Cognitive Training With Healthy Older Adults: Investigating the Effectiveness of the Brain Age Software for Nintendo DS

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COGNITIVE TRAINING WITH HEALTHY OLDER ADULTS: INVESTIGATING THE EFFECTIVENESS OF THE BRAIN AGE$^{\text{TM}}$ SOFTWARE FOR NINTENDO

By

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ABSTRACT

COGNITIVE TRAINING WITH HEALTHY OLDER ADULTS: INVESTIGATING THE EFFECTIVENESS OF THE BRAIN AGE^{TM} SOFTWARE FOR NINTENDO

Shaun M. English, M.S.

Marquette University, 2012

An increasing number of empirical studies have demonstrated the effectiveness of cognitive training (CT) with healthy, cognitively intact older adults. Less is known regarding the effectiveness of commercially available “brain training” programs. The current study investigated the impact of daily CT presented via the Brain Age® software for Nintendo DS on neurocognitive abilities in a sample of healthy, community-dwelling older adults. Over the six-week study, participants in the CT group completed training activities and were compared to an active control group who played card games on the Nintendo DS. At pre-test and post-test, a wide range of empirically validated neuropsychological outcome measures was administered to examine the proximal and distal transfer effects of training. Although within normal range, the average MMSE score was significantly higher in the control group at pre-test; no other baseline differences in demographics or performance on primary neuropsychological outcome measures were observed. In the CT group, estimated “brain age” decreased and performance on daily training tasks significantly improved over the six-week study period. Importantly however, performance improved from pre-test to post-test on measures of everyday verbal memory, visual working memory, and math fluency in both the CT and active control groups. Participants in the CT group rated usage of the Brain Age software as significantly more mentally challenging and endorsed greater subjective memory improvement at post-test than participants in the control group. These findings demonstrate that both CT and cognitive stimulation protocols produced transfer effects in the current study. That is, Brain Age software use led to enhanced cognitive performance over time, but it did not do in a manner that exceeded the effects achieved by general cognitive stimulation. Enhanced working memory in the CT group and executive attention in the control group are discussed as possible explanation for improved performance on the outcome measures.

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Overview

During the course of normal aging, many older adults experience cognitive decline, often including reductions in memory performance. Memory problems and cognitive impairment can also arise and be exacerbated by neurological diseases associated with aging, most notably, Alzheimer's disease (AD) and various other types of progressive dementia. In 2009, the population of individuals in the United States over the age of 65 numbered 39.6 million, or 12.9% of the total population; and this number is expected to grow to 72.1 million by 2030 (Administration on Aging, 2011). Given that the percentage of older adults in our society will continue to rise over the coming decades, there is a demand for low-cost, practical cognitive interventions to increase older adults' ability to thrive in old age and maintain their independence.

One of the most exciting new research directions to address this demand is in the area of cognitive rehabilitation, often referred to as neuropsychological rehabilitation. Cognitive rehabilitation draws upon the theoretical and empirical foundations of the cognitive sciences to develop interventions to treat cognitive dysfunction in many different diagnostic groups and healthy older adults with milder, undiagnosed cognitive impairment. The common medical approach to the treatment of cognitive impairment in older adults involves prescribing cholinesterase inhibitors, which may delay the progression of cognitive decline (McAllister & Arnsten, 2008). However, in recent years, rehabilitation of cognitive impairment using non-pharmacological means has become an important aim of clinical psychologists, neuropsychologists, and applied cognitive researchers (e.g., Acevedo & Loewenstein, 2007; Douglas, James, & Ballard, 2004).

Cognitive training (CT) differs from cognitive rehabilitation in that it is not specifically focused on clinically-derived rehabilitation goals and centers on improving general functioning across a number of neurocognitive domains (e.g., Clare, Woods, Moniz Cook, Orrell, & Spector, 2005; Rabipour & Raz, 2012). In the past two decades, a wide variety of CT programs have been developed, often inspired by the motto “Use it or lose it!” (Ackerman, Kanfer, & Calderwood, 2010). Indeed, the term “brain training” has become increasingly common lingo to describe cognitively stimulating activities designed to improved mental fitness. An increasing number of cognitive training programs are computerized, including those designed for older adults (e.g., Manckhe et al., 2006). Video game systems provide a convenient platform for presenting cognitive training programs and a number of video game-based cognitive training protocols, that present players with a wide range of complex cognitive tasks, have been developed and marketed to older adults, such as Brain Age™ (Kawashima, 2006). Although recent well-designed studies have investigated the effectiveness of computerized brain training with adults under the age of 60 (e.g., Owen et al., 2010), empirical support for many of these protocols with older adults is currently lacking.

The forthcoming paragraphs will review a number of non-pharmacological approaches to the remediation of cognitive deficits in older adults. To begin, the effects of aging on human memory systems and other cognitive domains will be discussed. Second, the concept of cognitive rehabilitation will be further defined and different forms of cognitive rehabilitation, and the manner by which they have been applied with older adults, will be reviewed. Important distinctions between the terms cognitive rehabilitation, cognitive training, and cognitive stimulation are highlighted. Third, a variety of approaches that focus specifically on memory training strategies will be presented, including mnemonic techniques, implicit learning paradigms, and external memory aids. The effectiveness and utility of computerized and strategy-based cognitive training protocols, including a discussion of randomized clinical trials of cognitive training programs with healthy older adults, will also be considered. Next, the effectiveness of computerized “brain training” programs will be reviewed, with a focus on the developing literature on video game-based cognitive training programs. A summary of important methodological limitations of the extant literature on cognitive interventions will also be provided. Finally, the foundations for the present study will be addressed.

Age-related Changes in Cognition

Human memory systems. The taxonomy of human memory has been well-established and specifies that long-term memory is comprised of two basic components - explicit and implicit memory (e.g., Tulving, 2000). Explicit memory, also referred to as declarative memory, includes any type of *conscious* memory that requires attention and purposeful recollection. Explicit memories are typically verbally mediated in that they can be described through language. Explicit memory is further subdivided into episodic and semantic memory. Episodic memory, which is a major focus of memory interventions addressed in the current paper, refers to recall of personal experiences that were acquired in a specific context, such as memory for details of a conversation.

Semantic memory refers to general facts, categorizations, and knowledge about the world that are not particularly personally relevant, such as knowledge acquired in school.

Long-term episodic memory has been conceptualized as being comprised of two basic components: item memory and source memory (e.g., Eichenbaum, Yonelinas, & Ranganath, 2007; Johnson, Hashtroudi, & Lindsay, 1993). Item memory represents recall of specific features of to-be-remembered stimuli, while source memory represents recall of contextual details associated with the to-be-remembered item. *Recollection* occurs when individuals accurately recall both item and source elements during retrieval; and *familiarity* occurs when only item specific information is recognized and source details are forgotten or confused (Yonelinas, 2002). Source memory failures have been implicated in the formation of false memories, such as occurs during the misinformation effect, whereby misleading suggestions are retrieved along with inaccurate source information (e.g., Loftus, 2005).

Implicit memory, also referred to as non-declarative memory, is defined as any type of *non-conscious* memory that does not require attention or intentional recollection (Toth, 2000). Because implicit memories form without awareness or intent, it is difficult or impossible to verbally describe these memories. Implicit memory has been theoretically subdivided into three types: perceptual priming, conceptual priming, and procedural learning. Priming refers to any type of learning in which non-conscious habituation to repeated stimuli occurs as a result of earlier exposure. Perceptual priming is centered around the facilitated identification of target stimuli based on incomplete cues (Tulving & Schacter, 1990); and conceptual priming is based on information and associations from semantic memory but occurs at a pre-conscious level (Toth, 2000).

Procedural learning involves the acquisition and performance of skills. Implicit memory has also been targeted in various memory interventions discussed in the current paper.

Working memory is a form of short-term memory that facilitates the temporary storage of verbal or visual information (Baddeley & Hitch, 1974). The Baddeley-Hitch model of working memory posits that verbal information, stored within the *phonological loop*, and visuospatial information, stored within the *visuospatial scratchpad*, is moderated by a central executive system that coordinates the use and transfer of memoranda buffered within working memory to long-term memory. Given that working memory plays a vital role in mental rehearsal of information and is an important marker of global cognitive functioning, many memory intervention studies have utilized outcome measures of working memory. Additionally, other intervention studies that were designed to improve working memory storage will be discussed.

Aging effects on memory functioning. During the course of normal aging older adults experience a variety of age-related cognitive changes including general slowing, reduced processing speed, and reduced cognitive control (Luo & Craik, 2008). In particular, complaints of memory problems are relatively common among older adults. Deficits in episodic memory are associated with normal aging; and they are correlated with a number of physiological and structural changes in the brain that occur with age. These most prominent of these changes is the finding that whole brain volume, as indicated by longitudinal MRI studies, decreases at a slow rate beginning in early adulthood and continuing into old age (e.g., Fotenos, Snyder, Girton, Morris, & Buckner, 2005). These changes are particularly evident in the medial temporal lobe which is the locus of memory formation in the brain (Craik, 2002; Lister & Barnes, 2009). Although memory problems are not ubiquitous among older adults, many studies have demonstrated that anxiety stemming from memory problems is extremely common among older adults (Verhaegen et al., 2000). Such anxiety can disrupt cognitive functioning in and of itself suggesting that coping with anxiety associated with cognitive decline should be considered a key aspect of memory interventions with older adults.

Effective encoding requires elaboration and organization of memoranda in order to foster storage into long-term memory; and retrieval refers to the process of searching for cues in long-term memory in order to facilitate recall. Older adults consistently exhibit deficits at the encoding and retrieval stages of episodic memory formation (Luo & Craik, 2008). These deficits can be explained by the findings that older adults appear to process to-be-remembered information in a shallower fashion during encoding; however, recall is improved to the level of younger adults if information is processed more "deeply" and strategically rehearsed (Troyer, Hafliger, Cadieux, & Craik, 2006). Empirical findings have also demonstrated that older adults exhibit deficits when engaging in more effortful and attentional resource-demanding retrieval operations (Craik & Byrd, 1982). Thus, older adults tend to access stored information more efficiently when they are provided with more cues during the retrieval process.

An expanding body of literature has demonstrated that older adults consistently exhibit memory deficits for source or contextual information (e.g., Naveh-Benjamin, 2000). Consequently, older adults often exhibit deficits in *recollection*, the process of accurately recalling both item and source details of an episodic memory (Yonelinas, 2002). Older adults are often more prone to exhibiting false memory as a result of source monitoring failures (Normal & Schacter, 1997). Mnemonic techniques that seek to improve the recollection process will be discussed later in this paper.

During the course of normal aging, explicit memory tends to decline while implicit memory systems remain intact. Interestingly, even severely amnesic patients often exhibit performance in the normal range on implicit learning tasks despite a general loss of explicit memory (Hamann & Squire, 1997). Performance on implicit priming tasks is typically preserved in healthy older adults. Older adults experiencing cognitive decline due to progressive conditions such as dementia do exhibit slight decreases in implicit learning on priming tasks, although these decrements are minor relative to the observed impairment of explicit memory systems (Fleischman, 2007). A similar pattern is observed with regard to procedural (i.e., skill) learning among healthy older adults and those with progressive cognitive decline (e.g., Squire, 2004).

Aging effects on executive functioning. One such domain investigated in the proposed study is executive functioning. Executive functioning refers to a range of higher-level cognitive processes that control switching of attention as well as sequencing, inhibiting, and monitoring of information (Kolb & Wishaw, 2003). A large body of prior research has localized executive functioning abilities to the frontal lobes, in particular the prefrontal cortex (PFC; e.g., Stuss & Knight, 2002). Accumulating evidence supports the integral role of the PFC in “top-down” processing and in maintaining control over cognitive functions in other parts of the cerebral cortex (Miller & Cohen, 2001). Decreases in executive functioning abilities may also explain a corresponding increase in disinhibited behaviors in a variety of contexts (e.g., social situations) with advancing age (Apfelbaum, Krendl, & Ambady, 2010).

Neuroimaging studies have demonstrated that the PFC is particularly vulnerable to the effects of aging. The PFC exhibits decreases in volume and reduced activation in functional MRI investigations among older adults (e.g., Raz, 2000). Aggregate neuropsychological normative data indicates that with advancing age, adults perform less proficiently on most executive functioning measures (cf. Albert & Kaplan, 1980). Older adults experience more difficulty in maintaining “executive control” during complex cognitive tasks. For example, research has indicated that older adults experience more difficulty than younger adults in switching between tasks and corresponding imaging data reveals that extraneous PFC areas are recruited during these tasks than are represented among younger participants (Friedman, Nessler, Johnson, Ritter, & Bersick, 2008). Inhibition of extraneous or irrelevant stimuli is also viewed as an essential component of executive functioning (Hasher & Zacks, 1988; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). During the course of normal aging inhibitory control has been shown to decline via behavioral data and a similar pattern of additional recruitment in the PFC is also observed (e.g., Nielson, Langenecker, & Garavan, 2002). These data suggest that inefficiency in the manner that neural regions are recruited may explain decrements in executive functioning performance. In effect, this “over-recruitment” has been identified as a possible compensatory mechanism of the brain to adapt to age-related decline (e.g., Grady, 2008).

Aging effects on other neurocognitive domains. In addition to age-related changes in memory and executive functioning abilities, older adults also experience age-related declines in other cognitive domains (Craik & Salthouse, 1992). One area of general decline among older adults is processing speed. Using meta-analytic techniques, Verhaeghen and Salthouse (1997) demonstrated that older adults demonstrate significant decreases in perceptual speed and reaction time across a variety of tasks. Indeed, given the importance of psychomotor speed in cognitive operations, declines in processing speed are postulated to underlie the decrements in performance on most neuropsychological tests (Salthouse, 1996).

Additional research has indicated that decreases in attentional resources during aging may disrupt strategic and effortful memory processes discussed previously in this section (e.g., Craik & Byrd, 1982). Older adults also exhibit declines in efficiency on visual search tasks and other measures of visual attention (e.g., Madden, 2007). Neuroimaging studies across a variety of neurocognitive domains have indicated that the efficiency with which neural regions are activated (i.e., recruited) during cognitive operations decreases with age (Grady, 2008). Other research studies have made the supposition that this generalized decrease in efficiency is responsible for a reduction in performance in areas that have traditionally been assumed to be unaffected by aging, including fund of knowledge, reasoning, and problem solving (e.g., Park, 2000). Although the structural and functional changes observed in the brain during aging are well established, there is evidence to suggest that cognitive training may be effective in reversing deleterious effects. Notably, a recent study found that intensive memory training over the course of eight weeks resulted in a significant increase in cortical thickness among a sample of older adults (Engvig et al., 2010). Preliminary neuroimaging findings have also demonstrated evidence of increased cortical plasticity (i.e., activation) associated with performance improvements following cognitive training (e.g., Erickson et al., 2007; Nyberg et al., 2003). These data hold promise that cognitive intervention programs may also influence tangible changes in the brain in addition to known cognitive benefits.

Mild Cognitive Impairment. MCI is considered a precursor stage to dementia that is more severe than typical decreases in cognitive functioning discussed previously. Older adults with amnestic MCI, the most common form of the condition, report memory problems without cognitive decline in other domains. Other criteria for MCI include: 1) performance on neuropsychological memory measures at or below the 10th percentile, or, 1.5 SD below the level predicted upon the basis of the age-normed IQ; 2) performance in other cognitive domains at normal levels or above the 10th percentile; and 3) no difficulties in ADL performance (Petersen et al., 1999). Some researchers have suggested that individuals with MCI may experience greater difficulty with ADLs and exhibit more decline in ADL performance over time than originally proposed (Wadley et al., 2007). Petersen et al. (1999) documented the rate of progression from MCI to AD among 76 MCI participants over four years and the found the conversion rate was 12% per year whereas those in the healthy control group developed MCI or AD at a rate of 1 – 2% per year. A more recent study reported a conversion rate to dementia of 6.6% in a sample of 2882 MCI participants (Artero et al., 2008). Similar to the Petersen et al. study, a greater percentage of men (8%) than women (6%) developed dementia over the four year duration of this study.

Given that many individuals with MCI are at greater risk for eventually developing AD, interventions for cognitive deficits associated with MCI are becoming increasingly more common. Treatment during this time may help to delay the progression to full dementia. In addition, patients with MCI typically exhibit memory deficits but often retain intact executive functioning and language abilities which allows for learning and practicing of more complicated mnemonic strategies before further cognitive decline sets in.

Dementia and Alzheimer's disease. Dementia is a condition characterized by progressive cognitive decline, which may be caused by a variety of different etiological processes, such as Alzheimer's disease, vascular disease, or Parkinson's disease. DSM-IV-TR criteria for dementia specifies that multiple cognitive deficits must be present including impairment of memory and new learning, and impairment in one or more other cognitive domains (e.g., executive functioning; language; visuospatial abilities). These criteria further specify that cognitive deficits must impair social or occupational functioning and reflect a significant decline from previous level of functioning.

The most common type of dementia, accounting for an estimated 55% of all incidences of dementia, is Alzheimer's disease (Dugue, Neugroshl, Sewell, & Marin, 2003). AD is characterized by a number of neurodegenerative changes in the brain including the development of amyloid plaques and neurofibrillary tangles which leads to synaptic loss and neuronal death throughout the brain. Although empirical findings have demonstrated that healthy older adults without cognitive impairment often develop plaques and tangles, individuals with Alzheimer's are observed to have a higher density of plaques in key areas of the brain responsible for memory and cognition (e.g., Price & Morris, 1999). In contrast to the cognitive changes associated with normal aging and MCI, Alzheimer's disease involves more severe impairment of episodic memory, attention, and language and causes significant impairment of Independent Activities of Daily Living (IADLs).

Many types of cognitive interventions have been implemented with AD patients. Intervention studies have focused on improving episodic memory, facilitating new learning through implicit memory processes, and managing behavioral problems associated with the disease. Given the profundity of declarative memory deficits in AD patients, many intervention studies have implemented techniques that rely on implicit memory processes. Interventions that aim to remediate episodic memory deficits associated with AD will be discussed later in this paper to illustrate the wide variety of non-pharmacological approaches currently in use.

Cognitive Rehabilitation Defined

Cognitive rehabilitation is a process whereby individuals suffering from the cognitive sequelae of various neurological disorders learn strategies to "remediate, reduce or alleviate their cognitive deficits" (Wilson, 2002, p. 98). Neuropsychological rehabilitation is a term that is used to describe cognitive intervention techniques conducted by clinical neuropsychologists as a follow-up to neuropsychological assessment (e.g., Wilson, 1999). Although the terms *cognitive rehabilitation* and *neuropsychological rehabilitation* are often used interchangeably in the literature, Wilson draws a distinction between the two. She opines that neuropsychological rehabilitation is more encompassing and addresses "cognitive, emotional, psychosocial, and behavioral deficits caused by an insult to the brain" (2008, p. 143). Other experts in the field have defined cognitive rehabilitation, generally, as the amelioration of cognitive deficits to improve adaptive functioning in everyday life (Ben-Yishay & Prigatano, 1990; Sohlberg & Mateer, 1989). Ultimately, the goal of any rehabilitation program to treat neurological disorders is to assist individuals in achieving the greatest well-being on physical, psychological, social, and vocational levels (McClellan, 1991). Cognitive rehabilitation programs strive to provide impaired individuals with the opportunity to reintegrate into their lives and improve IADL performance. Regardless of the specific moniker (i.e., cognitive versus neuropsychological) used to refer to rehabilitation programs, rehabilitation experts take a holistic approach to improve functional adaptation in patients suffering from cognitive impairment (e.g., Ben-Yishay, 1996).

Cognitive rehabilitation programs are typically individualized to meet the needs of each patient and his or her family. Neuropsychological evaluation is an important first step of the rehabilitation process, in that it helps clinicians to determine which cognitive domains are most affected by neurological insults and directs intervention strategies (e.g., Caramazza & Hillis, 1993). Many neuropsychologists recommend assessing across several neurocognitive domains, including working memory, visuospatial function, episodic memory, and executive functioning prior to initiating cognitive interventions (e.g., Papp, Walsh, & Snyder, 2009). Given the emphasis on holistic treatment of cognitive impairment, rehabilitation strategies are typically devised collaboratively by the patient and their family with expert direction from the clinician, professional staff and results of psychometric tests (Wilson, 2008; 2009). Patients and their families develop personally meaningful goals for treatment in a way that fits life routines (Ylvisaker & Feeney, 2000). Recent research has demonstrated that psychosocial factors must also be taken into consideration during the course of any cognitive rehabilitation program as these factors can strongly influence treatment outcomes (e.g., Krpan, Levine, Stuss, & Dawson, 2007; Winocur et al., 2007). Thus, the development of personalized, mutual goals for rehabilitation is often considered an important method for determining the direction of treatment, even more effective than relying on the results of a neuropsychological evaluation to guide intervention (Wilson, 2003).

The main diagnostic groups commonly seen by rehabilitation experts are Traumatic Brain Injury (TBI), stroke, encephalitis, hypoxic brain damage, progressive neurological conditions (e.g., AD), cerebral tumors, and epilepsy (e.g., Wilson, 2008). Cognitive rehabilitation strategies have been successfully utilized in the remediation of a variety of neuropsychological deficits associated with the preceding conditions (e.g., Sohlberg & Mateer, 2001). Treatments for aphasia are considered to be the most developed form of cognitive rehabilitation, with a large base of research beginning after World War II (e.g., Leon et al., 2008). Cognitive rehabilitation strategies have also been developed to treat visual neglect (e.g., Robertson, Hogg, & McMillan, 1998), executive dysfunction (e.g., Cicerone, Levin, Malec, Stuss, & Whyte, 2006), attentional problems (e.g., Sturm, Willmes, Orgass, & Hartje, 1997).

