide evidence for or against the persistence of the cognitive improvements. A larger, more diverse

sample would enable for greater generalization of the results. Specifically, further research would benefit from the inclusion of more male participants and individuals with a wider range of age, cognitive functioning, and educational and employment background. While not the focus of the current study, the inclusion of a measure of independent activities of daily living as well as a depression/mood measure would allow future research to speak to the effectiveness of computer-based cognitive intervention in the broader emotional and day-to-day functioning of older adults.

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Appendix

ANTIOCH UNIVERSITY
SANTA BARBARA

#_____

Informed Consent Form

Antioch University is committed to the ethical protection of participants in research. This form will provide you with information about the study so that you can decide whether you wish to participate. Participation in this study is voluntary and anonymous. Your answers and results will be identified only by a code number, not by your name.

The study is about age related cognitive decline. The study may require a significant time commitment. Participants will undergo two neuropsychological evaluations which will require 45 minutes to 1 hour to complete. The evaluations will involve being asked to complete certain tasks designed to measure your memory, attention, and other cognitive abilities. You can receive a summary of you evaluation results and, if you wish, can partake in a feedback session to go over your results in more detail. Participants will need to commit to using a computer for 10-15 minutes a day, 4 days a week, for 8 weeks. Participants will use the computer to engage in activities requiring the use of their memory, attention, and other cognitive abilities.

If you decide to participate, your results may help researchers understand the effectiveness of computer based cognitive activities in improving thinking abilities. While it is unlikely, the possibility exists that undergoing the neuropsychological evaluations and/or engaging in the cognitive activities may be upsetting, in that participants' cognitive weaknesses may be revealed. Be assured that if this happens, you may contact the licensed psychologists listed below for counseling and support:

Rebecca Goodman, P.hD.
22 W. Micheltorena St, Suite B
Santa Barbara CA 93101
Phone: (805) 563-2644

Annette Swain
15928 Ventura Blvd, Suite 231
Encino CA 91436
(818) 385-0913

You may also contact the study investigators with your concerns, and steps will be taken to insure that you receive a list of local resources that can also provide counseling and support to you.

If you have any further questions concerning this study please feel free to contact research assistant Camilla Seippel, M.A., or Juliet Rohde-Brown, PhD., at Antioch University Santa Barbara, 801 Garden Street, Santa Barbara, California, 93101, (805) 962-8179. If you agree to the terms of this agreement, and wish to include your answers to the questionnaire in this study, please sign on the space below that you understand your rights and agree to participate in this study.

Your participation is invited, yet strictly voluntary. All information will be kept confidential and your name will not be associated with any research findings.

_____

Signature of Participant

James Fortman, M.A., Investigator
Antioch University Santa Barbara

Juliet Rohde-Brown, PhD., supervisor
Antioch University Santa Barbara

(Print name)

Demographic Questionnaire #

Age:

Sex (please circle one): Male Female

Educational level obtained (High school, graduated high school, some college, graduated from college, some post-graduate work, post-graduate degree (circle highest degree obtained).

Circle category that best describes your occupation
Executive/managerial/professional Skilled technical/clerical/service Labor/manufacturing

Have you ever had a brain injury, stroke, or brain tumor?

Have you ever had a concussion?

Have you ever had general anesthetic?

Have you been diagnosed with diabetes?

Do you have circulatory problems/heart issues?

Please list medications you currently take

What physical activities do you engage in?

How often? (rarely, monthly, weekly, daily)

How often do you use a computer? (please circle one): (never, rarely, monthly, weekly, daily)

What do you use the computer for? (circle as many that apply):
Email
Research
Social networking
Instant messaging
Games
Word processing documents
Other:

Do you engage in any of the following activities? (circle as many that apply):

Crosswords
Sudoku
Board games
Art
Reading
Watching television/movies
Continuing education

Email address:

LUMOSITY INSTRUCTIONS FORM

ID #

USE THE LUMOSITY TRAINING:
- COMPLETE THE DAY'S TRAINING PROGRAM
- 4 TIMES PER WEEK
- FOR 8 WEEKS
TRY TO ADHERE TO A TRAINING SCHEDULE AS BEST YOU CAN, BUT IF YOU MISS A FEW SESSIONS, DON'T GIVE UP! JUST CONTINUE TRAINING AS USUAL.

HOW TO START:

1. Open web browser
2. Type "lumosity.com" in the address bar
3. Click on "Start Training"
4. If it prompts you for your login and password, use the ones provided below.
5. Record date and start time on provided record sheet
6. Complete the day's training
7. Record end time on record sheet.
8. Record the names of the games you played
9. DO NOT DO ANY EXTRA TRAINING EXERCISES OR TAKE ASSESSMENTS

LOGIN: PASSWORD:

VIDEO GAME INSTRUCTIONS FORM

ID:
PLAY THE PROVIDED GAMES:
- FOR 10-15 MINUTES
- 4 TIMES PER WEEK
- FOR 8 WEEKS
TRY TO ADHERE TO A TRAINING SCHEDULE AS BEST YOU CAN, BUT IF YOU MISS A FEW SESSIONS, DON'T GIVE UP! JUST CONTINUE TRAINING AS USUAL.

HOW TO START:

1. Open web browser.
2. Type http://www.play.vg/ into the web browser address bar.
3. Select from the available games
4. Record date and start time on provided record sheet
5. Spend 10-15 minutes playing.
6. Record end time on record sheet.
7. Record the names of the games you played

ACTIVITIES LOG

ID # __________

DATE	TIME START	TIME END	GAMES PLAYED

Form B

Insuring Informed Consent of Participants in Research:
Questions to be answered by AUSB Researchers

The following questions are included in the research proposal.