Major Approaches to Cognitive Intervention

Before reviewing specific non-pharmacological cognitive and memory interventions, the basic context of cognitive interventions with older adults will be discussed in this section. Clare and colleagues (2005) differentiated between the following three approaches to non-pharmacological cognitive intervention with older adults: *cognitive rehabilitation*, *cognitive training*, and *cognitive stimulation*. These different forms of cognitive intervention can be organized from specific to general according to the scope of treatment. As defined earlier, cognitive rehabilitation is at the most specific level of intervention. Cognitive rehabilitation aims to improve adaptive functioning (i.e., IADLs) utilizing individualized intervention strategies (e.g., Sohlberg &

Mateer, 1989). Many of the techniques used in the field of cognitive rehabilitation have provided a historical and theoretical basis for research on cognitive training.

Cognitive training (CT) is a broad term that encompasses a wide range of protocols for improving mental fitness with individuals of various ages. CT protocols are often based on theoretically motivated strategies to improve a wide range of cognitive functions, such as memory, reasoning, problem solving, and various others (Belleville, 2008; Green & Bavelier, 2008). Although less goal-directed than cognitive rehabilitation, CT may still be intensive and involve daily training activities over extended periods of time. Mowzowski, Batchelor, and Naismith (2010) divided CT into two basic types: *strategy-based* and *computerized*. Strategy-based CT is often provided face-to-face and teaches both internal and external strategies to adapt to cognitive deficits. Computerized CT, which is the focus of the current study, involves games and exercises targeting various cognitive domains that are usually completed individually with minimal professional support. Both strategy-based (e.g., targeted memory interventions) and computerized CT will be discussed later in this review.

Finally, cognitive stimulation refers to various non-specific activities, often provided without professional support, that have been shown to enhance cognition (For review see Hertzog, Kramer, Wilson, & Lindenberger, 2009). Examples of cognitive stimulation include reading, playing cards, engaging in intellectual discourse, or playing a musical instrument. Lifelong participation in mentally stimulating activities promotes cognitive health in general and even reduces the risk of developing AD (Belleville, 2008; Hertzog et al., 2009). Thus, cognitive stimulation can be viewed as an essential protective factor against cognitive decline throughout the lifespan.

Although it may not specifically address rehabilitation goals, participation in mentally stimulating activities may be a helpful adjunct to the intervention process. For example, clinicians might encourage patients to engage in supplementary activities, such as random memorization of word lists, playing cards, or solving crossword puzzles, as a means of bolstering treatment effects. In fact, one recent study demonstrated the effectiveness of incorporating a supplementary mental stimulation session (e.g., solving crossword puzzles, performing mathematical calculations, etc.) in addition to cognitive training presented via computer for both healthy and impaired elderly participants (Eckroth-Bucher & Siberski, 2009). Although cognitive stimulation is often conceptualized as a preventive means to forestall cognitive decline, the previous study demonstrates that cognitive stimulation can bolster the effects of cognitive training in older adults.

Cognitive stimulation has also proven useful in treatment of older adults with more severe forms of cognitive decline. In a large randomized controlled study, dementia patients who received cognitive stimulation therapy were compared to elderly controls (Spector et al., 2003). All participants were recruited from residential and day treatment centers and not prescribed cholinesterase inhibitors. Participants in the cognitive stimulation group received reality orientation therapy, which was focused on the presentation and repetition of personal and orientation information and encouraged reminiscence. Following intervention, participants in the cognitive stimulation group exhibited significantly better performance on the MMSE, ADAS-Cog, and the Quality of Life in Alzheimer’s Disease Questionnaire than AD controls. Cognitive stimulation in this study was less complicated and focused on basic redirecting to orientation and autobiographical information. This was a well-designed, large study that demonstrated the efficacy of cognitive stimulation with more severely impaired dementia patients (i.e., inclusion criteria specified MMSE scores were between 10 and 24). One limitation, however, is that gains exhibited by more severely demented patients are temporary and continued reorientation and reminding is necessary to maintain gains. While a comprehensive discussion of cognitive stimulation is beyond the scope of this review, it is important to recognize that all of the empirical evidence in support daily mentally stimulating activity to promote cognitive reserve.

Memory Training with Older Adults

Memory disorders are a pervasive problem in society and negatively impact quality of life among adults and older adults (e.g., Wilson, 2009). A cursory review of the literature on cognitive interventions reveals that the vast majority focuses on or addresses memory deficits as a target of intervention. Within the context of memory disorders, rehabilitation techniques often seek to teach individuals to utilize intact abilities (e.g., executive functioning skills) to compensate for memory deficits. Many memory rehabilitation techniques arose from strategies aimed at treating victims of TBI (Wilson & Kapur, 2008). In fact, the first rehabilitation programs began following World Wars I and II as the return of soldiers suffering from head injuries necessitated the development of treatments for cognitive symptoms in addition to occupational and physical therapies (Boake, 1989). The fundamental difference between memory interventions designed for TBI patients and those designed for elderly patients is that the latter are typically more time-limited. Given the progressive nature of conditions that typically afflict older adults, such as dementia, rehabilitation techniques are generally more intensive and comprehensive (e.g., Hill, Backman, & Neely, 2000). Additionally, there appears to be a bias towards implementing technological aids and computer-based training programs with TBI patients (e.g., Kapur, Glisky, & Wilson, 2004) considering the average rate of head injury is highest among individuals aged 15 to 24 (Langlois, Rutland-Brown, & Thomas, 2006). This is not uniformly the case, as more recently, researchers have begun to implement computerized training procedures with geriatric patients (e.g., Gunther, Schafer, Holzner, & Kemmler, 2003).

Types of Memory Interventions. Glisky and Glisky (2008; Table 31.1) identified three broad classes of memory interventions organized according to the general goals for rehabilitation. First, there are methods that seek to optimize residual memory function. These include mnemonic tactics for improving encoding of information, such as visual imagery formation, semantic elaboration, self-referential processing, and integrative encoding, or, tactics that improve the retrieval process. Into this first category, Glisky and Glisky also include non-mnemonic methods that factor into optimizing memory function, such as allowing for increased rehearsal time and pharmacologic treatments. These non-mnemonic factors are not discussed in depth in the present review. The second class of memory rehabilitation techniques includes those that seek to substitute intact function for lost or declining function. These methods are strategies that utilize intact cognitive processes (i.e., implicit memory) to compensate for decreased explicit memory function. Examples of this second class of interventions include spaced retrieval, vanishing cues, and errorless learning. Thirdly, there are methods that seek to provide external compensation for lost function. This class of interventions includes external memory aids and environmental support for individuals with memory problems. In the following sections, a variety of the mnemonic aids and other interventions outlined by Glisky and Glisky (2008) are described as well as the theoretical underpinnings that have led their development.

Mnemonic techniques. Mnemonic aids are “systems that enable people to organize, store, and retrieve information more efficiently” (Wilson & Kapur, 2008, p. 527). Countless mnemonic techniques have been developed over the years by educators, psychologists and cognitive scientists alike, as knowledge about the mechanics of human memory have been elucidated. Perhaps the most ubiquitous example of a mnemonic technique is the proliferation of acronyms in use in society. Acronyms are one of the most basic forms of a mnemonic device whereby words are related to letters in order to facilitate recall. Mnemonic devices facilitate recall by “chunking” information and associating it with cues.

One of the most common mnemonic techniques used to improve encoding is visual imagery formation. The effectiveness of visual imagery mnemonic training is supported by a large literature which demonstrates that humans possess a large capacity for remembering visual information (e.g., Paivio, 1969). Imagery mnemonic training involves the formation of distinctive, detailed images to help encode to-be-remembered materials (e.g., Hill, Evankovich, Sheikh, & Yesavage, 1987). Individuals can form images mentally or they may be presented with actual pictures of to-be-remembered items. This strategy has been used in a variety of ways to assist memory-impaired individuals in improving everyday memory performance, such as training to better remember people’s names (e.g., Backman, Josephsson, Herlitz, & Stiggsdotter, 1991).

In a typical face-name mnemonic task, participants are presented with several photographs and corresponding names; and then directed to identify a distinctive feature of each face, create a visual association with the name, and connect the association to the selected facial feature. Although the aforementioned strategy has been found to be only marginally effective in improving recall of face-name associations among AD patients (Backman et al., 1991), similar strategies have been shown to be effective among younger TBI patients (Hux, Manasse, Wright, & Snell, 2000), perhaps suggesting that this task may be too complex or effortful for patients with cognitive decline of the variety associated with AD. Visual imagery formation has, however, been demonstrated to improve learning and retention of foreign vocabulary in healthy elderly participants (Gruneberg & Pascoe, 1996). Another study presented older adults with a variety of mnemonic strategies, among them visual imagery, and found that those who were subjected to more intensive training demonstrated greater gains in task performance with regard to memory for names (Woolverton, Scogin, Shackelford, Black, & Duke, 2001). These findings suggest that visual imagery formation may be a more complicated method that is, however, worthy of the more protracted training required to improve episodic memory. The finding that visual imagery training does not appear to generalize to everyday functioning persists as a major critique of this method (Verhaeghen, Marcoen, & Goossens, 1992).

Semantic elaboration refers to any number of elaborative encoding strategies that are implemented as mnemonic aids. According to the levels of processing theory developed by Craik and Lockhart (1972), deep processing of to-be-remembered material, including such previously discussed strategies such as semantic processing or visual imagery formation, fosters enhanced long term recall. During elaborative encoding, individuals are encouraged to engage in deep processing by linking aspects of the to-be-remembered material together to create a more meaningful memory trace. Thus, material that is semantically organized during encoding is better recalled than unorganized rote material. One of the most common examples of semantic elaboration is building a meaningful story from rote verbal material, such as a word list. Many studies have demonstrated that when older adults semantically elaborate on presented information, recall is drastically improved compared to when simple rehearsal is employed as the only encoding strategy (e.g., Cherry et al., 1996).

In a recent study, university students and older adults were presented with numerous surnames and instructed them to use one of four different encoding strategies: physical processing (i.e., repeating first letter of the names); phonemic processing (i.e., generating words that rhymed with target surnames); semantic processing (i.e., linking the surname to another meaningful fact or making an association); and simple repetition of the surnames (Troyer et al., 2006). Among older adults, recognition memory for names was most improved in the semantic processing condition compared to the other three strategies; and, importantly, older adults recognized a greater proportion of names than younger adults who used the semantic encoding strategy. Interestingly, semantic elaboration appears to be limited in effectiveness when older adults are presented with emotionally salient memoranda. One study found that when that when older adults were presented with emotional objects (e.g., snake) embedded into complex scenes, and instructed to use elaborative encoding processes, they demonstrated enhanced memory for only the emotional objects and not for background details, whereas younger adults showed enhanced recall for both emotional and visual specifics of the scene if they employed elaborative encoding (Kensinger, Gutchess, & Schacter, 2007). Therefore, semantic elaboration may be a strategy best reserved for memorizing neutral information.

Personal relevance of memoranda is also an important factor in the formation of episodic memories. An interesting aspect of the investigations discussed above is that participants in both studies were allowed to develop their own unique semantic processing strategies for memorization. In the Kensinger et al. study participants were encouraged to develop stories linking together aspects of visual scenes; and in the Troyer et al. study participants linked surnames to their own fund of knowledge (i.e., self-generated facts). Many researchers have noted that self-generated encoding strategies are often more effective than taught strategies (e.g., Glisky & Glisky, 2008). For example, older adults demonstrate increased recall of numerical stimuli when they are allowed to select their own memorization strategy (Derwinger, Stigsdotter Neely, Persson, Hill, & Backman, 2003). Moreover, when older adults are able to relate to-be-remembered materials to autobiographical details, recall is greatly enhanced (Glisky & Marquine, 2009). Similarly, elderly individuals demonstrate better recall for self-generated memoranda than for externally presented information (e.g., Glisky & Rabinowitz, 1985).

Attempts to teach older adults strategies to integrate source details with the item during encoding have met with success. Essentially, integrative encoding strategies are based on the same fundamental mechanism (i.e., deep processing; Craik & Lockhart, 1972) of other elaborative encoding strategies; however, the focus of the former is on improving recollection. Research has demonstrated that age-related source memory deficits are not as evident if older adults are encouraged to engage in deep processing during encoding with regard to source elements (Glisky, Rubin, & Davidson, 2001). A practical application of this notion was demonstrated in a study of prospective memory in which older adults were encouraged to use environmental (i.e., contextual) cues to facilitate compliance with completing future experimental tasks (Schmidt, Berg, & Deelman, 2001). In this study, elderly participants were instructed to mentally image the retrieval context of prospective tasks (e.g., envisioning the room in which they would be asked to make phone call at a specified time) during encoding as a means of increasing the likelihood that source details would serve as reminders to complete said tasks. Older adults who were trained to anticipate source cues completed more prospective tasks than participants in a control group that received psychoeducation about memory processes. These findings show that older adults may be able to overcome age-related source memory deficits if they are mindful of contextual cues present in their daily life during the encoding process.

The method of loci technique (Yesavage & Rose, 1983) is another common mnemonic device. Method of loci is a technique in which to-be-remembered information is linked to specific locations in a familiar setting. For example, individuals instructed in the use of this strategy are encouraged to conjure a mental image of their own home and associate words from a presented wordlist with different rooms of the house. The method of loci technique has been used successfully with older adults to memorize wordlists (Hill, Allen, & McWhorter, 1991). In this study older volunteers were presented with a list of 52 nouns, instructed to relate the words to locations in each participant’s principal residence, and during recall encouraged to “take a mental walk” through their house to facilitate recall. The method of loci group performed comparably with regard to both immediate and delayed recall to a group that used a story-telling mnemonic (i.e., semantic elaboration).

Method of loci appears to effectively combine aspects of two aforementioned techniques, visual imagery formation and self-referential processing. When participants relate memoranda to a mental image of their home, they are more likely to succeed in retrieving this information because cues are based on autobiographical and overlearned spatial knowledge. Numerous studies have demonstrated that the most innate function of the hippocampus, the locus of memory formation in the brain, is to construct spatial maps of an organism's environment (Squire, Stark, & Clark, 2004). It follows that older adults have developed highly detailed maps of familiar environments that may be used as a basis to facilitate new learning.

Compensatory strategies. Compensatory strategies are techniques that utilize intact cognitive processes to substitute for episodic memory deficits. A variety of compensatory strategies that draw upon research findings on implicit learning are discussed in the following sections. As discussed previously, implicit memory tends to decline more slowly than explicit memory during the process of aging, which suggests that memory-impaired elderly retain the ability to learn, albeit not in the traditional manner. Moreover, strategies that seek to exploit implicit cognitive processes may provide opportunities for rehabilitation in older adults suffering from severe cognitive decline as a result of AD.

Errorless learning. One of the most well researched compensatory strategies that ostensibly relies on implicit memory is errorless learning. Errorless learning refers to paradigms that seek to eliminate errors during the training process (Clare & Jones, 2008).

The theoretical origins of the errorless learning paradigm arose from behavioral studies with pigeons conducted by Terrace (1963a, 1963b). The general finding of these studies was that pigeons could be taught to discriminate between two stimuli by positive reinforcement alone, without the use any negative reinforcement, to the extent that the animal's performance on pecking tasks was deemed "errorless." With regard to human learning, this theory has been adapted to show that individuals with severe episodic memory deficits can acquire familiarity and subsequently correctly recognize items that are continuously reinforced over multiple trials. Errorless learning paradigms aim to provide continual feedback during learning in order to provide repeated exposure to correct information, which ostensibly fosters implicit learning. To this end, participants are discouraged from guessing and researchers gradually provide fewer and fewer prompts as accuracy rates increase. A variety of errorless learning methods have been developed and implemented with older adults with more severe episodic memory deficits (e.g., Clare & Jones, 2008); and these methods are posited to be superior to trial-and-error, also known as *effortful*, learning for these individuals (Evans et al., 2000).

Evans and colleagues (2000) compared between errorless learning and trial-and-error learning in groups of severely amnesic patients. Evans et al. were able to successfully teach patients to complete a variety of everyday tasks using the errorless learning method. In the first study phase (Experiments 1-3) participants were trained to remember names, learn a route around a room or program an electronic organizer. For example, in Experiment 1 participants were taught to remember the names using a form of errorless learning called "backwards chaining" in which they were initially presented with the full name (e.g., SALLY) and on successive trials they were presented with fewer and fewer letters of the name (e.g., SALL, etc.); while another errorless learning group used an inverse of backwards chaining called stem completion (e.g., Given “S” and told the full name, then given “SA” and told the full name). Participants in both errorless learning groups performed better than a trial-and-error condition at immediate and delayed recall. Similar backwards chaining and stem completion methods were developed for each task in successive experiments. The authors concluded across experiments that errorless learning methods were more effective than trial-and-error learning; however, beneficial effects were more evident if the delay between learning and recall was shorter. Given the intensive training regimen necessary for errorless learning tasks, these results call into question the clinical utility of these tasks for any older adults except those with severe declarative memory deficits.

Another common form of errorless learning is the method of vanishing cues (Glisky, Schacter, & Tulving, 1986). It is another form of rehabilitation often reserved for more processes by providing patients with progressively weaker cues over repeated presentations pending correct recall (e.g., mind, min_, mi__, m___, ____). The technique was originally developed as a means to teach amnesic patients computer terminology (Glisky et al., 1986). In this study the amnesic patients acquired the computer terms through both backward and forward chaining procedures. Forward chaining is simply the inverse of the previous example whereby participants are given the full word and then expanding cues starting with the presentation of the first letter of target words. One study found that the vanishing cues method did not produce any significant learning advantage for face-name associations compared to other effortful processing conditions (Dunn & Clare, 2007). Contrary to other studies demonstrating the effectiveness of errorless learning, the authors concluded that learning conditions that do not focus on reducing errors, thus inducing participants to exert more effort, are equally effective in new learning. The Dunn and Clare (2007) investigation must be evaluated cautiously, as the patients were early-stage dementia and experiencing less severe memory decline than is typical of dementia patients in other errorless learning studies (e.g., Glisky et al., 1986).

Spaced retrieval. Spaced retrieval refers to any learning strategies that involve expanded rehearsal of to-be-remembered material (e.g., Wilson, 2009). Memoranda are retrieved at gradually increasing intervals, during which participants are engaged in mental distraction, and when information is correctly recalled the retention interval is increased. This method of learning is particularly effective in teaching elderly patients to remember names, addresses, and other important pieces of information. Spaced retrieval has been compared to other rehearsal schedules in patients with dementia with the frequency of errors being monitored in the training process (Hochhalter, Overmier, Gasper, Bakke, & Holub, 2005). Although spaced retrieval training did improve long-term retention of pill names and visual patterns, it did not increase performance more than other rehearsal schedules used in the study.

Spaced retrieval is frequently used as a means of structuring the acquisition of other errorless learning methods. In one spaced retrieval study (Clare et al., 2000) six patients with memory problems were assisted in the relearning of various pieces of personal information and in the use of a technological memory aid (e.g., Neuropage) according to a “multiple single-case experimental design” (p. 135). With all of the patients, the study coordinators coupled the method of vanishing cues with expanded rehearsal all while attempting to minimize errors during the learning process. As an example, one participant who wanted to learn the names of members of his social club was instructed in the visual imagery method focusing on prominent facial features and the name was trained using vanishing cues with expanded rehearsal. All six participants demonstrated significant gains in everyday memory task performance during the intervention, at post-intervention, and at a follow-up 6 months later.

One study directly compared the effectiveness of spaced retrieval, vanishing cues, errorless learning, and two different trial-and-error methods with either explicit or implicit instructions (Bier et al., 2008). In this study a group of early AD patients and healthy elderly controls attempted to learn face-name associations under each of the five learning conditions. One of the key methodological variations in their study was that the instructions were provided implicitly in all of the learning conditions (except for the explicit trial-and-error condition). That is, detailed task instructions were not explicitly provided and cues appeared without explanation. Participants in both the AD and control group showed significantly improved free recall, cued recall, and recognition under all of the learning conditions. Similar to Hochhalter et al. (2005), there were no significant differences among the five learning groups with regard to task performance. Although the errorless, spaced retrieval, and vanishing cues conditions facilitated lower error rates than trial-and-error conditions, there were still errors committed in the “errorless” conditions. Moreover, error rates were not highly correlated with task performance.

A two case study report demonstrated that errorless learning and spaced retrieval techniques were effective in helping AD patients relearn forgotten ADLs (Thivierge, Simard, Jean, & Grandmaison, 2008). After five weeks of training both participants achieved nearly perfect performance on specific ADL goals, which involved learning to check voicemail and learning to use an answering machine, respectively. In another study ten AD patients completed spaced retrieval training and observed the effect on memory for target objects trained via spaced retrieval and several other memory measures (Cherry & Simmons-D'Gerolamo, 2005). Five of the participants had participated in a prior study, which provided an opportunity to study the long-term effectiveness of spaced retrieval training. Training effects (i.e., memory for target objects) were observed among these five participants 6 to 11 months after their original exposure to the procedure. This study demonstrates that gains in implicit learning may have long-lasting effects. Further research with larger sample sizes is necessary to determine whether implicit learning procedures can be applied to improve adaptive functioning.

Findings from the previous studies suggest that errorless and spaced retrieval learning may not be any more advantageous than traditional learning methods. In both of these studies AD patients were nonetheless able to increase recall of to-be-remembered stimuli under trial-and-error conditions as well as errorless conditions. Additionally, performance gains in errorless learning often only occur after intensive training over the course of several sessions. These drawbacks call into question the efficacy of utilizing errorless learning methods in rehabilitation settings with elderly clients. In general, errorless learning methods appear to be most beneficial for patients with more advanced memory problems. Given the time necessary to achieve learning gains, errorless learning methods may be best reserved for elderly patients in residential settings where there would be more time for an intensive training regimen and staff can assist in selecting the most vital verbal information for each resident to remember on an individual basis.

Finally, procedural memory is another form of implicit memory that may be a promising target for intervention as an indirect means of rehabilitating explicit memory. It has been demonstrated that AD patients can learn new motor skills and perform as well as younger adults on lexical priming tasks (another form of implicit memory) despite profound declarative memory deficits (Deweer et al., 1994). Even individuals with severe dementia may be able to compensate for memory deficits by learning new motor movements. AD patients have been retrained to perform IADLs (e.g., face-washing) by occupational therapists repeatedly modeling and encouraging continual practice of the necessary motor movements (Zanetti et al., 2001). Although improvement of IADL performance is especially helpful for caregivers of dementia patients, more research needs to be conducted on methods to utilize intact procedural learning to compensate for declarative memory deficits.

External memory aids. The third major class of memory interventions involves external memory aids (Glisky & Glisky, 2008). Unlike the internal mental strategies discussed previously, external memory aids are designed to decrease reliance on memory functioning by changing the individual’s environment to provide reminders of vital information. External memory aids are extremely effective in rehabilitating memory functioning in cases of mild memory impairment and are often easier to implement than internal strategies in that they circumvent persistent memory difficulties without the risk of forgetting. Based on anecdotal reports of their efficacy, many clinical neuropsychologists recommend that their patients use simple memory aids, such as electronic calendars, pillboxes, or notebooks. In the United Kingdom public health officials have recognized the negative impact of memory problems among the populace and have set up memory clinics at hospitals throughout the country (Wilson, 2009). A major aim of these memory clinics is to provide external memory aids to memory-impaired citizens and educate them about their use.

A wide variety of external memory aids have been suggested for use and empirically validated with memory-impaired elderly, ranging from the simple (e.g., usage of a pocket calendar) to the technologically complex (e.g., Blackberry devices with programmed reminders). Another form of external memory aid is the “environmental memory aid” (Wilson & Kapur, 2008). These are defined as methods of reorganizing the patient’s environment to facilitate reminding (e.g., color coordinating folders with important documents). There are countless ways that rehabilitation experts can assist patients in rearranging their homes to circumvent forgetfulness. A thorough discussion of external memory aids is clearly beyond the scope of this paper; however, many of these aids have been empirically validated and demonstrated as effective (e.g., Sohlberg et al., 2007).

Cognitive Training

One of the primary aims of both strategy-based and computerized cognitive training (CT) is the generalized improvement of abilities across multiple neuropsychological domains (i.e., multimodal). Accordingly, many cognitive training programs train multiple cognitive processes simultaneously or engage participants in completion of higher-level tasks that involve multiple brain areas (e.g., speeded arithmetic; reading aloud) rather than focusing specifically on mnemonic techniques (e.g., Ackerman et al., 2010; Richmond, Morrison, Chein, & Olson, 2011). Training goals based on theoretical teaching models may also be organized into separate *modules* to emphasize different cognitive skills (e.g., Ball et al., 2002; Craik et al., 2007).

As an example of the multimodal approach, Belleville and colleagues (2006) presented elderly MCI patients and cognitively intact elders with attentional training, executive organizational skills, and memory training over the course of eight two-hour sessions. Participants received computerized attentional training, were trained in various mnemonic strategies (e.g., interactive imagery) to improve episodic memory, and in the last session participants were trained in verbal organization techniques. The intervention was effective for both MCI participants and those with no cognitive impairment: all trained participants demonstrated significant improvements in delayed recall of wordlists and face-name associations. These findings indicate that mnemonic training was effective in increasing recall of rote information (i.e., wordlists) and face-name associations but was not able to be successfully applied to narrative text. Participants also exhibited greater subjective assessment of their own memory ability following training. A psychoeducation component was effectively included into the memory training regimen which impacted the improved subjective memory rating in this study.

One recent study implemented a novel approach in that their training program was developed in order to foster transfer of benefits from the training context into “real world” situations (Levine et al., 2007). The authors employed a multimodal approach focusing on three modules: memory skills training, goal management training, and psychosocial training (cf. Stuss et al., 2007, Methods). The primary aim of the goal management training module was to assist participants in learning to effectively use a variety of mnemonic strategies in vivo to meet personal goals for improving everyday memory. Moreover, psychosocial training aimed to improve participants' self-confidence in their cognitive abilities and enhance psychological well-being. Levine and colleagues demonstrated that participants in the program, compared to those in a wait-list control group, performed significantly better on simulated real life tasks in the laboratory (e.g., arranging people into carpool groups). Analysis of a wide range of psychosocial outcome measures showed a significant increase in psychological well-being among those participants that received training (Winocur et al., 2007). While other investigations have investigated the impact of cognitive interventions on everyday functioning (e.g., Wadley et al., 2007), only a few recent studies specifically focused on the transferability of training from the laboratory to the real world (Levine et al., 2007; Winocur et al., 2007).

Memory enhancement training was implemented with nine MCI participants consisting of relaxation training, psychoeducation regarding memory deficits, and various mnemonic strategies (Rapp, Brenes, & Marsh, 2002). Participants were assessed at pre, post, and follow-up for memory task performance, perceived control over memory, and their usage of mnemonic skills. There was a marginally significant impact of training on memory for wordlists at follow-up. At post-intervention, participants in the training group reported greater perceived memory ability, significantly stronger belief in their ability to control their own memory, and less concern that their cognitive abilities would decline. At six month follow-up, the training group reported greater perceived memory ability and usage of mnemonic techniques. The study demonstrated that memory enhancement training might significantly affect participants' subjective belief in their memory ability; however, this confidence did not affect objective measures of memory.

A few intervention studies have taken a more comprehensive approach to rehabilitation by coupling cognitive interventions with concurrent pharmacologic treatment. Loewenstein and colleagues (2004) investigated the efficacy of a cognitive rehabilitation program versus nonspecific mental stimulation with AD patients who were prescribed cholinesterase inhibitors. The cognitive rehabilitation group received spaced retrieval training for learning face-name associations, orientation training through the use of a memory notebook and calendar, and practiced various skills to improve performance of ADLs (e.g., Practice making change for a $20 bill). In the mental stimulation group, participants played interactive computer games (e.g., Hangman) that were intellectually stimulating. With regard to trained tasks, the rehabilitation group performed significantly better than the mental stimulation group on face-name association learning, orientation tasks, change-for-a-purchase task, and an attentional task (i.e., Continuous Performance Test) at post-intervention and three month follow-up. Performance on untrained neuropsychological measures was not drastically affected by training, aside from increased performance on a list-learning task in both groups. These findings suggest that focused rehabilitation training, as opposed to nonspecific stimulation may supplement the effects of medication in patients with AD.

Randomized clinical trials with healthy older adults. Several recent randomized controlled trials have examined the impact of strategy-based cognitive training programs among older adults without diagnosable memory impairment. In contrast to most of the intervention studies discussed previously, these studies appear to be of better methodological quality and have employed larger sample sizes. Additionally, there is a greater emphasis on internal mnemonic strategies, rather than implicit memory processes as seen in many of the studies with AD participants. Research with cognitively intact older adults is essential to determine whether training is effective during a period of life when normal age-related declines in cognition are inevitable. In addition to the known benefits of lifelong participation in mentally stimulating activities, focused cognitive training in older adulthood may delay cognitive decline and serve as an additional protective factor.

The largest randomized controlled trial ever conducted that investigated the effectiveness of cognitive and memory training with older adults was the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study by Ball and colleagues (2002). The ACTIVE study was a multi-site study in which 2,832 older adults who were living independently and cognitively healthy, were recruited. Older adults were assigned to either control, memory, speed of processing, or reasoning training groups. In the memory training group, participants were taught various mnemonic strategies to remember word lists, sequences of items, and text material over the course of 10 sessions. Outcome measures focused on assessing the impact of training on objective memory using standardized neuropsychological measures (e.g., Hopkins Verbal Learning Test), everyday memory, and performance of IADLs. Ball et al. found that memory training significantly improved performance on memory outcome measures over the 24 months of the study; and among participants that received booster sessions of memory training performance was not significantly enhanced beyond the original group. One striking finding of the ACTIVE study was that memory training only improved performance on memory outcome measures but did not impact processing speed, reasoning, or measures of everyday functioning (e.g., driving habits, IADLs). The authors speculated that the lack of improvement in performance on measures of everyday functioning was due to the fact that participants in this study were already performing at or near ceiling levels on these measures. In general, the ACTIVE study was a well-designed investigation that demonstrated that memory training can effectively enhance memory skills, even among cognitively healthy older adults, but may not easily transfer into everyday functioning.

A major follow-up investigation was conducted with the ACTIVE sample five years after the original investigation (Willis et al., 2006). Of the older adults who participated in follow-up assessments, those who received booster training experienced less decline in abilities in the cognitive domain in which they were trained. Once again, training effects did not extend beyond the specific domains targeted. Contrary to the original ACTIVE study, Willis and colleagues found that cognitive training reduced self-reported difficulties with ADLs compared to the control group; however, this was only statistically significant among the reasoning training group. Interestingly, memory training did not impact everyday functioning over the five years of the ACTIVE study. The advantage observed as a result of reasoning training may be due to the ubiquity of reasoning skills in daily life, whereas memory training may be more limited in this regard. This study suggests a need for cognitive training protocols to continue to focus on improving the degree of transfer to everyday life.

The Donostia Longitudinal study examined the effectiveness of an intensive multimodal cognitive training protocol over the course of two years (Buiza et al., 2008). Older participants in this study reported mild age-related memory complaints (i.e., 1 SD below average) but did not meet criteria for MCI or any other form of dementia. There were two intervention groups in which training was directed at all cognitive functions with the only difference being that the second intervention group was less structured than the first. Over the course of the two years of the study, participants in both intervention groups performed significantly better on working memory and immediate memory measures. In addition, scores on "learning potential" measures, which assesses the ability to learn from past experiences and adapt using abstract reasoning, improved significantly in the experimental groups relative to the control condition. Training did not significantly impact performance in the areas of visuomanual coordination or processing speed. The authors suggested that the memory improvement was likely due more to practice effects, as the researchers used the same measures (e.g., Logical Memory from the WMS-III) repeatedly. Regardless, the increase in learning potential observed in this study suggests that cognitive plasticity remains relatively stable in old age and these skills may be more transferable to daily life.

Psychosocial aspects of CT. Another important component of cognitive training programs is psychoeducation. For instance, metamemory training, which educates older adults participating in rehabilitation programs about the mechanics of human memory and informs them about additional psychological factors (e.g., anxiety) that may affect their memory, is often employed. Program developers have incorporated metamemory training into multimodular interventions in a variety of ways. In the case of rehabilitation programs that are designed for older adults with MCI or AD, it is often necessary to provide psychoeducation sessions to describe and discuss the symptoms and course of neurodegenerative disorders.

In studies with MCI older adults, researchers have presented participants with information on dementia and various factors that influenced memory performance, such as fatigue, anxiety, and motivation (e.g., Rapp et al., 2002). Another training program for MCI patients included an intensive four week structured program with continuous psycho-education, health education, and metamemory education (Kurz, Pohl, Ramsenthaler, & Sorg, 2009). This program included information on health and lifestyle, education about MCI and medical treatments, and, strategies for coping with stress and anxiety; and for family caregivers of the MCI participants, the program developers included psychoeducation and problem-solving to resolve difficult behaviors. Studies with healthy elderly have focused on providing information on how psychological well-being is related to memory functioning and discussing changes in memory related to normal aging (e.g., Buiza et al., 2008). In all of the aforementioned studies psychoeducation played in important role in the training protocol.

In addition to psychoeducation regarding the nature of memory impairment, many rehabilitation programs also teach participants coping strategies to deal with stress, and symptoms of anxiety and depression, which often co-occur with age-related memory problems. It is widely recognized that memory problems inspire fear in older adults and can often lead to development of clinical depression and situational anxiety when memory disturbances occur in daily life (Verhaeghen et al., 2000). Memory training programs that include a psychosocial intervention module engender improvements in overall psychological well-being, including perceived happiness, use of appropriate coping strategies, and quality of life (Winocur et al., 2007). Given the large literature in support of the Yerkes-Dodson curve (1908), whereby moderate arousal enhances cognitive performance, but very low or very high arousal states (e.g., anxiety) lead to decreased cognitive performance, it is important for researchers to teach psychosocial intervention strategies for coping with situational anxiety. Many researchers have addressed anxiety among older adults by teaching relaxation strategies alongside mnemonic training (Yesavage, 1984). Numerous multimodal memory training studies have instructed participants in the use of various relaxation strategies to reduce the potential impact of anxiety in daily life (Kurz et al., 2009; Londos et al., 2008; Rapp et al., 2002).

Risk studies have demonstrated that older adults with depression are at greater risk for experiencing clinically significant cognitive decline to the extent that depression is often considered a prodromal stage for dementia (e.g., Steffens et al., 2007). An increasing number of cognitive training studies have incorporated self-report measures of depression. Additionally, a few prior studies have indicated that CT often produces the beneficial impact of reducing depressive symptoms (e.g., Kurz et al., 2009; Rozzini et al., 2007). The findings are not entirely uniform: Not all CT studies incorporating mood measures have demonstrated an effect on depressive symptoms (e.g., Elgamal, McKinnon, Ramakrishnan, Joffe, & MacQueen, 2007; Naismith et al., 2011). At a minimum, the prior studies underscore the importance of assessing the impact of cognitive interventions on depression and mood.

Computerized CT

Mowzowski and colleagues (2010) defined computerized cognitive training as any program that targets various cognitive functions through the use of individually tailored games and exercises and incorporates graded difficulty levels. In recent years, there has been an explosion in the development of computerized cognitive training programs that fit with the aforementioned definitional criteria. A cursory internet search reveals many commercially marketed software programs touted as “exercise for the brain.” Examples of some of the most popular programs include BrainTrain, Captain’s Log, CogniFit, and Mastermind. Cognitive training programs designed for use on video game consoles (e.g., Brain Age^{TM}; Big Brain Academy^{TM}) have also become popular. However, the effectiveness of these programs with older adults has not been fully examined. Establishing empirical support for those software programs widely advertised on the commercial market and internet that target healthy older adults is essential.

Importantly, researchers in the United Kingdom recently conducted the largest scale study to date investigating the effectiveness of computerized cognitive training (Owen et al., 2010). Although the study included over 11,000 participants, it focused only on adults aged 18 to 60. Participants were assigned to either a control group, an experimental group focusing on tasks emphasizing reasoning, planning, and problem-solving, or an experimental group focusing on “broader cognitive functions” (e.g., attention, visuospatial processing, mathematics). In the CT groups training was implemented for 10 minutes a day, three times per week. Both of the experimental CT groups demonstrated large effect size increases in performance on trained tasks over the course of the six-week study; however, CT did not translate to improved performance on untrained benchmarking tasks at post-test (e.g., spatial working memory; verbal short-term memory). Although these findings do not readily generalize to older adults, the results are congruent with other large-scale CT studies, which have demonstrated a limited transferability of training beyond trained tasks (e.g., Ball et al., 2002). A major weakness of the Owen et al. (2010) investigation is that the duration of training (i.e., 10 minutes a day, three times per week for six weeks) may not have been extensive enough to produce gains across cognitive domains. Several other methodological limitations have been highlighted (Katsnelson, 2010). Nonetheless, findings from the Owen et al. (2010) may suggest limitations to the utility of computerized CT even as further studies emerge.

Computerized CT with older adults. In the following paragraphs, emergent studies investigating a variety of approaches to computerized CT with older adult, including evidence regarding specific software programs, will be reviewed, concluding with an examination of the burgeoning literature on the effectiveness of video game-based training programs. Finally, a number of studies of CT programs used with cognitively impaired older adults populations are discussed.

Brain plasticity-based training. A group of related randomized clinical trials investigating the effectiveness of a novel approach to CT, known as ‘brain plasticity-based” training, have recently been published (Manckhe et al., 2006; Smith et al., 2009; Zelinski et al., 2011). Manchke and colleagues (2006) developed a plasticity-based experimental training regimen, known as the Brain Fitness Program, consisting of six computerized exercises that focused on improving efficiency in processing incoming auditory information in order to increase “neuromodulatory control” over learning and memory through repetitive and increasingly complex recognition tasks. For example, participants were asked to discriminate and/or match between confusable syllables in recognition tasks or identify details in a verbally presented story. Participants (N=182) were randomized to the experimental computer-training group, active control group (i.e., cognitive stimulation consisting of viewing educational DVDs regarding art history and literature followed by quizzes on the material), or no-contact control group for 8 to 10 weeks. First, results indicated that participants' performance on the trained tasks improved substantially with regard to computerized measures of processing speed and forward word recognition span. Second, on broader neuropsychological measures of memory functioning, participants in the trained group exhibited significantly higher scores than the active and no-contact control groups. Third, the training gains demonstrated in the experimental group were maintained at three-month follow-up. The authors concluded that the brain-plasticity based approach was successful in achieving two important goals of cognitive training studies: 1) Training generalized beyond performance on trained tasks; and 2) Gains were maintained up to three months after cessation of training. Importantly, brain-plasticity based training significantly improved performance on measures of processing speed – a domain that has been found to be unaffected in many other cognitive training studies (e.g., Ball et al., 2002). One drawback of this study, however, was the lack of outcome measures to document changes in everyday memory performance or adaptive functioning.

Another large-scale (N=487), multisite randomized controlled trial, known as the Improvement in Memory with Plasticity-based Adaptive Cognitive Training (IMPACT) study, investigated the effectiveness of brain plasticity-based training principles via the Brain Fitness Program (Smith et al., 2009). The experimental and active control groups completed activities identical to the Manckhe et al. (2006) study. However, Smith and colleagues did not include a no-contact control group because in the Manckhe study, no significant differences were found between the no-contact and active control conditions.

Participants completed 40 hours of training or cognitive stimulation over the eight week study. Performance in the CT group improved significantly following training on the primary outcome measure, the Auditory Memory/Attention scale of the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS). Significant performance gains in the CT group were also observed on digit span backward, wordlist total score and delayed recall from the Rey Auditory Verbal Learning Test (RAVLT), letter-number sequencing from the WMS-III, and a directly trained processing speed exercise presented as part of the training regimen. Subjective estimations of cognitive abilities (i.e., Cognitive Self-Report Questionnaire-25) also improved in the CT group. Narrative memory, assessed using the RBMT Story Recall subtest performance, was not impacted in the CT group.

Using alternate forms of the outcome measures, maintenance of training gains in the multi-site IMPACT study trial (Smith et al., 2009) was assessed after a three-month, no-contact period (Zelinski et al., 2011). A total of 415 participants (out of an original N=487) returned to complete longitudinal assessment. From baseline assessment to the three-month follow-up, performance gains in the CT group were maintained on RAVLT wordlist total score, the directly trained processing speed exercise, letter-number sequencing, and subjective estimation of cognitive abilities. Previously noted training-related gains on digits backward and RAVLT wordlist delayed recall were not maintained over the three-month follow-up. Effect size between baseline and follow-up were also smaller than those from baseline to initial post-test, evidencing less than complete maintenance.

Taken together, the studies of the Brain Fitness program (Manchke et al., 2006; Smith et al., 2009; Zelinski et al., 2011) provide empirical support for the effectiveness of plasticity-based training over cognitive stimulation alone. Training-related gains also transferred to a variety of untrained outcome measures; and performance gains were primarily maintained for at least three months. Given that the aim of the training was to improve processing of auditory information, a skill that is used frequently across memory and attention tasks, transfer effects were facilitated to a range of outcome measures compared to prior CT studies focusing on improvement of specific cognitive skills (e.g., Ball et al., 2002). Thus, training programs that practice complex skills that are broadly applicable in a variety of cognitive tasks may produce greater transfer effects.

Working memory training. An increasing number of researchers have begun to investigate whether training of working memory may facilitate generalized cognitive improvement. Typically these studies have focus on computerized exercises intended to improve verbal and visual working memory span through repetitive practice. Richmond and colleagues developed a computerized protocol that was divided equally between verbal working memory and spatial working memory tasks. The verbal working memory task involved encoding short sequences of letters; and the visual working memory task involved encoding locations of dots on a grid while simultaneously engaging in a distracting task. Healthy older adult participants in the training group completed twenty 30 minute training sessions over the course of 4 weeks while the active control group engaged in online “trivia learning.” Participants in the training group exhibited improved performance on a reading span task and reduced repetitions on the California Verbal

Learning Test (CVLT). Among the training group, subjective ratings of daily attentional abilities also increased relative to the control group.

A similar study (Buschkuehl et al., 2008) with 32 old-old (i.e., > 80-year-old) healthy participants investigated the effectiveness of computerized working memory training versus an active control group that engaged in supervised aerobic exercise. Training sessions were scheduled twice weekly over 12 weeks and focused on improving visual and verbal working memory span. Results demonstrated performance gains in visual working memory (i.e., computerized block span task) and visual free recall among the working memory training group only. The prior studies suggest that computerized training focused on improving working memory span may be a promising means of producing transfer effects to proximal and distal neurocognitive domains, similar to previously discussed brain plasticity-based training (i.e., Brain Fitness program; Manckhe et al., 2006). The primary difference between the two approaches to training is that the Brain Fitness program focuses on improving processing of auditory information while working memory training focuses on both verbal and spatial exercises. Both training protocols, however, focus on training broadly applicable skills that provide the "building blocks" for transfer to distal cognitive domains.