1. **Are your proposed participants capable of giving informed consent? Are the persons in your research population in a free-choice situation?…or are they constrained by age or other factors that limit their capacity to choose? For example, are they adults, or students who might be beholden to the institution in which they are enrolled, or prisoners, or children, or mentally or emotionally disabled? How will they be recruited? Does the inducement to participate significantly reduce their ability to choose freely or not to participate?**
   The participants in my study, adults aged 60-85 years of age without dementia, are capable of giving informed consent. The decision to participate in the study is completely voluntary, as will be explained in the accompanying documents. The only identifying information on the demographic questionnaire and test results will be a code number. A single master list associating participant name and code number will be kept under lock.Participants will be recruited via informational flyers and brief informational presentations conducted at local retirement communities, assisted living homes, and social groups and through word of mouth. There will be no inducement to participate other than the possibility of furthering research on the benefits of cognitive training in older adults like themselves, the possibility of free access to cognitive training for the duration of the study.

2. **How are your participants to be involved in the study?**
   Potential participants will fill out an informed consent agreement, demographic questionnaire and undergo a mini-mental status exam. If selected for the study, participants will be evaluated on two occasions using the psychological and neuropsychological test instruments discussed above. Depending on which group they are assigned to, participants will either partake in aninternet-based cognitive training program or play free internet-based video games for 10-15 minutes a day, 4 days a week, for 8 weeks.

3. **What are the potential risks – physical, psychological, social, legal, or other? If you feel your participants will experience "no known risks" of**

any kind, indicate why you believe this to be so. If your methods do create potential risks, say why other methods you have considered were rejected in favor of the method chosen.
The only potential risk faced by participants in this study might be emotional discomfort associated with contemplating their cognitive status. In particular, participation in the study may reveal cognitive deficits which the participant may find distressing.Referrals will be available for any patient who feels they might require counseling to aid in the processing of emotions that might arise as a result of participation in the study. Specifically, the contact information for licensed mental health service providers will be included in the informed consent form. In addition, contact information for thegraduate student research assistant and dissertation chair will be provided. Both individuals will be prepared to facilitate additional community mental health referrals to any participant who expresses discomfort associated with participation in the study.

4. **What procedures, including procedures to safeguard confidentiality, are you using to protect against or minimize potential risks, and how will you assess the effectiveness of those procedures?**
The only identifying piece of information on each questionnaire will be a code number, which will linked to a participants name only through a single master list which will be kept in a locked cabinet.Upon completion of data collection, these records will be kept in a secured location for a period of 5 years, at which time they will be shredded.

5. **Have you obtained (or will you obtain) consent from your participants in writing? (Attach a copy of the form.)**
Each participant will be asked to review and sign an informed consent document at the outset of the initial interview
6. **What are the benefits to society, and to your participants, that will accrue from your investigation?**
Age related cognitive decline affects the quality of life of millions of people and as such, effective treatments for ARCD will benefit a large portion of the population. This study will contribute to the body of research on determining the effectiveness of cognitive training as treatment for ARCD. In addition, participants in the study will receive 2 neuropsychological evaluations free of charge, a service that typically costs over $1000, and will be provided with a hard copy of their results.

7. **Do you judge that the benefits justify the risks in your proposed research? Indicate why**.
   I believe that the risks associated with participation in this survey are minimal and clearly are outweighed by potential benefits to society associated with enhancing understanding of the effectiveness of cognitive training.

Both the student and her Dissertation Chair must sign this form and submit it before any research begins. Signatures indicate that, after considering the questions above, both student and faculty person believe that the conditions necessary for informed consent have been satisfied.

Date:_____

Signed:_____
Student

Date:_____

Signed:_____
Dissertation Chair

When completed, this form should be included in the proposal and the final paper.

CITI Collaborative Institutional Training Initiative

Human Research Curriculum Completion Report
Printed on 10/11/2011

Learner: James Fortman (username: sydb1367)
Institution: Antioch University
Contact Information Phone: 8054511463
Email: sydb1367@rocketmail.com
Antioch Santa Barbara Social and Behavioral Sciences:

Stage 2. Refresher Course Passed on 10/11/11 (Ref # 3818158)

Required Modules	Date Completed	
Biomedical 101 Refresher Course - Introduction	10/11/11	no quiz
SBR 101 REFRESHER MODULE 1 - History and Ethics	10/11/11	5/5 (100%)
SBR 101 REFRESHER MODULE 2 - Regulatory Overview	10/11/11	5/5 (100%)
SBR 101 REFRESHER MODULE 3 - Risk, Informed Consent, and Privacy and Confidentiality	10/11/11	4/5 (80%)
SBR 101 REFRESHER MODULE 4 - Vulnerable Subjects	10/11/11	4/4 (100%)
SBR 101 REFRESHER MODULE 5 - Education, International, and Internet Research	10/11/11	4/5 (80%)
How to Complete The CITI Refresher Course and Receive the Completion Report	10/11/11	no quiz

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI participating institution. Falsified information and unauthorized use of the CITI course site is unethical, and may be considered scientific misconduct by your institution.

Paul Braunschweiger Ph.D.
Professor, University of Miami
Director Office of Research Education
CITI Course Coordinator

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