Computerized CT focused on multiple cognitive domains. In contrast to the prior approaches emphasizing unitary training constructs (i.e., brain plasticity-based training; working memory practice), many computerized CT programs target multiple cognitive domains through numerous distinct training tasks. An example of this approach is the widely available CogniFit Personal Coach program for which there is now emerging empirical support. The CogniFit program was recently implemented with multiple sclerosis (MS) patients with mild cognitive complaints (Shatil, Metzer, Horvitz, & Miller, 2010). Israeli older adults (N=107) with MS were assigned to either a training group that completed 20 to 30 minutes of training three times per week, or a no-contact control group, over the course of 12 weeks. The CogniFit software personalizes training protocols for each individual culled from 21 complex cognitive tasks (e.g., “Hot Air Balloon” task requiring participants to track and remember the route of a balloon). Personalized training is selected based upon baseline results of 8 neuropsychological outcome measures built-in to the program. Results at post-test revealed that the majority of trained participants (i.e., 71%) were compliant with the training regimen (i.e., completed at least some training activities unprompted at home); however, only 37% completed all of the required training activities. Despite this limitation, the CT group demonstrated an advantage over the control group in general memory, visuospatial working memory, and verbal working memory. Significant performance improvements in the CT group were also observed on outcome measures of naming speed, speed of information recall, focused attention, and visuomotor vigilance. Although the primary learning objective of the CogniFit program was on training a variety of cognitive skills, several training tasks appear to be heavily dependent on working memory (e.g., tasks requiring monitoring of objects and remembering locations after a momentary delay). Similar to other studies that targeted working memory (Buschkuehl et al., 2008; Richmond et al., 2011), a broadly applicable cognitive skill, training effects seemingly improved cognitive efficiency and produced transfer effects to distal cognitive domains.

Another recent study compared the effectiveness of the CogniFit Personal Coach program with cognitive stimulation via computer games in a sample of 155 healthy older adults (Peretz et al., 2011). Training activities and duration in the CogniFit group was similar to the Shatil et al. (2010) study (i.e., 3 times per week for 12 weeks). Participants in the cognitive stimulation group selected from 12 classic computer games (e.g., Tetris; Tennis; Memory Simon; Snake) over the course of 24 sessions. At post-test, performance gains were observed on all 8 outcome measures in the CT group and 4 outcome measures in cognitive stimulation group. Among those participants who adhered to completing all study-related activities, CT was more effective than cognitive stimulation in improving visuospatial working memory, visuospatial learning, and focused attention. Consistent with the Shatil et al. (2010) study, performance gains in the CT group were observed in a variety of proximal and distal domains. Smaller gains were also noted in the cognitive stimulation group, which may suggest that computerized games may provide a marginal beneficial impact on cognition.

Another recent study employed computerized CT via the Neuropsychological Educational Approach to Remediation (NEAR) software with 41 otherwise healthy older adults with a lifetime history of depression (Naismith et al., 2011). Participants, who were screened to ensure depressive symptoms were controlled to within the normal to mild range, were assigned to a training group or a wait-list control group. A multimodal approach was used, combining psychoeducation on various cognitive functioning topics, mnemonic strategies, and depressive symptom management, along with 10 total hours of training on NEAR over ten weeks. The NEAR program incorporates a top-down approach to remediation by presenting tasks that employ several skills at once in a contextualized format in order to simulate real-life cognitive tasks (Medalia & Freilich, 2008). At post-test, significant improvements in performance associated with the treatment condition were observed on measures of visual memory (i.e., Rey Complex Figure Test) and delayed verbal memory (i.e., Rey Auditory Verbal Learning Test; Logical Memory). Although training did beneficially impact cognitive abilities, there was no effect on depressive symptoms, which is notable given that all participants had a lifetime history of depression.

The preceding studies of CT programs that targeted multiple cognitive skills through repetitive, individualized training protocols demonstrated positive transfer effects to a variety of outcome measures. Distal transfer was noted in two studies in that verbal and visual delayed recall were improved following training (e.g., Naismith et al., 2011; Shatil et al., 2010). Training tasks emphasizing processing speed also contributed to improved speed of information recall in the group that trained using CogniFit in the Shatil et al. (2010) study. Another commonality in the previous studies that examined the CogniFit software (Peretz et al., 2011; Shatil et al., 2010) is that both verbal and visual working memory was preferentially enhanced in the trained group. Spatial and verbal working memory abilities comprise a significant portion of the available training tasks in the CogniFit program and, as discussed earlier, these skills may be easily generalized to other cognitive domains.

Video game based CT with older adults. Recently a number of cognitive training programs have been developed for use with various video game consoles. Nintendo has been on the forefront of creating fun and engaging "brain training" games (e.g., Brain Age™; Big Brain Academy™), which purportedly improve cognitive performance across all age groups. Only recently have a few published studies addressed the effectiveness of video game-based CT. The literature on the positive effects of video game-based skill training is still limited. In particular, the effectiveness of implementing video games with older adults has been less researched. One ubiquitous example of this is the current popularity of the Nintendo Wii gaming system. Anecdotally, many nursing homes and residential facilities have begun encouraging older adults to play Wii games, which provide physical exercise as well as mental stimulation. They have been so popular at such sites that residents even form leagues for each type of game (K. Nielson, personal communication). It has been demonstrated that playing Nintendo Wii games is effective in improving development and maintenance of psychomotor skills (e.g., coordination and balance; Hill, 2009). In fact, occupational therapists have begun to specially develop games for rehabilitation of motor skills, referred to as “Wiihab” (Anderson, Annett, & Bischof, 2010). The claims that playing Wii exercise games beneficially impacts cognition have not been confirmed in the literature aside from anecdotal reports in case studies (Weybright, Dattilo, & Rusch, 2010).

Important questions about the practical utility of video game-based CT have yet to be fully addressed. Will older adults actually be able to easily learn how to use a video game console in order to complete training tasks? Several researchers have questioned the utility of computerized and/or technological training programs as older adults frequently interface with such tasks in a manner that engenders confusion and frustration (e.g., Rogers & Fisk, 2010). One recent study evaluated older adults’ reactions to brief use of a Nintendo DS console, a handheld, compact video game platform (Nacke, Ing, Nacke, & Lindley, 2009). Participants were assigned to groups that completed a brief calculation task from Dr. Kawashima’s Brain Training™ (i.e., AKA Brain Age™ in North America) or a group that performed calculations on paper. Older adult participants took longer to solve calculations on the DS console than on paper. Additionally, subjective arousal reports were higher in the group that completed calculations on the DS. The authors concluded that engagement with technology was less efficient and more highly arousing for older adults. These findings have implications for the general design of video game-based brain training for older adults in that the technology must be geared for ease of use. It should be noted that the training using the Nintendo DS occurred during only one experimental session. With more extensive practice and training, older participants have been able to increase their proficiency in completing CT on the DS console (e.g., McDougall & House, 2012).

There is little evidence as of yet demonstrating the effectiveness of video game playing on cognitive skills with older adult participants. There is emerging empirical support that the playing of video games enhances visuospatial skills but studies have focused on school children (e.g., Lorant-Royer, Munch, Mescle, & Lieury, 2010) or younger adult participants who logged significant hours playing action-based games that are not explicitly designed to enhance cognition (Spence & Feng, 2010). Ackerman, Kanfer, and Calderwood (2010) recently investigated the effectiveness of a commercially available cognitive training program entitled Big Brain Academy™ (BBA) developed for Nintendo. BBA includes 15 games that tap a variety of underlying cognitive processes (e.g., sorting; computation; visual scanning). Middle-aged adults (i.e., 50 to 71) partook in the study and completed BBA tasks on a Nintendo Wii for one hour a day for a total of 20 hours over four weeks. Substantial gains in performance on BBA tasks were observed; however, training did not transfer to improved performance on measures of crystallized intelligence, fluid intelligence, and perceptual speed from the Cognitive

Abilities Test battery. Weaknesses of this study include that fact that the authors used the Cognitive Abilities Test battery to evaluate transfer effects, in lieu of more common and well-validated neuropsychological measures. Additionally, despite the improved proficiency in completing BBA tasks, most participants (i.e., 49 out of 78) indicated at post-test that they strongly agreed they would *never* be interested in using the BBA game again!

One study investigated the impact of playing a battle strategy computer game on general cognitive abilities (Basak, Boot, Voss, & Kramer, 2008). Healthy older adult participants (N=40) played a computer game entitled “Rise of Nations,” in which they were presented with complex battle scenarios over the course of 7 to 8 training sessions (Basak et al., 2008). Participants were assigned to the CT group or a no-contact control group. At three different junctures throughout the training session, participants were given neurocognitive measures of verbal working memory, executive control, visual short-term memory, nonverbal reasoning (i.e., Raven’s Progressive Matrices), and visuospatial attentional tasks. Participant proficiency at playing the computer game increased significantly from pre- to post-training. In addition, the effects of training transferred into increased performance on selected executive control tasks and on a mental rotation (i.e., visuospatial) task. Basak and colleagues did not observe significant effects on other domains, in particular visual or verbal working memory. The aforementioned study presented participants with a complex task that taps multiple higher-level cognitive processes simultaneously, including attention, memory of past experiences to guide performance, and abstract reasoning skills. Therefore, the computer game utilized in the Basak et al. study differed from other computerized CT programs (e.g., CogniFit) that train various cognitive skills independently. However, the protocol was similar to other game-based protocols (e.g., Big Brain Academy™) that present tasks in an enjoyable and entertaining format in order to facilitate engagement in training.

Finally, another recent study in the United Kingdom evaluated the effectiveness of Dr. Kawashima's Brain Training™ with community dwelling healthy older adults (McDougall & House, 2012). The aforementioned game includes daily training tasks that emphasize four separate cognitive skills: arithmetic, language skills, working memory, and mental rotation. Twenty-one participants were randomly assigned to the training group and 20 participants to a no-contact control group over a six-week study period. Participants in the Nintendo training group were not provided with any specific recommendations on how frequently to use the software over the intervention period; however, most participants played between two and three times per week. Outcome measures were four subtests from the Wechsler Adult Intelligence Scale – third edition (WAIS-III). Training produced significant improvement in performance on the Digits Backwards portion of the Digit Span subtest. Frequency of use of the Nintendo software was not associated with greater gains on outcome measures. Performance gains were related to the effect of significant covariates (i.e., perceived quality of life; perceived cognitive functioning). That is, participants with better perceived quality of life and estimates of their own cognitive functioning were more likely to benefit from training. These findings indicate that individuals with greater perceived self-efficacy to successfully engage in cognitively demanding tasks may obtain greater gains and may represent a possible limitation of the training regimen itself.

Computerized CT with cognitively impaired older adults. An increasing number of studies have targeted cognitive dysfunction in older adults with diagnosable cognitive disorders, including MCI and AD. A variety of computer programs that can be implemented with individuals with cognitive impairment have been investigated.

A recent study developed a novel approach of targeting recognition memory via computerized training in a sample of amnestic MCI patients (Herrera, Chambon, Michel, Paban, & Alescio-Lautier, 2012). All participants completed 24 one-hour sessions of training in laboratory over 12 weeks. The CT group (n=11) engaged in six training tasks focused on improving recognition memory (i.e., visual memory, visuospatial memory, and visual working memory) and attention (i.e., visual focused attention, visuospatial focused attention, and divided attention). An active control condition (n=11) engaged in various cognitively stimulating exercises (e.g., highlighting letters in newspaper articles; categorizing lists based on organizational principles) for the same duration as trained participants. Significant performance gains were observed in the CT group at post-test on neuropsychological outcome measures assessing visual recognition memory (e.g., Doors and People recognition memory battery), verbal working memory (i.e., forward digit span), and verbal delayed recall (e.g., BEM-144 12-item word-list recall). Performance gains were maintained at a 6-month follow-up session. Although training was primarily focused on improving visual recognition memory, training effects were also observed on visual and verbal delayed recall processes, a function of episodic memory that is typically impaired in MCI. These results suggest that computerized CT may hold promise as a behavioral method for preventing further cognitive decline in MCI.

In a cognitive training study conducted in a residential facility, elderly participants with “benign memory problems” completed 14 weeks of computer-assisted cognitive training using the “Cognition I” software program designed to increase attention, visuomotor performance, reaction time, vigilance, attentiveness, memory, verbal performance, and general knowledge (Gunther et al., 2003). Participants performed better on measures of verbal memory (i.e., CVLT) following training and at five-month follow-up. Although a major limitation of this study was that participants were not confirmed to meet diagnostic criteria for MCI, results suggest that individual with mild cognitive complaints may benefit from computerized CT and maintain gains upon longitudinal follow-up assessment.

Computerized interventions have also been implemented with AD patients. One investigation examined the effectiveness of the “MultiTask” computer program in the rehabilitation of memory deficits among AD patients (Schreiber, Schweizer, Lutz, Kalveram, & Jancke, 1999). All stimuli given by the program (across ten 30-minute sessions, twice weekly) revolved around the completion of tasks within a virtual apartment, which was designed to help participants remember target objects and meaningful routes. Immediate visual memory, indicated by scores on the picture recall test of a German-language neuropsychological battery, was significantly improved in the training group relative to controls from pre- to post-test. A marginally significant beneficial effect was also observed among the training group on the Route Learning test from the Rivermead Behavioral Memory Test (RBMT), whereby participants must learn to walk a route around a room. These findings show promise that computerized training in virtual environments may eventually become a useful means of teaching AD patients to “rehearse” daily tasks that are adversely impacted by memory problems.

In another study investigating the efficacy of a computerized training regimen, mildly impaired AD patients, who were taking cholinesterase inhibitors, utilized a multimedia internet-based cognitive stimulation system (Tarraga et al., 2006). In the multimedia group, AD patients completed stimulation tasks across various domains (e.g., memory, attention, calculation) with the online Smartbrain program in addition to participating in an interactive psychostimulation program, which was completed face-to-face with experimenters. The Smartbrain program was administered three times per week for 20 minutes each. The multimedia group was compared to a group that received psychostimulation alone, and a third group prescribed cholinesterase inhibitors alone. After 24 weeks, participants in the cholinesterase-alone group declined on two abbreviated measures of cognitive functioning, the Mini-Mental Status Exam (MMSE) and Alzheimer’s Disease Assessment Scale-Cognitive (ADAS-Cog), while both stimulation groups improved on these measures. Participants in the experimental multimedia group also exhibited improvement on the Story Recall subtest of the RBMT, which was greater than the improvement of psychostimulation-alone group. Unfortunately, due to error, these data were not assessed in the cholinesterase-alone group, making group comparisons impossible. Nonetheless, the observed improvement across several cognitive domains suggests that generalized cognitive stimulation training administered via an online may be a practical means of delivering treatment to older adults.

Contrary to preconceived notions regarding the inability of cognitively impaired patients to utilize technological interventions, the preceding studies demonstrate that older adults with clinically significant cognitive deficits are able to engage in computerized CT and may experience improvement in cognition resulting from training. CT programs may be specifically tailored to attenuate memory deficits in MCI older adults (e.g., Herrera et al., 2012) or used to reduce functional impairment in everyday functioning in AD patients (Schreiber et al., 1999; Tarraga et al., 2006). Thus, computerized CT may have broader utility for clinical samples aside from healthy older adults. More randomized clinical trials are necessary to provide further support for this mode of intervention in cognitively impaired populations.

Conclusions regarding computerized CT. In summary, a large variety of computerized CT protocols have been implemented with older adults, and numerous brain training programs continue to be developed and marketed to elders. Computerized CT programs range from tasks emphasizing unitary training principles (e.g., auditory processing efficiency; Smith et al., 2009) to software comprised of several tasks each emphasizing different abilities (e.g., Shatil et al., 2010). Several new brain training programs have also been developed for use with popular video game consoles, such as the Nintendo Wii and Nintendo DS. These programs tend to present training materials in a more engaging format fit that still fits into the basic tenets of computerized CT, including individually tailored exercises and progressive difficulty levels responsive to players' abilities (e.g., Mowszowski et al., 2010). Across computerized CT studies, training effects have been reliably observed on verbal (e.g., McDougall & House, 2012) and visual (e.g., Peretz et al., 2011; Richmond et al., 2011) working memory outcome measures.

It is important to evaluate the extent to which the effects of cognitive training generalize from trained tasks to untrained tasks (Hertzog et al., 2009). In the literature the importance of assessing these transfer effects is clear. Depending on the type of training, effects may extend to either proximal outcome measures testing similar cognitive processes to the original training, or to distal outcome measures incorporating different neurocognitive processes than the original training. This is also known as “near” and “far” transfer, respectively (e.g., Zelinski, 2009). Historically, the terms “near” and “far” transfer have been defined and operationalized in numerous ways (cf. Barnett & Ceci, 2002), which can lead to confusion when comparing across CT studies. In general, Barnett and Ceci (2002) posited that transfer is more likely to take place when the outcome measures are proximal, that is, similar to or identical to the training itself. As reviewed in the preceding paragraphs, some cognitive training studies have demonstrated that circumscribed pattern of performance on cognitive outcome measures (e.g., Ball et al., 2002; Buiza et al., 2008); however, many computerized CT studies have demonstrated broader transfer to distal measures (e.g., Basak et al., 2008; Peretz et al., 2011).

Lastly, an important distinction must be drawn between studies that investigate specific interventional techniques (e.g., vanishing cues; Glisky et al., 1986) and those that emphasize generalized, naturalistic skills via cognitive training, which is often the method employed in computerized CT (e.g., Manchke et al., 2006; Smith et al., 2009). Although most of the randomized controlled trials with healthy older adults discussed in the previous sections are of good methodological quality, it is more difficult to pinpoint the exact source of performance gains due to the multimodal nature of training. Whenever several techniques are blended together it is obviously more difficult to disentangle the effects of the intervention. A few studies have demonstrated the effectiveness of training programs that emphasize the development of broadly applicable cognitive skills through repetitive exercises in order to promote far transfer. A proposed target of such training program is verbal and visual working memory span, a cognitive ability that is engaged frequently in daily activities (Buschkuehl et al., 2008; Richmond et al., 2011). Other studies have implemented holistic, "plasticity-based" cognitive training, focusing on increasing the efficiency of processing auditory information (e.g., Manckhe et al., 2006; Smith et al., 2009; Zelinski et al., 2011). The “plasticity-based” approach appears to produce far transfer more reliably across multiple neurocognitive domains, and this may be a promising new direction in CT research. Nonetheless, future studies of this approach need to adapt ecologically valid outcome measures to examine the adaptability of CT-related skills to everyday functioning.

Methodological Limitations of Cognitive Remediation Studies

Given that the literature on cognitive remediation is relatively young, a number of studies have been less than ideally designed. Only recently have more well-designed randomized controlled trials (e.g., Ball et al., 2002; Owen et al., 2010) emerged to establish definite empirical evidence of the effectiveness of experimental techniques and protocols. One of the weaknesses inherent in many cognitive remediation studies is the lack of reliable instruments to measure the transfer of training into everyday life. Standard neuropsychological measures do not adequately capture the impact of memory problems in daily life. For instance, many studies focus on subjective estimates of memory functioning by patients and their family; however, these are likely to be biased. The Rivermead Behavioral Memory Test (RBMT) developed by Wilson, Cockburn, and Baddeley (1989) is one of the most commonly utilized tests for monitoring everyday memory problems. Although the RBMT was originally developed for use with patients with nonprogressive brain injuries, it has been used frequently in studies with older adults with progressive conditions (e.g., Schreiber et al., 1999). The RBMT is comprised of subtests that assess orientation, recall for pictorial information and passages from news articles, prospective memory, facial recognition, and learning a route to walk around a room. The RBMT has been found to be a better predictor of everyday memory problems than the Wechsler Memory Scale (Wilson, 2009). The RBMT is being used more often in intervention studies but should be compared with subjective estimations of memory.

Many early cognitive remediation studies included small samples sizes (e.g., Clare et al., 2000, N=6); and case studies, which do not allow for generalization from single instances of success, were frequent in the literature (e.g., Thivierge et al., 2008). Recently, several large-scale randomized controlled trials have demonstrated the effectiveness of CT (e.g., Ball et al., 2002; Owen et al., 2010; Smith et al., 2009). Due to the often intensive nature of study protocols, recruitment of potential participants remains a challenging process. Some intervention studies suffered from small sample sizes because they attempted to recruit participants who met specific inclusion criteria. For example, MCI participants are often difficult to recruit and must be assessed to ensure that they meet diagnostic criteria. For example, Rapp et al. (2002) began with 168 potential participants and ended up with 9 MCI participants who completed the study.

Selection of appropriate control conditions is another common challenge in cognitive remediation studies. Several studies have compared intervention groups to no-contact or waitlist control groups (e.g., Basak et al., 2008; Levine et al., 2007; McDougall & House, 2012; Shatil et al., 2010), or in some instances did not include control groups at all (e.g., Loewenstein et al., 2004). Comparing interventions to no-contact or waitlist control conditions only allows for limited interpretation of the effectiveness of an intervention, whereas the inclusion of an active control condition provides the opportunity to guard against possible placebo effects. An increasing number of studies have incorporated active control conditions. However, there is wide variability in the types of activities selected for active control conditions, ranging from supervised aerobic exercise (Buschkuehl et al., 2008) to social stimulation (Tarraga et al., 2006). Several studies have compared experimental interventions with cognitive stimulation alone (e.g., Buiza et al., 2008; Peretz et al., 2011; Richmond et al., 2011). Activities defined as cognitively stimulating tend to vary widely in the literature, including highlighting certain letters in newspaper articles (Herrera et al., 2012), online trivia learning (Richmond et al., 2011), viewing educational DVDs and completing quizzes on the material (e.g., Smith et al., 2009), or social stimulation (Tarraga et al., 2006). Importantly, cognitively stimulating activities should be presented in the same modality as the type of training in experimental groups. For example, Peretz and colleagues (2011) compared computerized CT with an active control condition that played classic computer games. Comparing structured, theoretically based training programs with conceptually similar, nonspecific mentally stimulating activities allows opportunity to draw better conclusions on the effectiveness of CT.

Observed gains in cognitive functioning are often only achieved after extensive training administered over multiple sessions. It is important for clinicians to evaluate the clinical utility of comprehensive training programs when improvements are often minimal. Of the studies discussed previously in this paper, many chose to focus heavily on subjective measures of participants' own confidence in their cognitive abilities and did not measure objective memory appropriately (e.g., Londos et al., 2008). Thus, rehabilitation practitioners need to carefully measure cognitive outcomes using standardized neuropsychological measures and everyday memory measures, such as the RBMT, at various time points to ensure that selected interventions are effective. In examining the clinical utility of rehabilitation procedures, it is essential to take into consideration the setting that interventions may be employed. Essentially, clinicians need to estimate the duration of treatment and determine if older adults could practically benefit from interventions. For example, if errorless learning is warranted for an AD patient in a residential facility it might only be implemented if the patient can manage the time required to complete training.

Finally, more studies should include longitudinal assessments of cognitive functioning to evaluate the durability of training gains. Recent studies have demonstrated continued performance gains at follow-up periods from three months (Zelinski et al., 2011) to five months (Gunther et al., 2003) following training. One study found that training gains as a result of spaced retrieval were still evident up to 6 to 11 months post-intervention (Cherry & Simmons-D'Gerolamo, 2005). Since this intervention was based on implicit memory, which has been found to decay less rapidly than explicit memories (Toth, 2000), it is hard to estimate whether explicit memory intervention strategies would remain as robust over time. Other studies have demonstrated that CT gains can be maintained but only with continuing booster sessions (e.g., Willis et al., 2006). The inherent weakness of all interventions for progressive neurological diseases is that eventually patients' conditions deteriorate and often treatment may only serve to delay inevitable rapid decline. Regardless of the sample population, longitudinal assessments provide further support for the utility of cognitive interventions and estimate whether gains can be maintained with or without the need for extended training.

Foundations for the Present Study

Cognitive failures are commonly encountered by older adults during the course of normal aging. Older adults without diagnosable cognitive impairment frequently report mild decrements in episodic memory, word-finding, attention, psychomotor speed and problem-solving. Neuroimaging investigations corroborate neuropsychological findings to demonstrate structural and functional changes in the brain that produce inefficient recruitment of neural regions - leading to observable cognitive decline among older adults. When associated with progressive neurological disease, such as AD, these changes may lead to eventual functional impairment. Given that the population of older adults in the United States is steadily rising, the number of individuals suffering from both benign impairment and diagnosable conditions (i.e., MCI versus dementia) will increase to a level never before observed in society. As a result, the costs imposed on the already overburdened healthcare industry will skyrocket. Non-pharmacological cognitive interventions offer a low-cost means of reducing cognitive complaints without relying on expensive pharmacological treatments.

As reviewed earlier, there are three major approaches to non-pharmacological cognitive remediation: cognitive rehabilitation, cognitive stimulation, and cognitive training (CT). Cognitive rehabilitation techniques are traditionally tailored to remediate specific deficits associated with neurological disorders and usually employed with more severely impaired patients. Cognitive stimulation is a broad term used broadly to describe a range of mentally engaging activities. Cognitive training refers to structured learning paradigms to optimize cognitive functioning, and has been used in a variety of contexts with individuals of all ages. There are a wide array of CT protocols described in the literature, from specific strategies to improve episodic memory (e.g., Terrace, 1963b) to holistic interventions designed to increase executive control over cognitive operations (e.g., Smith et al., 2009) to working memory training (e.g., Buschkuehl et al., 2008). CT programs that target multiple cognitive domains in parallel may be used by healthy older adults to enhance everyday cognitive functioning (e.g., Ball et al., 2002), or as a preventive strategy intended to forestall further cognitive decline in at risk populations (e.g., Herrera et al., 2012; MCI patients).

The burgeoning literature on the effectiveness of computerized CT programs has yielded mixed results regarding the ability of such programs to produce transfer effects (Owen et al., 2010; Smith et al., 2009). Empirical investigation is key, since numerous companies and websites now offer so-called "brain-training" games commercially, and evidence that skills acquired during brain training actually transfer to other cognitive domains is needed for an ever-expanding catalog of CT software. Video game systems provide a convenient platform for presenting brain training programs (e.g., Ackerman et al., 2010; McDougall & House, 2012), which are often marketed to members of the more technologically savvy “Baby Boomer” generation.

The current study evaluates the effectiveness of the widely available Brain Age™ game developed for use on the Nintendo DS gaming system. The program incorporates a variety of complex, natural tasks that draw upon a variety of cognitive skills for successful completion (e.g., speeded arithmetic tasks; reading aloud) and progresses in difficulty the more players use the game. The training tasks in the Brain Age$^{\text{TM}}$ program are predicated on the theoretical training model put forth by Japanese neuroscientist Dr. Ryuta Kawashima (Kawashima et al., 2005). Prior fMRI studies by Dr. Kawashima and colleagues (Kawashima et al., 2004; Miura et al., 2003) and earlier findings (e.g., Hagoort et al., 1999; Rickard et al., 2000) consistently demonstrated increased activation in areas of bilateral dorsolateral prefrontal cortex, as well as parietal and temporal association cortices, during the reading aloud of long sentences and while performing simple arithmetic calculations. Dr. Kawashima and colleagues (Kawashima et al., 2005) implemented these two paper and pencil task in a intervention study with 32 nursing home residents with Alzheimer’s over a six month period and demonstrated significant improvement in verbal abstract reasoning in the experimental training group. Based on the findings of this pilot study, Dr. Kawashima proposed that increased regional cerebral blood flow (rCBF) and metabolism in the aforementioned cortical areas during the completion of speeded arithmetic and reading aloud may produce improvements in executive functioning and overall cognitive performance. As a result, these two tasks became the basis for the development of the Brain Age$^{\text{TM}}$ program and are highly emphasized in daily training activities.

To this author's knowledge, only one prior study has directly investigated the effectiveness of Dr. Kawashima's Brain Age^{TM} program (McDougall & House, 2012). However, this study employed a limited selection of outcome measures to evaluate performance-related gains (i.e., 4 subtests of the WAIS-III). In the current study, a comprehensive battery of neuropsychological outcome measures was administered at pre-test and post-test to evaluate both near and far transfer effects. Measures were specifically selected to evaluate effects on proximal cognitive domains similar to training tasks (e.g., written speeded arithmetic common to both Calculations X 20 on Brain Age and evaluated with and WJ Math Fluency test) as well as distal cognitive domains (e.g., narrative memory on RBMT Story Recall test). The majority of outcome measures in the current study can be classified as distal because of the complexity of Brain Age^{TM} training tasks requiring the combination of multiple cognitive skills. Proximal outcome measures were classified as those neuropsychological measures that closely resembled (i.e., WMS-III Spatial Span), or in some cases directly replicated training tasks (i.e., Trailmaking Test; WJ Math Fluency).

Further research is necessary to determine the effectiveness of structured CT programs versus nonspecific cognitive stimulation. The previously mentioned study that investigated the effectiveness of the Brain Age^{TM} program (McDougall & House, 2012) compared trained participants to a no-contact control group. The current study compared the effectiveness of the Brain Age^{TM} program versus an active control condition that played video game-based card games on the Nintendo DS. An active control condition was employed in order to evaluate whether possible transfer effects are due to engagement in specific training tasks and not simply due to the novelty of learning to use a new technological device, nonspecific interaction with the experimenters, or both.

Both rehabilitation and cognitive training programs often combine several individual interventional techniques into protocols that may last from 6 to 12 weeks. These programs are often intensive with training sessions frequently lasting an hour or more. A pragmatic criticism of past research is that the length of individual sessions may make training impractical for many older adults to implement in their daily lives (e.g., Acevedo & Loewenstein, 2007). The current study incorporated a less intensive amount of training (i.e., 14 hours) over a six-week period with participants instructed to play the Nintendo DS for a minimum of 20 minutes per day. Additionally, many CT studies deliver training tasks within the controlled context of the laboratory versus in a naturalistic setting where most commercially available brain training programs are intended for use. All daily Nintendo tasks in the current study were completed at home to fit into the participants' daily schedules.

Psychosocial factors must also be taken into consideration within the context of cognitive training. Some researchers posit that addressing psychosocial aspects of training (e.g., metamemory education) is as important as the primary interventions. Psychosocial components may seek to train older adults how to cope psychologically with anxiety and depression, which often accompany cognitive changes. Notably, a few prior CT studies (e.g., Elgamal et al., 2007) have demonstrated an impact on participants' mood including reduction in depressive symptoms following training. The current study incorporated self-report measures of depression and anxiety at pre-test and post-test to monitor the impact of training on mood.

As discussed previously, objective improvement in cognitive functioning corroborated by various neuropsychological measures must be established to provide evidence of transfer of training to proximal and distal cognitive domains. Accordingly, measures of everyday cognitive functioning should be incorporated to determine the impact of training on daily life. The proposed study will utilize the RBMT (Wilson, 1989) as an index of everyday memory performance. While it is important that CT beneficially impacts performance on objective neurocognitive measures, it is also essential to incorporate subjective self-report measures. Given the finding that older adults often experience anxiety at the first sign of cognitive decline, it may be necessary to assuage these fears and monitor the impact on cognition. The current study incorporated a self-report measure of subjective memory complaints (i.e., Memory Functioning Questionnaire) and assessed baseline participation in cognitively stimulating activities.

Preliminary studies on the effectiveness of video game-based cognitive training programs have demonstrated the need to assess older adults' game play experience (Nacke et al., 2009; Rogers & Fisk, 2010). Initial findings have been discouraging, in that many older adults rate their experiences using Nintendo consoles negatively and would not use the product in their daily lives (e.g., Ackerman et al., 2010). The current study incorporated brief ratings scales regarding participants' reactions to using the Nintendo DS consoles (e.g., level of enjoyment, mental challenge, etc.) over the course of the six-week study. Additionally, participants completed a questionnaire at post-test assessing personal estimation of the training effectiveness and the likelihood that they would consider purchasing and continuing to use a Nintendo DS.

Aims of the Present Study

The present study examined the effectiveness of an in-home, commercially available brain training program with healthy older adult volunteers. Participants in the CT group used the Brain Age™ (2006) software developed for Nintendo DS for 20 to 45 minutes daily over a period of six weeks. Participants in the active control (AC) group played various card games (i.e., Clubhouse Games™) on a Nintendo DS over the study period. At pre- and post-test sessions participants completed a variety of empirically validated neuropsychological outcome measures across proximal (e.g., a written speeded arithmetic task) and distal cognitive domains (e.g., episodic memory, executive functioning, attention). At pre- and post-test sessions participants also complete self-report measures of depression and anxiety symptoms. Subjective reports of participation in cognitively stimulating activities (i.e., Leisure Activities Survey) and current memory complaints was assessed at pre-test using a comprehensive self-report measure (i.e., Memory Factors Questionnaire) to assess how these factors impacted engagement in study-related activities. Thus, there are three main objectives for the present study: 1) To specifically validate the effectiveness of the training regimen presented via the commercially available Brain Age™ software versus cognitive stimulation alone; 2) To examine whether daily usage of Brain Age™ produces positive transfer effects to proximal and distal outcome measures; 3) To examine the impact of daily CT on mood.

Hypotheses

The following hypotheses were tested in the current study:

H1: There will be no baseline differences in demographic characteristics and participation in cognitively stimulating activities (i.e., per the Leisure Activities Survey) between the CT and AC groups.

H2: There will be no baseline differences in performance across neuropsychological measures between the CT and AC groups.

H3: There will be no baseline differences in subjective memory complaints between the CT and AC groups.

H4: There will be no baseline differences in depression and anxiety symptoms between the CT and AC groups.

H5: There will be a significant improvement in the CT group in performance on all "Daily Training" tasks over the course of the six-week study period.

H6: Mean "Brain Age" score will significantly decrease over the six weekly assessment points (i.e., "Brain Age Check" tasks) in the CT group.

H7: At post-test the CT group will exhibit significant improvement in immediate and delayed visual (i.e., Brief Visuospatial Memory Test) and verbal (i.e., Rey Auditory Verbal Learning Test) recall compared to the AC group. Significant differences in recognition accuracy are not expected at post-test.

H8: At post-test the CT group will exhibit significant improvement in performance on a measure of everyday memory performance (i.e., Rivermead Behavioral Memory Test) compared to the AC group.

H9: At post-test the CT group will exhibit improved performance on a measure of verbal abstract reasoning (i.e., WAIS-III Similarities) compared to the AC group.

H10: At post-test the CT group will exhibit significant improvement in visual (i.e., Spatial Span) and verbal (i.e., Digit Span) working memory compared to the AC group.

H11: At post-test the CT group will exhibit a significant improvement in performance on executive functioning measures (i.e., Trails B; Controlled Oral Word Association Test; Semantic fluency) compared to the AC group.

H12: At post-test the CT group will exhibit significant improvement in performance on processing speed measures (i.e., Trails A; Digit Symbol Coding; Digit Symbol Copy) compared to the AC group.

H13: Participants who endorsed more subjective memory complaints at pre-test will complete fewer study-related tasks over the six-week study because it is anticipated that they have lower confidence in their cognitive abilities.

H14: At post-test the CT group will exhibit a significant reduction in depression and anxiety symptoms (i.e., Geriatric Depression Scale; Beck Anxiety Inventory) compared to the AC group.

Method

Design

This study investigated the effectiveness of the Brain Age™ (2006) software developed for the Nintendo DS gaming system to improve cognitive performance among cognitively intact, community-dwelling older adults. During the first session older adult volunteers completed a wide variety of pre-test neuropsychological measures. Participants were then randomly assigned to either the cognitive training (CT) group or active control (AC) group. Those in the CT group used the Brain Age™ software at home on a daily basis. The AC group played card games on the Nintendo DS via the Clubhouse Games™ software on a daily basis. After six weeks all participants returned to complete post-test neuropsychological measures. Refer to Figure 1 for a diagrammatic overview of the study design.

Participants

Healthy, community-dwelling older adult participants (N = 42) were recruited from a variety of sources. First, potential participants from the Marquette University Retiree's Association who expressed interest in participating in research studies were recruited. Second, an email advertisement for a study on "Successful Aging" was sent to members of the Marquette University community via the *Newsbriefs* periodical. The "Successful Aging" moniker has been used previously for other studies conducted by the Aging, Imaging, and Memory Lab at Marquette University. All potential participants were contacted by this author to screen if inclusion criteria were met and for the purposes of scheduling. All participants were screened over the phone for inclusion so that they typically: 1) were 50 years of age and above; 2) were not diagnosed with dementia or

Mild Cognitive Impairment (MCI); 3) reported having sufficiently good eyesight to effectively read newspaper print (with or without correction); 4) had not previously used the Brain Age™ software.

Unfortunately, effect size data have not been consistently reported in the CT literature; however, a recent, comparable study that implemented Nintendo-based CT reported medium to large effect sizes after 20 hours of training (Ackerman, Kanfer, & Calderwood, 2010). A priori power analyses, estimating medium effect size (i.e., f = .25), revealed an estimated N of 34 would achieve a power level of .80 according to Cohen's conventions (e.g., Cohen, 1992). In total, 81 participants were recruited for participation and 57 participants were randomly assigned. Twenty-eight participants were assigned to the CT group and 29 to the AC group. As expected at the outset of the current study, there was considerable attrition (See Figure 2 depicting flow of participants through the study). At post-test, 21 CT and 21 AC participants had completed all study related tasks. Of participants who completed the study, the age range was from 50 to 87 (M = 64.52 years; SD = 9.51). Participants were predominantly female (73.8%), Caucasian (85.7%), highly educated (M = 16.51 years; SD = 2.85), and most were retired (57.1%). There were no significant differences (p's > 0.05) in demographic characteristics between the study sample and 15 participants who voluntarily withdrew from the study prior to session two.

Measures

Neuropsychological outcome measures. Multimodal CT studies often purport that training results in improvement across multiple cognitive domains (e.g., executive functioning, visuospatial, verbal memory, etc.). Thus, it has been recommended that researchers use a wide range of standardized neuropsychological outcome measures in order to estimate changes in pre- to post-test functioning (e.g., Papp et al., 2009). The majority of the following tests can ostensibly be classified as distal measures of transfer as they are cognitively distinct from the complex Brain Age^{TM} daily training tasks. Three tests (highlighted below) were included as proximal measures of transfer, given close similarities to training tasks.

Memory measures.

Rivermead Behavioral Memory Test – 3rd Edition (RBMT). The RBMT (Wilson et al., 1989) is a commonly used measure of everyday memory functioning. The RBMT was originally developed for use with brain-injured patients (Wilson, 2009) but has been extended as an outcome measure in several memory and cognitive training studies with healthy older adults (e.g., Ball et al., 2002). The RBMT is comprised of 12 brief subtests that assess for everyday memory problems that may hinder daily functioning. For instance, the First and Second Names subtest assesses immediate and delayed face-name memory for two fictional people. Total administration time for the RBMT is 25 to 30 minutes. Participants were administered form A of the Story Memory subtest during session 1 and parallel form B during session 2. Parallel form reliability between forms A and B is reported to be excellent (i.e., r = .84; Wilson et al., 1989).

Brief Visuospatial Memory Test-Revised (BVMT). Although many large-scale investigations of CT have included visual memory outcome measures, there is wide variability in the specific measures selected and in some cases these are not well-validated (e.g., Owen et al., 2010). The BVMT (Benedict, 1997) is a visual memory test with a display of six geometric figures that are presented for three trials of 10 seconds.

After each trial participants are prompted to draw the display from memory. Administration guidelines suggest that after approximately 25 minutes participants should be prompted for delayed free recall. A 12 item discrimination test with 6 distractor items interspersed target items follows delayed free recall. A simplified d′ measure is calculated by subtracting false alarms from total hits. The test has demonstrated excellent inter-form reliability among the six equivalent alternate forms (Benedict, Schretlen, Groninger, Dobraski, & Shrpritz, 1996). During session one, form 1 of the BVMT was administered; and during session two, form 4 was administered.

Rey Auditory Verbal Learning Test (RAVLT). The RAVLT (Rey, 1964) is a verbal learning task that is widely used in empirical studies and clinical settings. The RAVLT is a 15-item list of unrelated words. The target wordlist is presented over five trials and following each trial there is a free recall whereby participants are encouraged to list all the word they can remember including those mentioned on previous trials. A 15 item distractor list is presented immediately before a short-delay free recall of the target wordlist. The delayed recall component consists of a free recall and recognition test. Total hits and false alarms are recorded on the recognition test. Form 1 was presented during session one and alternate form 2 was presented during session two. Alternate form reliability coefficients range from .67 to .90 on various forms of the RAVLT (Dawkins, Dean, & Pearlson, 2004; Shapiro & Harrison, 1990).

Executive functioning measures.

Phonemic fluency. The Controlled Oral Word Association Test (COWA; Benton, Hamsher, & Rey, 1989) is a commonly used measure of verbal fluency that has been utilized as an outcome measure in previous CT studies (e.g., Wadley et al., 2007). This task requires examinees to say as many words as possible beginning with a certain letter in a one-minute period. No proper nouns (e.g., people, places, or brand names) or repeated words are counted in the total for each letter. The most common form of the COWA requires examinees to generate words for letters F, A, S; this version was administered during session one. The alternate PRW version was administered during session two. Alternate form reliability across different versions of COWA is high (Ruff, Light, Parker, & Levin, 1996). Raw scores of the sums of all three letters were computed and pre and post administrations and used as the primary dependent measure.

Semantic Fluency. The Animal Naming test is a commonly used measure of semantic fluency (e.g., Tombaugh, Kozak, & Rees, 1999). This test is often used in conjunction with COWA and has been employed in previous CT studies (e.g., Wadley et al., 2007). Examinees are required to name as many animals as possible in 90 seconds. Repeats and set loss errors are not included in raw scores totals. Animal naming was administered during session one; and during session two, an alternate semantic fluency task will be administered. Boy's names is a widely-used alternative to animals and was utilized in the current study (Delis, Kaplan, & Kramer, 2001).

Trail-making Tests (TMT). The TMT (commonly referred to as Trails) is a measure of motor speed, visual attention, and executive functioning (Reitan, 1958). The TMT has been used ubiquitously in CT studies as an outcome measure (e.g., Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007). In the current study, Trails was classified as a proximal measure of transfer effects because one of the Brain Age Check tasks (i.e., Connect Maze) that participants completed periodically throughout the study is directly designed after the rapid alternate sequencing concept of Trails B/D. There are two parts to the Trails test: Part A and Part B. Alternate forms C and D have been developed to correspond to parts A and B, respectively. Part A is primarily a measure of processing speed: Examinees are instructed that they will complete a connect-the-dots test and asked to draw lines connecting numbers chronologically from 1 to 25 as rapidly as possible. Examiners inform the examinees of any errors made during completion of the task and redirect them. Total time to complete the task is recorded along with the total number of errors. Part B is a more direct measure of executive functioning in that the task requires alternating and sequencing which are well established correlates of frontal lobe functioning (Lezak, Howieson, & Loring, 2004). Part B consists of 25 numbers and letters which must be connected switching back and forth between numbers and letters. Administration is identical to Part A; total time to complete the task is recorded along with total number of errors. Performance on alternate forms of the TMT (i.e., A/C; B/D) is significantly correlated; however, Form C scores have been demonstrated to be consistently lower than Form A scores (Franzen, Paul, & Iverson, 1996). Given this consideration, Forms A/B and Forms C/D were administered in either the pre or post session in a counterbalanced fashion across conditions.

Auditory working memory. Working memory has been found to be significantly impacted following CT and several prior studies have demonstrated that digit span as a valid indicator of improvements in auditory working memory (e.g., Bugos et al., 2007; Mahncke et al., 2006; McDougall & House, 2012). The Digit Span subtest from the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, 1998) was used in the current study due to ease of administration and availability of alternate forms for pre and post testing. Single digits are verbally presented at a rate of one per second and examinees repeat the sequence exactly as they heard it. The test is discontinued following two consecutive failed trials. Good alternate form reliability has been demonstrated on the RBANS (i.e., .77; Wilk et al., 2004). Longest digit span forward (LDSF) was used as the primary dependent variable in the current study.

Visual working memory. Previous research has demonstrated that prolonged playing of video games significantly enhances visual attention and perceptual-motor skills among older adults (e.g., Schueren, 1986) and positive effects of training on visual working memory have also been observed in CT studies (Peretz et al., 2011; Shatil et al., 2010). The Spatial Span subtest is a visual working memory task from the Wechsler Memory Scale-III (Wechsler, 1997a) and it is distinct from other working memory tasks because it is presented entirely in the visual modality. A stimulus board with a pattern of blocks in a random array is presented and examiners touch the blocks in random order in increasingly longer sequences. During the Span Forward part of the subtest, examinees must the reproduce the original pattern from working memory; and during the Span Backward part examinees are prompted to touch the blocks in reverse order of the original pattern. Maximum number of blocks recalled forward (i.e., LSSF) and backward (i.e., LSSB) were used as dependent measures in the current study. The Spatial Span test is considered a proximal measure of transfer effects in the current study because of its close resemblance to two of the Brain Age^{TM} daily training tasks (i.e., Low to High; Head Count).

Psychomotor speed. CT research has long posited that psychomotor speed may be positively impacted by training regimens but there is wide variability in the inclusion of processing speed measures in prior studies (e.g., Willis et al., 2006). The digit symbol task is a test of attention and psychomotor speed (Spreen & Strauss, 1998). The digit symbol task requires examinees to rapidly substitute arbitrary symbols for digits from 1 to 9 by using a key at the top of the page. The time limit is 120 seconds. The total number of symbols filled in correctly before the time limit expires will be recorded as the primary dependent variable. Following the substitution portion of the test, an optional symbol copy trial whereby examinees copy symbols rapidly was utilized in the current study as a primary test of psychomotor speed. Moderate practice effects have been observed at one to two week retest intervals with the digit symbol substitution task (Hinton-Bayre & Geffen, 2005). Thus, in the current study the digit symbol test from the WAIS-III (Wechsler, 1997b) was administered during session one and the digit symbol test from the WAIS-IV (Wechsler, 2008) was administered during session two. The WAIS-III symbol copy test was administered during sessions one and two of the current study as there is no alternate version available. Given that the retest interval in the present study is six weeks and digit symbol performance significantly decreases with age due to psychomotor slowing (Joy, Fein, & Kaplan, 2003) it is not likely that practice effects were a confounding factor.

Reasoning. A few studies have examined the impact of CT on abstract reasoning abilities (Ackerman et al., 2010; Ball et al., 2002; Owen et al., 2010). In the current study participants were administered the Similarities subtest from the WAIS-III (Wechsler, 1997b) as an index of verbal abstract reasoning abilities. The task requires examinees to describe how several word pairs are alike (e.g., "How are praise and punishment alike?"). For the purposes of pre- and post-testing, the odd and even items were divided into two alternate forms. These forms are likely to be equivalent, given that Similarities items have demonstrated high split half reliability (Wechsler, 1997b).

Math fluency. Speeded written arithmetic is a common training task in commercially available "brain training" software (Ackerman et al., 2010; McDougall & House, 2012; Nacke et al., 2009) and is major component of the daily training tasks for the Brain Age^{TM} in the current study (i.e., Calculations X 20; Calculations X 100). Thus, a written speeded arithmetic task, the Math Fluency subtest from the Woodcock-Johnson III Tests of Achievement (Woodcock, McGrew, & Mather, 2001), was administered in the current study as a proximal measure of training-related transfer effects. The Math Fluency test is 180 basic arithmetic problems that participants have three minutes to complete as many problems as possible within the time limit. Form A of Math Fluency was administered during session one and form B was administered during session two. Although alternate form reliability data was not available, median test-retest reliability for Math Fluency is .90 (Woodcock et al., 2001).

Self-report symptom measures. A variety of self-report measures were administered to assess mood, perceptions of cognitive functioning, and reactions to using the Nintendo DS during the at home portion of the study.

Geriatric Depression Scale (GDS). Older adults with depression are at greater risk for experiencing further cognitive decline, to the extent that depression is often considered a prodromal stage for dementia (Steffens et al., 2007). Additionally, prior CT studies with older adults have demonstrated a decrease in depressive symptoms following training (e.g., Kurz et al., 2009; Rozzini et al., 2007). The GDS is included in the present study to monitor baseline depressive symptoms and determine if CT impacts the level of endorsed depression. The GDS is 15-item brief screen for depression that is designed for adults aged 60 or older (Sheikh & Yesavage, 1986). Participants are asked to answer the questionnaire items to describe their mood "over the past week including today." Total scores > 5 on the GDS are indicative of depression. Notably, the GDS does not contain any items assessing for suicidal ideation or intent. In the present study, researchers did not assess for suicidal ideation or intent as this not a primary aim of the study.

Beck Anxiety Inventory (BAI). Recent CT studies have demonstrated that training positively impacts overall psychological well-being and reduces anxiety regarding cognitive complaints (e.g., Verhaeghen et al., 2000; Winocur et al., 2007). The BAI (Beck & Steer, 1993) is a widely-used self-report measure of general anxiety symptoms and was administered at pre and post-test in the current study.

Memory Functioning Questionnaire (MFQ). Prior research suggests that assessing participants' subjective belief in their own memory abilities may be an important aspect of cognitive interventions (e.g., Rapp et al., 2002). A recent study of the effectiveness of the Brain Age^{TM} software demonstrated that participants with higher perceived estimates of their own cognitive abilities were more likely to benefit from training (McDougall & House, 2012). The MFQ is a 64-item self-report questionnaire that assesses participants' estimates of their own memory failures in a variety of everyday situations (Gilewski, Zelinski, & Schaie, 1990). Participants are required to rate the frequency of occurrence of each memory problem from 1 = "Always" to 7 = "Never." Four main scales are included in the MFQ: General Frequency of Forgetting, Seriousness of Forgetting, Retrospective Functioning, and Mnemonics Usage. The scales have demonstrated excellent internal consistency with Cronbach's alphas ranging from 0.83 to

0.94 (Gilewski et al., 1990). Overall, lower scores on the MFQ scales are indicative of more subjective memory complaints.

Leisure Activities Survey. Numerous studies have demonstrated that lifelong participation in cognitively stimulating activities beneficially impacts cognitive abilities in older adulthood (e.g., Hertzog et al., 2009). The Leisure Activities Survey includes a wide variety of typical leisure activities for which participants rate the estimated number of hours spent per week engaging in each activity. Participants were also asked to rate how mentally engaging each task is to complete.

Nintendo ratings scales. Prior Nintendo-based CT studies have demonstrated the need to assess older adults' reactions to utilizing game consoles (Ackerman et al., 2010; Nacke et al., 2009). A five-item ratings scale assessing participants' reactions to using the Nintendo DS console was created for the purposes of the current study (See Appendix A). Participants in the CT and active control groups completed these questionnaires at home on a weekly basis over the course of the six-week study. Within the current sample, the aforementioned ratings scales demonstrated good internal consistency (i.e., mean Cronbach's $\alpha = 0.85$; see Table 1). During session two, participants completed an *Exit Questionnaire* with nine additional questions (i.e., appended to week 6 ratings scale questions) regarding general perceptions of participation in the study and interest in continuing use of the Nintendo DS (see Appendix B).

Procedure

Session one. Participants who were screened via phone completed pre- and post-testing in the Aging, Imaging, and Memory Lab at Marquette University. Explanation of risks, benefits, and study requirements were explained and informed consent was obtained during session one. Participants completed a "Demographic Questionnaire" including detailed demographic information and assessed baseline level of participation in cognitively stimulating activities (i.e., Leisure Activities Survey). Participants then completed a battery of neuropsychological and self-report measures to assess baseline neurocognitive performance (see Measures above). Participants were quasi-randomly assigned to either the CT or active control groups for the duration of the six-week study; assignment was determined before the participants' arrival to the lab. At the conclusion of the session, a follow-up appointment was scheduled six weeks from the date of the pre-test session and participants were provided with a reminder card. Throughout the six-week study, participants were contacted on a weekly basis to address questions and provide reminders to complete ratings questionnaires related to using the Nintendo DS. Participants also received reminder calls the day before the scheduled follow-up session.

Cognitive training group. Participants in the CT group received a Nintendo DS console along with a copy of the Brain Age™ (2006) software. At the end of session one, research assistants provided participants in the CT group with a tutorial on using the game, including an explanation of the basic operation of the Nintendo DS console. Participant were allowed time to acclimate to using the touch screen and stylus pen and set up a personal data file in order to complete the first "Brain Age Check." The "Brain Age Check" is series of three short tests that provide an index of a player's proficiency in completing cognitive tasks via an estimated "brain age." Players are frequently reminded of any discrepancies between estimated "brain age" and his or her actual age. For reference, the lowest possible brain age score is 20; and the highest possible brain age score is 90.

After completing the “Brain Age Check” participants were instructed briefly on how to access the “Daily Training” menu. Each game that is included as part of “Daily Training” is preceded by detailed instructions when it is first presented. Participants completed the first three available training tasks in the lab in order to practice and address any questions. Before embarking on at home tasks, participants were given a binder with a cushioned carrying case, power cord for recharging the Nintendo DS, sheets to track completion of various training tasks, and weekly ratings scales. Participants also received the written Instruction Booklet that accompanies the game to provide further explanation and reminders of different facets of the program.

“Daily Training” at home. Participants in the CT group were instructed to use the Brain Age™ software for a minimum of 20 minutes per day for six weeks. Participants completed a total of 14 hours of training over the study period. Participants were instructed to select and complete at least three daily training tasks per day and allowed to repeat them if necessary until they played for 20 minutes (See Appendix C for a detailed description of the “Daily Training” tasks). The program initially provides only three tasks (e.g., Calculation X 20; Calculation X 100; Reading Aloud) but as players continue to play the game daily, more difficult training tasks are “unlocked” and become available. Six of the nine total daily training tasks were available to participants by the end of week one of the study. An additional three difficult tasks (i.e., Triangle Math, Time Lapse, and Voice Calculation) became available by the end of week two. Participants were instructed to complete at least three daily training tasks, after which they were allowed to complete any of the Sudoku puzzles listed under the “Daily Training” menu. Completion of these puzzles was optional and not analyzed in the

current study. Given that many individuals find Brain Age™ tasks mentally engaging and interesting, participants were instructed not to play more than 45 minutes per day. The software program provided a built-in manipulation check by automatically recording players' usage and performance on training tasks over the six-week study. During the orientation to using the game, participants were instructed about the variety of training tasks and encouraged to complete each available task thrice weekly.

Starting from the date of session one, participants completed one "Brain Age Check" at the end of each week of training. Following the completion of regular daily training, participants accessed the "Brain Age Check" menu and completed tasks as prompted. Again, these data were automatically recorded and stored by the Brain Age program and later accessed to ensure completion. Refer to Appendix D for detailed description of the tasks used to estimate the "Brain Age Check."

Control group. Participants in the active control group received a Nintendo DS console along with a copy of the Clubhouse Games™ (Agenda, 2006) software. At the end of session one, research assistants provided participants in the control group with a tutorial on the basic operation of the Nintendo DS console and how to access the card games. Clubhouse Games™ offers a variety of popular parlor games, including three tiers of card games: Basic, Intermediate, and Advanced. For the purposes of the current study, control participants were instructed to select and play two different card games per day over the six-week study period (See Appendix E for list of available card games). In order to promote non-specific cognitive stimulation, no specific guidelines regarding card game selection were provided. Daily training time was matched between the CT and control group (i.e., minimum of 20 minutes, no more than 45 minutes total). As with the

CT group, control participants were given a binder with a cushioned carrying case, power cord for recharging the Nintendo DS, sheets to track completion of various training tasks, and weekly ratings scales. Participants also received the written Instruction Booklet that accompanies the game to provide further explanation and reminders of different facets of the program.

Session two. Participants returned to the lab six weeks from the date of the first session to return all study-related materials and completed post-test measures. Whenever possible, alternate forms of neuropsychological measures were administered to reduce practice effects (See Figure 1). Due to scheduling conflicts, three participants in the CT group and five participants in the control group returned later than the date of the originally planned follow-up session (i.e., days past scheduled follow-up date: Mean = 4; SD=3.51). At the conclusion of session two all participants completed an “Exit Questionnaire” regarding their experiences during the study, including perceptions towards using the Nintendo DS.

Statistical Analyses

The current study is based on a 2 within-subjects (i.e., pre-test/post-test) by 2 between-subjects (i.e., CT/control groups) experimental design. All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 19.0 for Windows. An alpha level of $p < .05$ was applied as criterion for significance in all analyses.

Results

Demographic Characteristics and Baseline Measures

All participants completed a detailed demographic and medical questionnaire during session one. To test for baseline group differences in demographic, medical, and lifestyle variables (Hypothesis 1), independent sample t-tests and chi-square analyses were utilized as appropriate. There were no significant differences between the CT and control group for demographic variables (see Table 2). No participants endorsed having been diagnosed with MCI, Parkinson's, Alzheimer's, or other dementing disorders. Per the medical history checklist, there were no differences in rate of endorsement of any other medical conditions or subjective ratings of health (all Chi-square p values > 0.05). Time spent engaging in various cognitively stimulating activities did not differ by group (see Table 3). Although both groups scored fully within normal limits (i.e., no scores $<$ 26), MMSE total scores at baseline were significantly higher in the control group than in the CT group ($t(34.92) = -2.24$, $p < 0.05$).

To test for baseline group differences on neuropsychological measures (Hypothesis 2), independent samples t-tests were computed. No other significant differences in baseline performance on neuropsychological measures were observed (see Table 4). To test for baseline group differences in subjective memory complaints (Hypothesis 3) and mood (Hypothesis 4), independent samples t-tests were used. There were no significant differences between groups on symptoms of depression, anxiety, or subjective memory complaints (i.e., MFQ) at baseline (see Table 5).

Daily Training Activities

Performance on daily training activities. In order to test whether performance on daily training tasks improved in the CT group (Hypothesis 5), frequency of training completion and performance on various Brain Age tasks were analyzed. Out of a total of 42 possible days of at-home training, participants in the CT group completed a mean of 36.9 (SD = 8.82) days of training. See Table 6 for a summary of completion of daily training tasks. Performance across daily training activities available via the Brain Age software was analyzed using growth curve modeling. Dependent variables (DV) were the aggregated raw scores within-subjects for each weekly time point (i.e., 1 through 6). Five time points were included for analyses of performance on Triangle Math, Time Lapse, and Voice Calculation as these tasks did not become available to participants until week 2.

Table 7 presents a summary of the statistical results from the daily training activity analyses. Performance significantly improved over time on Calculations X 100, Syllable Count, Triangle Math, and Time Lapse as indicated by significant negative linear trends (i.e., lower scores indicate better performance). Low to High scores significantly improved over time (i.e., increased) as indicated by a significant positive linear trend. Significant linear and quadratic trends were noted on Calculations X 20, Reading Aloud, and Head Count, indicating that performance initially improved and the rate of increase slowed over time. Voice Calculation scores did not significantly improve over time. Linear, quadratic, and cubic models were tested but did not reveal significant effects (all p’s > 0.05).

Brain age scores. To test whether "brain age" scores improved over the course of the study (Hypothesis 6), aggregated scores for each weekly time point (i.e., 1 through 6) were analyzed using growth curve modeling. Estimated "brain age" significantly decreased over time, as indicated by a significant negative linear trend ($\beta = -14.33$, $t(112.29) = -6.47$, $p < 0.001$). Addition of a quadratic parameter significantly improved model fit ($\chi^2(1) = 19.13$, $p < 0.01$). Significant positive quadratic growth ($\beta = 1.39$, $t(102.04) = 4.59$, $p < 0.001$) indicated that scores plateaued after an initial decrease (see Figure 3).

Control group. Due to limitations of the Clubhouse Games® software, specific performance data on individual card games was unavailable; however, data was recorded indicating the frequency with which each card game was attempted over the course of the six-week study. Out of a total of 42 possible days of at-home training, participants in the control group completed a mean of 39.21 (SD = 4.49) days of training (i.e., defined as days on which participants attempted at least one card game)[1]. There was no difference between the CT and control groups in the total numbers of days of at-home training completed ($t(38) = -1.03$, $p = 0.31$). Mean total number of card games completed (i.e., sum of all games played per participant) was 186.76 (SD = 109.3). Basic card games were selected most frequently (M = 108; SD = 105.68), followed by the Intermediate card games (M = 52.67; SD = 22.66), and Advanced card games (M = 25.1; SD = 31.29). There was wide range in the frequency with which card games were selected by control group participants, as indicated by large standard deviations and several high outlier values across participants (see Table 8).

Neuropsychological Outcome Measures

Each outcome measure was administered at pre-test and post-test and analyzed using a 2 (Time; within-subjects) X 2 (Group; between-subjects) mixed ANOVA. See Table 9 for a summary of mixed ANOVA results for neuropsychological outcome measures.

Performance on memory measures. In order to test whether memory performance improved from pre-test to post-test (Hypothesis 7), several RAVLT and BVMT subtests were analyzed. RAVLT immediate recall total (i.e., sum of correct on trials 1-5), short-delay recall, and delayed recall performance significantly decreased from pre-test to post-test in both groups. There were no significant main effects or interactions for RAVLT recognition accuracy (i.e., hits minus false alarms). On the BVMT there was a marginally significant main effect of Time (i.e., p = 0.07; see Table 9). Immediate recall performance improved in both groups. There was a limited range of scores on the delayed discrimination index (i.e., 0-6), causing a significant negative skew (pre-test skewness = -1.84; post-test skewness = -3.91). Thus, these data were transformed prior to analysis by inverting scores and applying a square root transformation[2], according to a procedure recommended by Howell (2007) for moderately negatively skewed data. No significant main effects or interactions were observed on BVMT delayed recall or delayed discrimination (see Table 9).

Everyday memory abilities. In order to test whether everyday memory performance improved from pre-test to post-test (Hypothesis 8), two subtests were analyzed from the RBMT: immediate recall and delayed recall. RBMT immediate recall performance significantly improved from pre-test to post-test in both groups (see Figure

4). Delayed recall performance also significantly improved from pre-test to post-test in both groups (see Figure 5). No other significant main effects or interactions were observed (see Table 9).

Abstract reasoning. In order to test whether verbal abstract reasoning ability improved from pre-test to post-test (Hypothesis 9), total scores of the WAIS-III Similarities subtest were analyzed. No significant main effects or interactions were observed (see Table 9).

Working memory. In order to test whether verbal and visual working memory abilities improved from pre-test to post-test (Hypothesis 10), R-BANS Digit Span LDSF and WMS-III Spatial Span LSSF and LSSB were analyzed. LSSF performance significantly improved from pre-test to post-test in both groups (see Figure 6). LSSB performance also significantly improved from pre-test to post-test in both groups (see Figure 7). No other significant main effects or interactions were observed; and there were no significant effects of training on LDSF (see Table 9).

Executive functioning. In order to test whether performance on executive functioning measures improved from pre-test to post-test (Hypothesis 11), COWAT total score (i.e., phonemic fluency), semantic fluency total score, and Trails A&B and C&D time and total errors were analyzed. Trails forms A&B or C&D were administered at each session in counterbalanced order across participants; 26 (13 in CT, 13 in control) received order 1 (A&B, C&D) while 16 (8 in each group) received order 2 (C&D, A&B). There were no significant effects of training on Trails A/C and B/D times or total errors (see Table 9). However, there was a marginally significant (i.e., p = 0.06) Group main effect on Trails A/C errors. The control group had slightly more errors overall than the

CT group. No main effects or interactions were observed on phonemic fluency and semantic fluency scores (see Table 9).

Psychomotor speed. In order to test whether processing speed performance improved from pre-test to post-test (Hypothesis 12), digit symbol substitution total correct, symbol copy total correct, and symbol copy time to complete were analyzed. No significant main effects or interactions were observed on any measures of psychomotor speed (see Table 9).

Math fluency. The WJ-III math fluency test was administered at pre-test and post-test as a proximal measure of training effects. Math fluency total correct scores and total time to complete were analyzed. Total correct scores demonstrated a main effect of Time (see Table 9). Performance improved significantly in both CT and AC groups from pre-test to post-test (See Figure 8). No other main effects or interactions were observed. There was a limited range of time to complete scores due to a time limit of 3 minutes on the test causing a significant negative skew (pre-test skewness = -2.78; post-test skewness = -2.08). These data were inverted and square root transformed according to the same procedure described previously in this study for moderately negatively skewed data (Howell, 2007). Total time to complete the test significantly decreased in both CT and AC groups from pre-test to post-test (See Figure 9). No other main effects or interactions were observed (see Table 9).

Supplementary analyses of group effects. In order to further examine group differences for measures that demonstrated significant Time main effects in omnibus F analyses (i.e., RBMT; Spatial Span; Math Fluency; RAVLT), post hoc repeated measures ANOVAs were conducted for each experimental group separately.[3] See Table 10 for a summary of results. Notably, in the CT group alone performance gains from pre-test to post-test remained significant for all DVs, with the exception of Spatial Span LSSB. In the AC group alone, performance gains remained significant for RBMT delayed recall and Spatial Span LSSF only. Performance gains on all other DVs were no longer significant in the AC group. After parceling experimental groups, performance decrements on the RAVLT remained significant for immediate recall in the AC group alone, and for delayed recall in the CT group alone.

Covariance analyses of AC group effects. Given the wide variability in the frequency of game playing (i.e., total games played, range = 28 to 548) and types of card games selected by participants in the AC group (i.e., basic games vs. advanced games), supplementary ANCOVA analyses were conducted to evaluate whether these factors contributed to the measured performance gains. Separate ANCOVAs were conducted for each of the DVs that demonstrated significant Time main effects in omnibus analyses (see Table 9) with two covariates: number of advanced card games played and total number of card games played.

RBMT immediate recall. The covariates, number of advanced card games played and total card games played, did not significantly predict change in scores from pre-test to post-test (both F’s < 1). After controlling for the effects of the covariates, there was no significant improvement in scores from pre-test to post-test ($F(1,18) = 2.99$, $p = 0.10$, $\eta^2 = 0.14$).

RBMT delayed recall. The covariates did not significantly predict change in scores from pre-test to post-test (both F’s < 1). After controlling for the effects of the covariates, there was no significant improvement in scores from pre-test to post-test ($F(1,18) = 1.85, p = 0.19, \eta^2 = 0.09$).

RAVLT immediate recall. The covariates did not significantly predict change in scores from pre-test to post-test (both F’s < 1). After controlling for the effect of the covariates, immediate recall scores significant improved from pre-test to post-test ($F(1,18) = 4.87, p < 0.05, \eta^2 = 0.21$).

RAVLT short delay recall. The covariates did not significantly predict change in scores from pre-test to post-test (both F’s < 1). After controlling for the effect of the covariates, short delay recall scores significant improved from pre-test to post-test ($F(1,18) = 6.93, p < 0.05, \eta^2 = 0.29$).

RAVLT delayed recall. The covariates did not significantly predict change in scores from pre-test to post-test (both F’s < 1). After controlling for the effects of the covariates, there was no significant improvement in scores from pre-test to post-test ($F(1,18) = 1.12, p = 0.30, \eta^2 = 0.06$).

Spatial span LSSF. The covariate, total card games, significantly predicted change in LSSF scores ($F(1,18) = 5.45, p < 0.05, \eta^2 = 0.23$). The covariate, advanced card games did not predict change in scores from pre-test to post-test ($F < 1$). After controlling for the effects of the covariates, there was no significant improvement in scores from pre-test to post-test ($F(1,18) = 2.07, p = 0.17, \eta^2 = 0.10$).

Spatial span LSSB. The covariates did not significantly predict change in scores from pre-test to post-test (both F’s < 1). After controlling for the effect of the covariates, LSSB scores significantly improved from pre-test to post-test ($F(1,18) = 5.07, p < 0.05$, $\eta^2 = 0.22$).

Math fluency total correct. The covariates did not significantly predict change in scores from pre-test to post-test (both F's < 1). After controlling for the effects of the covariates, there was no significant improvement in scores from pre-test to post-test ($F(1,18) = 1.06$, $p = 0.32$, $\eta^2 = 0.07$).

Math fluency time. The covariate, advanced card games, significantly predicted change in math fluency time scores ($F(1,18) = 4.71$, $p < 0.05$, $\eta^2 = 0.21$). The covariate, total card games, did not significantly predict change in math fluency time scores ($F < 1$). After controlling for the effect of the covariates, math fluency time scores significantly improved from pre-test to post-test ($F(1,18) = 7.99$, $p < 0.05$, $\eta^2 = 0.31$).

Self-perceived Memory Ability

In order to evaluate whether self-perceived memory ability predicted engagement in training activities (Hypothesis 13), bivariate correlations between MFQ scales at pre-test and the total number of training days completed over the six-week study. No significant correlations were observed: General Frequency of Forgetting ($r = 0.22$, $p = 0.16$); Seriousness of Forgetting ($r = 0.11$, $p = 0.52$); Retrospective Forgetting ($r = 0.23$; $p = 0.16$); and Mnemonics Usage ($r = -0.30$, $p = 0.06$).

Symptom Measures

In order to test whether mood improved from pre-test to post-test (Hypothesis 14), the GDS and BAI were administered and analyzed using a 2 (Time; within-subjects) X 2 (Group; between-subjects) mixed ANOVA. Regarding depressive symptoms, there were no significant main effects of Time ($F(1,40) = 0.01$, $p = 0.92$, $\eta^2 < 0.001$), Group ($F(1,40) = 0.98$, $p = 0.33$, $\eta^2 = 0.02$), or interaction effect ($F(1,40) = 1.28$, $p = 0.27$, $\eta^2 = 0.03$). Regarding anxiety symptoms, there were no significant main effects of Time (F(1,40) =

0.51, $p = 0.48$, $\eta^2 = 0.01$), Group ($F(1,40) = 0.003$, $p = 0.96$, $\eta^2 < 0.001$), or interaction effect ($F(1,40) < 0.001$, $p = 1.0$, $\eta^2 < 0.001$).

Subjective Ratings of Gameplay Experience

All participants completed six weekly five-item questionnaires regarding experiences using the Nintendo DS (e.g., "How entertaining was it to use the Nintendo DS?"). Six (Time; within-subjects) X 2 (Group; between-subjects) mixed ANOVA was used to analyze participants' ratings with each of the five questionnaire items as DVs. Greenhouse-Geisser corrected F values are reported when sphericity assumptions (Mauchly p's < 0.05) were not met.

Mixed ANOVA with participants' ratings of enjoyability over the six-week study demonstrated no significant main effects of Time ($F(3.21,96.36) = 0.81$, $p = 0.50$, $\eta^2 = 0.03$), Group ($F(1,30) = 0.21$, $p = 0.65$, $\eta^2 = 0.01$), or interaction effect ($F(3.21,96.36) = 1.3$, $p = 0.28$, $\eta^2 = 0.04$). Participants' ratings of entertainment over the six-week study demonstrated no significant main effects of Time ($F(3.26,97.69) = 0.56$, $p = 0.66$, $\eta^2 = 0.02$), Group ($F(1,30) = 0.73$, $p = 0.40$, $\eta^2 = 0.02$), or interaction effect ($F(3.26,97.69) = 2.06$, $p = 0.11$, $\eta^2 = 0.06$). Participants' ratings of intellectual engagement as the dependent measure demonstrated no significant main effects of Time ($F(2.92,87.49) = 0.29$, $p = 0.82$, $\eta^2 = 0.01$), Group ($F(1,30) = 1.81$, $p = 0.19$, $\eta^2 = 0.06$), or interaction effect ($F(2.92,87.49) = 1.14$, $p = 0.34$, $\eta^2 = 0.04$). Ratings of mental challenge over the six-week study revealed a significant main effect Group ($F(1,30) = 4.35$, $p < 0.05$, $\eta^2 = 0.13$), whereby participants in the CT group rated usage of the Nintendo DS as significantly more mentally challenging. There was no significant main effect of Time

($F(3.44,103.24) = 1.24$, $p = 0.30$, $\eta^2 = 0.04$) or interaction effect ($F(3.44,103.24) = 0.89$, $p = 0.46$, $\eta^2 = 0.03$).

Exit questionnaire. Participants rated overall experiences in participating in the study on additional items of the exit questionnaire. At post-test, 50% of all participants “agreed” or “strongly agreed” that their memory improved as a result of using the Nintendo DS. Results of a Mann-Whitney U test demonstrated a significant difference between groups in ratings of memory improvement ($U(42) = 146$, $p < 0.05$). A greater percentage of participants in the CT group endorsed subjective memory improvement as a result of study participation (see Figure 10). There was no difference between groups in ratings of improvement of general mental abilities as a result of using the Nintendo DS ($U(42) = 163.5$, $p = 0.13$). The majority of all participants (42.9%) responded “neutral” to this question.

The majority of participants (52.4%) “strongly agreed” that they successfully completed all daily at home activities for the study. There were no significant differences in response distributions between groups ($U(42) = 244.4$, $p = 0.51$). Participants were also asked whether they would consider purchasing a Nintendo DS unit in the future; and, at post-test, response distributions did not differ between groups ($U(42) = 181.5$, $p = 0.32$). The majority of participants (26.2%) responded “neutral” to the question, 23.8% “agreed,” 16.7% “strongly agreed,” 19% “strongly disagreed,” and 14.3% “disagreed.”

Discussion

The current study investigated the impact of daily CT, presented via the Brain Age^{TM} software for Nintendo DS, on neurocognitive abilities in a sample of healthy, community-dwelling older adults. Over the six-week study, participants in the CT group completed training activities and were compared to an active control group who played card games on the Nintendo DS. At pre-test and post-test a multiple empirically validated neuropsychological outcome measures were administered to examine transfer effects of training. Specifically, there were three main objectives for the current study: 1) to specifically validate the effectiveness of the training regimen presented via the commercially available Brain Age™ software versus video game-based cognitive stimulation; 2) to examine whether daily usage of Brain Age™ produces positive transfer effects to proximal and distal outcome measures; and 3) to examine the impact of daily CT on mood.

Baseline Group Characteristics

Overall, the groups were quite comparable at baseline. Thus, the first four hypotheses were primarily supported in the current study. There were no differences in demographic characteristics, frequency of medical diagnoses, or engagement in cognitively stimulating activities (Hypothesis 1). With the exception of the MMSE, baseline performance on all neuropsychological outcome measures was comparable between groups (Hypothesis 2). Additionally, there were no baseline differences in subjective memory complaints (Hypothesis 3) or depression and anxiety symptoms (Hypothesis 4).

Baseline MMSE scores were significantly higher among the active control group. Although random assignment to groups theoretically controls such systematic differences, in this case, it was not effective. The MMSE was administered primarily as a screen for more significant symptoms of cognitive impairment, which would have precluded an individual from study participation. No scores below the cut-off for clinical significance (i.e., < 26) were obtained and no participant endorsed serious cognitive complaints or diagnoses on the demographic questionnaire. As mentioned previously, no baseline differences on primary neuropsychological outcome measures were observed. As such, this difference likely did not contribute to the experimental effects.

Effectiveness of Brain Age Training

The first major aim of the current study was to validate the effectiveness of the training regimen presented via the commercially available Brain Age™ software versus video game-based cognitive stimulation. As hypothesized, performance improved on eight (out of nine) daily training tasks (Hypothesis 5) and “brain age” scores significantly decreased over the six-week study in the CT group (Hypothesis 6). These findings align with other computerized CT studies, which have consistently demonstrated significant performance improvement on training tasks over time (Owen et al., 2010; Shatil et al., 2010; Smith et al., 2009). In the current study, the results showed that the CT group participants were engaged in Brain Age training tasks enough to effectively improve performance on said tasks over time. Moreover, the observed reduction in “brain age” scores offered a built-in manipulation check that ensured participants benefitted from training, as these scores were estimated based upon the results of randomly presented daily training tasks or similar tests. Better compliance with the training regimen in the

CT group allowed the potential for greater performance gains on other outcome measures.

To this author's knowledge, there is only one prior published study of the effectiveness of Brain Age^{TM} (McDougall & House, 2012). In their study, the Brain Age group was compared to a no-contact control group matched in level of education, computer experience, and time spent watching TV and reading. The training duration was six weeks; however, no recommendations were provided to participants on how often to use the program, or which training tasks to complete. Frequency data revealed that participants completed training between two to three days per week. McDougall and House (2012) observed training-related improvement on digit span backward; however, participants with better perceived quality of life and estimates of their own cognitive functioning were more likely to benefit from training. The authors' interpretations were limited, ostensibly, by the restricted variety of outcome measures (i.e., four subtests of the WAIS-III) utilized in their study.

The current study expands upon the findings of the McDougall & House (2012) study in two ways. First, participants in both CT and AC groups of the current study were instructed to complete training tasks on a daily basis, which resulted in more frequent training sessions and better compliance with the training regimen. Second, McDougall & House (2012) did not report on performance on daily training tasks or "brain age" scores, which does not address the internal validity of the training itself. In the current study, performance on daily training tasks and "brain age" scores were recorded throughout the six week training period. Third, we included a broader array of outcome measures in order to evaluate the scope of training effects. In the current study, performance improvements on measures of visual working memory, verbal memory, and math fluency were observed in both CT and AC groups. McDougall & House (2012) observed training-related transfer to the backward portion of WAIS-III Digit Span. It is impossible to directly compare our findings with the McDougall and House study, because we utilized a version of digit span from the RBANS, which does not include a backward portion. Taken together with findings of the McDougall & House study, our results suggest that Brain Age training effects have an advantage over a no-contact control condition, but these effects do not exceed the effects obtained in an AC condition.

Evaluation of Transfer Effects

The second major aim of the current study was to examine whether daily usage of Brain Age™ produces positive transfer to proximal and distal cognitive domains. Notably, performance improved from pre-test to post-test on measures of everyday memory, visual working memory, and math fluency in both groups, thereby failing to support Hypotheses 7 through 12. At post-test, the CT group demonstrated no significant performance advantage over the AC group across measures of verbal and visual memory (Hypothesis 7), everyday memory (Hypothesis 8), verbal abstract reasoning (Hypothesis 9), visual and verbal working memory (Hypothesis 10), executive functioning (Hypothesis 11), and processing speed (Hypothesis 12).

In the current study, three proximal neuropsychological measures were administered that closely resembled or directly replicated daily training tasks (i.e., WMS-III Spatial Span; Trail-making Tests; WJ Math Fluency). The majority of neuropsychological outcome measures were spread across distal cognitive domains in order to assess potential transfer effects. The effects of both CT and video game-based cognitive stimulation (i.e., card games) produced significant transfer to proximal (e.g., math fluency; visual working memory) and distal (e.g., everyday verbal memory) outcome measures. It was hypothesized that performance across outcome measures would be preferentially enhanced in the CT compared to the AC group (i.e., Time by Group interaction); however, no significant interactions or Group main effects were revealed. Instead, performance improved in both groups on the aforementioned measures (i.e., significant main effects of Time). Although unexpected, this finding reveals that the types of tasks associated with Brain Age^{TM} training may not have the ability to produce robust transfer effects across a variety of cognitive domains when compared to general cognitive stimulation alone.

The evaluation of near and far transfer effects remains a fundamental goal of empirical CT studies (e.g., Barnett & Ceci, 2002; Hertzog et al., 2009). Proximal (i.e., "near transfer") outcome measures engage cognitive processes similar to the original training regimen, while distal (i.e., "far transfer") outcome measures engage different cognitive processes than the original training (e.g., Barnett & Ceci, 2002; Zelinski, 2009). Transfer effects have been inconsistently demonstrated in the extant literature, with differing findings across studies demonstrating transfer to proximal domains only (e.g., Ball et al., 2002; Basak et al., 2008), both proximal and distal domains (Manchke et al., 2006; Richmond et al., 2011; Smith et al., 2009), and a few studies that demonstrated no transfer effects at all (e.g., Ackerman et al., 2010; Owen et al., 2010). Barnett & Ceci (2002) posited that transfer effects are most likely to occur when generalized cognitive skills have been obtained through training, outcome measures are similar to trained tasks, and there is less memory demand to access training-related information in everyday life.

Indeed, the types of generalized skills referred to by Barnett & Ceci (2002) are similar to those in the Brain Age training tasks.

Brain Age transfer effects. The training tasks included in the Brain Age™ software are based upon complex, natural cognitive skills, theoretically toward promoting transferability of gains to daily life. These skills are familiar to individuals of all ages (e.g., counting; basic arithmetic; reading aloud), easily accessible without the need for excessive instruction, and presented repetitively throughout training. McDougall & House (2012) identified four main cognitive themes among daily training tasks: 1) speeded arithmetic (i.e., Calculations X 20; Calculations X 100; Triangle Math; Voice Calculation); 2) working memory (i.e., Head Count; Low to High); 3) language skills (i.e., Reading Aloud; Syllable Count); and 4) mental rotation (i.e., Time Lapse). Of these categories, mental rotation is the most highly specific skill (e.g., Zacks, 2008), albeit one that is presumably used in a variety of everyday visuospatial tasks. No measures of mental rotation or visuospatial functioning were included in the current study, however, rendering it impossible to evaluate potential proximal transfer effects. Language skills were another targeted area. However, these tasks were primarily based on reading fluency abilities, which were likely well above average in the current sample due to the relatively high educational attainment of the participants.

Speeded arithmetic is by far the most heavily emphasized skill and represented in four of the nine daily training activities. This is due to the origins of Brain Age™ from neuroimaging investigations (Kawashima et al., 2004; Miura et al., 2003) and one pilot intervention study (Kawashima et al., 2005) demonstrating the possible benefits of speeded arithmetic as a form of CT. Math fluency, a proximal measure of training effects, significantly improved from pre-test to post-test in the CT and AC groups in the current study. This is a significant finding as there is evidence that arithmetic ability decreases in older age, primarily due to declines in processing speed (e.g., Rozencwajg, Schaeffer, & Lefebvre, 2010). Post hoc analyses of the CT group alone revealed that performance gains on Math Fluency accuracy and time scores remained significant, while in the AC group alone gains were no longer significant. The discrepancies in results between the omnibus and post hoc analyses may suggest the inability to detect interaction effects in the omnibus analyses likely due to the small sample size in the current study. Improved Math Fluency scores in the CT group are significant, given the preponderance of arithmetic based tasks included in Brain Age training.

Although McDougall & House (2012) found no effect of Brain Age training on WAIS-III Arithmetic scores, it should be noted that the latter test is administered orally versus the written Math Fluency test used in the current study, which more closely depicts the repeated practice with solving written arithmetic problems experienced through training. Moreover, the role or working memory in arithmetic operations has been well-established (e.g., Hitch, 1978); and several studies have linked mathematical proficiency to visual (e.g., Dumontheil & Klingberg, 2012) and verbal (e.g., Peng, Congying, Beilei, & Sha, 2012) working memory abilities. Therefore, improved math fluency performance in the CT group may also have been related to extended practice on other training tasks emphasizing working memory skills.

Two training tasks, Head Count and Low to High, specifically tax visual working memory by requiring participants to track objects on the screen and answer questions after a brief delay; and the current study demonstrated improved visual working memory on forward and backward portions of Spatial Span, a proximal outcome measure, in the CT group. Our findings support an increasing number of studies (e.g., Buschkuehl et al., 2008; Peretz et al., 2011; Shatil et al., 2010) that have demonstrated transfer to a visually mediated working memory outcome measures following training. Prior CT studies that have specifically targeted working memory (e.g., Richmond et al., 2011) have clearly demonstrated that span memory can be improved in older adults via extended practice in training protocols. Several other CT studies have implemented verbally mediated working memory outcome measures, particularly digit span (e.g., Buiza et al., 2008). In contrast to the McDougall and House (2012) study, which also investigated the effectiveness of Brain Age™ training, no effects on auditory working memory were revealed in the current investigation. As mentioned previously, this is likely due to limitations of the R-BANS digit span test that was administered in our study.

There is substantial empirical evidence that the working memory system is largely mediated by neural networks in prefrontal cortical regions (e.g., Alvarez & Emory, 2006; Baddeley, Emslie, Kolodny, & Duncan, 1998; Miller & Cohen, 2001). Specifically, the dorsolateral prefrontal cortex (DLPFC) is involved in monitoring and manipulation of items within working memory (e.g., Petrides, 2000). Working memory load is proposed to involve stores for both verbal and visual information (Baddeley & Logie, 1999), both of which may be utilized during Brain Age training. The Brain Age™ program was originally designed to increase rCBF and metabolism in the DLPFC through completion of tasks that are highly correlated with DLPFC activation, such as speeded arithmetic and reading aloud tasks (Kawashima et al., 2005). The aggregate effect of completing speeded arithmetic, reading aloud, as well as visual working memory tasks suggest that working memory is the predominant cognitive skill highlighted through Brain Age™ training. Similar to other CT studies that focus on repeated presentation of working memory span training tasks (e.g., Richmond et al., 2011), it is possible that daily accessing of Brain Age training tasks in the current study allowed participants the opportunity to continually engage working memory abilities over the course of the training period. This overarching engagement of working memory throughout the study likely facilitated observed transfer effects in the CT group. This is a significant finding considering evidence that working memory abilities typically decline in older adults (e.g., Hartman & Warren, 2005).

Gains in immediate and delayed verbal recall were noted on RBMT in both groups, which was the only significant far transfer effect resulting from training. The RBMT was included in the current study to assess the impact of training on everyday functioning. The gains observed on the RBMT in the current study are notable because it is a measure of "everyday memory" functioning, which is posited as an ecologically valid measure that approximates how effectively training may affect memory performance in daily life (Wilson et al., 1989). The story recall subtest is primarily a verbal recall test related to long-term episodic memory (e.g., Tulving, 2000). Various mnemonic techniques have been developed to improve episodic verbal memory (e.g., Glisky & Glisky, 2008). Additionally, there are an increasing number of multimodal CT protocols that have demonstrated transfer effects to verbal memory outcome measures (Belleville et al., 2006; Gunther et al., 2003; Manckhe et al., 2006; Richmond et al., 2011). Working memory has been associated with the organization and transfer of information into long-term episodic memory and promotes later recall (e.g., Blumenfeld & Ranganath, 2006).

It is likely that training of working memory via Brain Age contributed to improved performance on the RBMT, given the ubiquity of working memory skills in everyday functioning.

In contrast to the positive performance gains observed on the RBMT, immediate, short-delay, and delayed recall scores on the RAVLT significantly *decreased* from pre-test to post-test in both groups. Potential explanations for these significant differences may be related to use of alternate forms and order effects. Although overall alternate form reliability between forms 1 and 2 of the RAVLT have been demonstrated to be good, Dawkins and colleagues (2004) noted that form 2 has been found to be more difficult when administered chronologically after the original form (i.e., discrepancy was not observed when form 2 preceded form 1 in counterbalanced fashion). In the current study, form 1 was administered during pre-test and form 2 during post-test (i.e., form order was not counterbalanced), so the aforementioned finding may partially explained the decreased performance in scores during session two. Additionally, during session two, the RAVLT was the final memory measure administered towards the end of a relatively long (i.e., 2.5 hour) testing session. Thus, it is possible that fatigue and decreased motivation had a detrimental impact on performance on the RAVLT.

Cognitive stimulation (‘control’) group effects. The current study further contributes to the literature comparing CT versus cognitive stimulation alone (i.e., via card games). Belleville (2008) defined cognitive stimulation broadly as “brain jogging” – essentially, any periodic cognitively engaging exercise that promotes cognitive health. As can be expected by this definition, there is wide variability in the extant literature on what constitutes cognitive stimulation, including highlighting certain letters in newspaper articles (Herrera et al., 2012), online trivia learning (Richmond et al., 2011), viewing educational DVDs and completing quizzes on the material (e.g., Smith et al., 2009), or social stimulation (Tarraga et al., 2006). One other very recently published study (Simpson, Camfield, Pipingas, Macpherson, & Stough, 2012) compared computerized processing speed training to a cognitive stimulation group that played card games (i.e., online solitaire) and found significant gains in reaction time in the trained group only. Although the majority of prior studies found an advantage of CT over cognitive stimulation alone (e.g., Manckhe et al., 2006; Richmond et al., 2011), a few have demonstrated, similar to the current study, comparable improvement among both CT and active control groups receiving cognitive stimulation (e.g., Tarraga et al., 2006).

Card games were chosen as the activity for the AC group in the current study because it was hypothesized that this was a nonspecific, mentally stimulating activity with which many older adults would have interest and familiarity. Consistent with guidelines on cognitive stimulation (e.g., Belleville, 2008) the card games were considered to be mentally engaging but not designed to progress in difficulty related to individual performance on tasks as in the Brain Age^{TM} program. Card games were presented in the same modality (i.e., via Nintendo DS) as training activities comparable to other recent studies (e.g., Peretz et al., 2011). Assuming participants' familiarity with rules of various card games, it was anticipated that the greatest challenge for AC participants would be learning to operate, and becoming comfortable with using the Nintendo DS unit. Furthermore, it was expected that AC participants would select games from categories that presented the most comfortable level of intellectual challenge. Anecdotally, several participants in the AC group reported little to no prior experience with playing card games; and these participants were encouraged to learn games from the "Basic" category over the course of the study (i.e., each game provides tutorials on rules), but no other guidelines were provided. Although specific data on performance on card games was not available due to limitations of the Clubhouse Games^{TM} software, recorded frequency data of card game completion revealed that AC participants most frequently selected games under the "Basic" menu, which presented less of an intellectual challenge. This finding suggests that many participants selected simpler games in order to reduce cognitive load involved with playing (or learning to play) card games presented in a new format.

Accumulating evidence points to reduced risk of cognitive decline in older adults who engage in more frequent cognitively stimulating leisure activities, including playing cards (e.g., Hall et al., 2009). Although unanticipated, the results of the current study support the literature on the beneficial effects of card playing. Apparently, no prior studies have empirically examined specific cognitive correlates of recreational card playing. However, executive functioning processes may play an essential role in card playing, which perhaps provides some clues to the effects obtained in this study. Executive functioning, also known as 'executive attention' (EA) refers to various higher-level cognitive processes involved in switching of attention, sequencing, inhibiting, and monitoring of information (e.g., Miyake et al., 2000) as well as "top-down" processing used in controlling other cognitive operations, including working memory (e.g., Miller & Cohen, 2001). One important aspect of EA is its role in monitoring and manipulating attentional control in situations with shifting rules (e.g., Fan, McCandliss, Sommer, Raz, & Posner, 2002; Raz & Buhle, 2006). Indeed, EA is utilized in daily life across a variety of cognitive tasks (e.g., Kochanska, Murray, & Harlan, 2000). Thus, it is possible that observed performance gains in the AC group could be attributed to improved executive functioning.

Engagement of EA was a commonality of the wide variety of card games offered through the Clubhouse Games^{TM} program, even simpler “Basic” games. It is possible that participants in the AC group, particularly those who had newly learned card games, were more likely to engage EA skills while tracking rules for each card game. Take as an example the most frequently played game in the current study: Sevens. This game requires one to monitor cards on the “table,” track the suits and sequences of cards in one’s own hand, and attend to changes in cards being played. This game presumably does not possess a significant working memory load, because the cards are always visible to players. But it is possible that the need to constantly monitor the shifting parameters in the game likely consistently engages the EA system. The Wisconsin Card Sort Test (WCST; Heaton, Chelune, Talley, Kay, & Curtis, 1993) is one of the most well known and empirically validated measures of executive functioning that requires attending to changing rules and switching attention. The skills inherent to successfully complete the WCST likely approximate the attendance to various rules of multiple recreational card games in the current study.

As discussed earlier, Brain Age training tasks purportedly engage working memory load in a variety of ways through repetitive exercises; and this mode of training may be qualitatively different from the types of cognitive skills used when playing card games, that is, monitoring of changing conditions and mental set shifting via EA. Activation of the working memory and EA systems are highly correlated (e.g., D'Esposito, 2008), However, there is evidence that the storage component of working memory (i.e., load or capacity) is dissociable from cognitive processes that manipulate or update information in working memory (e.g., D'Esposito, Postle, Ballard, & Lease, 1999; Smith & Jonides, 1999). The latter cognitive processes are commonly associated with EA (e.g., Kane & Engle, 2002). Participants in the AC group may have received focused, repeated rehearsal of EA skills as a result of card playing that ostensibly contributed to the observed positive transfer effects.

Importantly, post-hoc analyses of each experimental group alone revealed differences between groups from pre-test to post-test. In the CT group alone, performance gains remained significant for all but one of the DVs that demonstrated significant Time main effects in the omnibus analyses; and in the AC group alone performance gains remained significant for only two DVs (RBMT delayed recall; Spatial Span LSSF). As discussed earlier, it was hypothesized that interaction effects would be observed on outcome measures demonstrating a performance advantage for the CT group. No such significant interaction effects were observed in the omnibus analyses; however, an overall trend of enhanced performance in the CT group relative to the AC group was observed in post-hoc analyses. These findings point to power limitations in the current study and a possible inability to detect significant interaction effects in the overall analyses. Thus, performance gains in AC group of the current study should be interpreted cautiously. Future studies with larger sample sizes may be able to better elucidate the differential effects of Brain Age training versus cognitive stimulation alone.

Another possible contributing factor to the observed performance gains in the AC group was the wide range in total number of card games completed across participants.

Supplementary analyses revealed that the total number of card games completed by the AC group significantly predicted visual working memory (i.e., LSSF) scores and, when entered as a covariate, eliminated previously observed performance gains. These results suggest that for at least one of the affected outcome measures in the AC group, the change in scores was due more to the total amount of time spent playing cognitively stimulating card games than the games themselves or their inherent level of difficulty. Post-hoc analyses of the AC group alone also revealed that the number of advanced card games played accounted for improved performance on math fluency time scores; however, when controlled, performance gains from pre-test to post-test remained significant. Taken together, these findings indicate that the frequency with which control participants engaged in card playing contributed to performance on outcome measures. Recorded frequency data on the Nintendo DS demonstrated that 19 out of 21 participants in the AC group played more total card games than they were expected to complete throughout the study (i.e., greater than two games per day over six weeks). Given the extensive play of many in the AC group, it is possible that repeated playing of games reached a level comparable to the repeated practice inherent to the Brain Age™ training group. Likewise, better regulation of activities in the AC group, such as restriction of the choices of cards games or providing stricter guidelines on the maximum number of games played, may have reduced the effect of this confounding factor.

Effect of Training on Mood

The third and final objective of the current study was to examine the impact of CT on mood. A small number of studies have demonstrated that an ancillary benefit of CT may include reduction in depressive symptoms in older adult samples (e.g., Kurz et al., 2009; Rozzini et al., 2007), while others have failed to demonstrate impact on depressive symptoms (e.g., Elgamal et al., 2007; Naismith et al., 2011). Although a few studies have revealed that CT reduces anxiety related to cognitive complaints (Verhaeghen et al., 2000; Winocur et al., 2007), there have been no studies focusing on the impact of training effects on generalized anxiety symptoms. Thus, depression and anxiety self-report measures (i.e., GDS; BAI) were included at pre-test and post-test as an exploratory aim of the current study. It was expected that CT would have a beneficial impact on depression and anxiety symptoms following training, but no effects on symptom measures were revealed, thereby failing to support Hypothesis 14. these hypotheses were not supported. The sample in the current study was comprised of highly educated, active, healthy older adults with low levels of baseline endorsement of depression and anxiety symptoms. As such, floor effects were likely observed (see Table 5). Although the current investigation may not have been sensitive to evaluate the impact of CT on mood, another recent study with a sample of participants with lifetime history of depression (Naismith et al., 2011) also failed to find positive effects of CT on depression. Even where a reduction of symptoms has been found (e.g., Kurz et al., 2009; Rozzini et al., 2007), it is as yet difficult to discern whether the cause was the training itself or the increase of activity resulting from participating in it. Future studies should further investigate the impact of CT on mood in demographically diverse samples.

A prior study (McDougall & House, 2012) demonstrated that perceived self-efficacy in cognitive abilities and higher subjective quality of life ratings significantly predicted training gains. In the current study, subjective ratings of memory abilities, per the MFQ, did not correlate significantly with the number of training days completed in either the CT or AC groups, as was originally hypothesized (Hypothesis 13). This demonstrates that subjective estimations of memory performance were not related to compliance with the training protocols. Post-test MFQ ratings were not collected in the current study as originally intended, which limits the ability of this study to assess this issue.

Although performance gains were comparable between the CT and control groups on a measure of verbal memory (i.e., RBMT), subjective ratings of memory improvement were higher among the CT group at post-test. This finding is consistent with a prior study with MCI participants, which demonstrated improvement in subjective memory ability in the absence of objective gains (Rapp et al., 2002). This may be due to raised expectations among the CT group based upon the manner in which daily training tasks were presented via the Brain Age software. More difficult training tasks were progressively “unlocked” throughout the course of the six-week study as “rewards” for completing easier tasks; and automatic tutorials lauded the possible benefits of the Brain Age software to provide encouragement to complete tasks on a daily basis. Additionally, the CT group participants rated the use of the Brain Age software as significantly more mentally challenging than control subjects rated their card games. Notably, at post-test both the CT and AC groups demonstrated comparable performance improvement on the RBMT, a measure of everyday verbal memory that has been found to highly correlate with daily memory functioning (Wilson, 2003). Thus, participants’ expectations regarding training protocols may have had a strong influence on subjective estimations of cognitive ability following training, regardless of objective effects on functioning.

Ratings of gameplay experience. Lastly, other studies of video game-based training via Nintendo consoles have focused on assessing older participants' gameplay experiences (Ackerman et al., 2010; Nacke, Nacke, & Lindley, 2009). These studies reported that older adults rated their experiences in using these devices negatively. In the current study, there were no differences between CT and AC groups in ratings of enjoyability or entertainment value in using the Nintendo DS unit. The majority of participants responded that they felt they completed all daily at home activities for the study. Responses regarding whether participants would consider purchasing a Nintendo DS unit in the future were widely varied; however, there was no difference in responses patterns between groups. The majority, approximately one-fourth of all participants, expressed indifference, responding "neutral" to this question. A combined total of 40% of participants "agreed" or "strongly agreed" that they would consider using a Nintendo DS unit in the future. Overall, the current study effectively demonstrated that older adults were able to learn to utilize the Nintendo DS without major difficulties within the course of a single tutorial and that they continued to use the unit on a daily basis at home. Thus, our findings are encouraging regarding the future applicability of video game-based training protocols with older adults.

Limitations

Our findings contrast with prior studies (e.g., Herrera et al., 2012) that demonstrated an advantage of CT over cognitive stimulation alone. This discrepancy in findings may be attributed to the choice of activity selected for the active control condition (i.e., card games) in the current study. As noted earlier, many participants in the AC group had little prior experience with card games. Thus, extensive learning of these games took place via the tutorials and play experience. When coupled with the challenge of learning to use the Nintendo DS, the demands of learning new rules for various games in the control condition may have engaged executive attentional control to a comparable degree as did the Brain Age tasks in the experimental condition. Additionally, the majority of AC participants played far more total card games (i.e., per automatically recorded frequency data) than they were instructed to complete at the outset of the study. Although AC participants were instructed that they could play up to 45 minutes per day (i.e., matched to CT group), this produced a wide range in the total number of games played and had a statistically significant impact on performance gains on a visual working memory task. Similar to another recent study in which active control participants played only one card game (i.e., solitaire) (Simpson et al., 2012), it would have been beneficial to restrict the range of choices in available card games and provide specific guidance on how to play each card game at pre-test.

In the CT group, performance on the Voice Calculation task did not significantly improve over the six-week study, which suggests a possible limitation with the difficulty level of this task. Voice Calculation was one of the last tasks to become "unlocked" and available as part of the Brain Age program and many participants reported that they found the task subjectively more difficult. Also, several participants reported problems with voice recognition when using the software, which would have slowed performance on any tasks using this component. As a result, Voice Calculation was not a popular task and was completed least frequently with no gain in performance levels over time. Notably, McDougall and House (2012) also reported that participants had similar complaints regarding this task in their study.

As expected, participant attrition rate was considerable in the current study, which lessened statistical power to detect Time by Group interaction effects between the CT and control groups. Out of a total of 57 enrolled in the study, 42 (74%) completed all study related activities. It is likely that the time commitment of the current study was a deterrent to completing all assigned at-home tasks and a central reason for attrition. Although the majority of participants in the current study were retired, many reported that they found fitting in 20 minutes of daily Nintendo DS tasks to be burdensome with their active schedules. Despite being provided with written and verbal instructions on how to access tasks on the Nintendo DS at baseline, most of the participants that withdrew from the study, as well as a minority of participants who completed both sessions, reported that in the early weeks of the study they struggled to interface with basic aspects of the operation of the game console and accessing menus for both of the software programs. It is possible that frustration related to using the Nintendo DS contributed to some participants' withdrawal from the study. Although there were no differences in demographic and lifestyle variable between participants who completed the study and those who withdrew, we did not include a baseline measure to assess proficiency with using technological devices, which may have helped to elucidate attrition patterns.

Finally, potential participants in the current study were recruited from Marquette University alumni groups. As a result, the final sample was predominantly Caucasian and relatively highly educated (i.e., M = 16.51 years; SD = 2.85). Given these demographic characteristics, it is possible that there was greater than average history of engagement in cognitively stimulating activities over the lifespan, which may have predisposed participants to be more motivated to complete study-related tasks and open to utilizing computerized tasks. Future studies with more diverse and less highly educated samples are warranted, in order to determine the effect of training on individuals with less cognitive reserve.

Future Directions

An increasing number of CT studies have incorporated longitudinal assessments of training effects, ranging from six-month to one-year follow-up intervals (Buiza et al., 2008; Cherry & Simmons-D'Gerolamo, 2005; Willis et al., 2006). Preliminary findings have been mixed with indications that training gains can only be maintained with continuing booster sessions (e.g., Willis et al., 2006). Further data collection at future time points would help to elucidate the possible longitudinal effects of training among participants in the current study. It is possible that although the groups were comparably enhanced after 6 weeks of training, these training effects may be better maintained in the CT group over time than in the control group.

Given the previously discussed limitations of the active control condition in the current study, future investigations of Brain Age$^{\text{TM}}$ should compare the program to other video game-based cognitively stimulating activities. It is important that selected control activities engage attention but do not involve a significant working memory component. For example, a recent study with French schoolchildren (Lorant-Royer et al., 2010) compared Dr. Kawashima’s Brain Training$^{\text{TM}}$ with an active control group that played an action-based video game (i.e., “Super Mario Brothers”). Future studies with older adults should consider comparing Brain Age$^{\text{TM}}$ to other video games that do not involve significant contribution of working memory or EA (e.g., Jeopardy or other trivia-based video games), both of which are purported to have contributed to performance gains in the current study.

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Footnotes

[1] Binders were not returned by two control group participants and only recorded frequency data were available.

[2] Each score (X) transformed using following formula: Square root (K – X), where K is the highest possible score + 1.

[3] Exploratory repeated measures ANOVAs were conducted for all other DVs for both the CT group and AC group alone. There were no significant Time effects for the CT group alone and AC group alone across all other DVs (all p's > 0.05).

Table 1

Reliability coefficients of weekly scales rating Nintendo gameplay experience

Measure	Cronbach’s α
Week 1	0.76
Week 2	0.83
Week 3	0.89
Week 4	0.87
Week 5	0.90
Week 6	0.87

Table 2

Comparison of demographic characteristics by group

	CT Group (n=21)	AC Group (n=21)	χ^2	*p* (two-tailed)[1]
Mean age (SD)	65.33 (10.8)	63.71 (8.21)	0.55[2]	0.59
Sex (%)			0.12	0.73
Male	28.6	23.8		
Female	71.4	76.2		
Education in years (SD)	15.98 (3.04)	17.05 (2.6)	-1.23[2]	0.23
Race (%)			2.11	0.55
Caucasian	81.0	90.5		
African-American	4.8	4.8		
Hispanic	4.8	4.8		
Asian	9.5	0		
Retired (%)			1.56	0.21
Yes	47.6	66.7		
No	52.4	33.3		

Note: [1] Significance level at $p<0.05$. [2] Independent *t*-tests. CT = cognitive training; AC = active control.

Table 3

Hours per week spent participating in cognitively-stimulating activities by group[1]

	CT Group (n=21)	Control (n=21)	*t*	*p* (two-tailed)[2]
Reading Literature	4.13 (3.37)	4.66 (3.37)	-0.49	0.62
Reading Nonfiction	5.14 (5.7)	4.2 (4.68)	0.58	0.57
Doing crossword puzzles	1.23 (2.52)	1.68 (2.57)	-0.56	0.58
Playing cards, chess, or other games	1.35 (1.9)	0.75 (1.11)	1.20	0.24
Playing solitaire	1.04 (1.79)	1.5 (3.51)	-0.52	0.60
Writing	2.63 (4.75)	1.75 (3.22)	0.66	0.52
Using a computer	15.88 (16.57)	18.71 (13.49)	-0.60	0.55

[1] Selected activities from the Leisure Activities Survey. [2] Significance level $p<0.05$. CT = cognitive training.

Table 4

Baseline performance on neuropsychological measures

	CT Group (n=21)	AC Group (n=21)		
	Mean (SD)	Mean (SD)	*t*	*p* (two-tailed)
MMSE Total score	28.52 (1.54)	29.43 (1.03)	-2.24	0.03*
RBMT				
Immediate recall	7.86 (3.08)	9.4 (3.95)	-1.41	0.17
Delayed recall	7.21 (2.96)	7.71 (3.32)	-0.52	0.61
RAVLT				
Immediate recall total	51.67 (10.45)	49.05 (7.71)	0.92	0.36
Short-delay recall	10.86 (3.43)	9.4 (3.38)	1.37	0.18
Delayed recall	9.86 (3.73)	8.7 (3.13)	1.07	0.29
Recognition accuracy	11.33 (4.33)	11.0 (3.61)	0.27	0.79
BVMT				
Immediate recall	21.86 (7.42)	21.29 (7.02)	0.26	0.80
Delayed recall	8.9 (3.09)	8.57 (3.01)	0.35	0.73
Delayed discrimination	5.76 (0.54)	5.62 (0.67)	0.76	0.45
Trails A/C Time^1	30.14 (11.71)	30.57 (11.95)	-0.12	0.91
Trails B/D Time^2	84.24 (31.5)	74.05 (28.15)	1.11	0.28
Digit Span LDSF	6.33 (1.83)	7.0 (1.38)	-1.34	0.19
WMS-III Spatial Span				
Longest span forward	5.29 (1.06)	4.76 (1.0)	1.66	0.12
Longest span backward	4.9 (1.14)	4.71 (1.1)	0.55	0.58
WAIS-III				
Digit Symbol total correct	71.95 (17.0)	74.33 (17.33)	-0.45	0.66
Symbol copy total correct	115.19 (18.85)	111.29 (19.73)	0.66	0.52
Similarities total	10.67 (2.39)	11.19 (2.25)	-0.73	0.47
Math Fluency correct	125.48 (26.25)	132 (22.96)	-0.86	0.40
COWAT total	50.24 (14.21)	44.19 (10.21)	1.58	0.12
Animal naming total	26.57 (7.72)	28.48 (6.31)	-0.88	0.39

[1] Trail-making A or C administered in counterbalanced order during session one. [2] Trail-making B or D administered in counterbalanced order during session one. $p<0.05$. CT = cognitive training; AC = active control; MMSE = Mini Mental Status Exam; RBMT = Rivermead Behavioral Memory Test; RAVLT = Rey Auditory Verbal Learning Test; BVMT = Brief Visuospatial Memory Test; LDSF = Longest Digit Span Forward; WMS-III = Wechsler Memory Scale-third edition; WAIS-III = Wechsler Adult Intelligence Scale-third edition; COWAT = Controlled Oral Word Association Test.

Table 5

Baseline scores on symptom measures and subjective memory complaints by group

	CT Group (n=21)	AC Group (n=21)		
	Mean (SD)	Mean (SD)	*t*	*p* (two-tailed)[1]
Geriatric Depression Scale	1.57 (1.83)	0.86 (1.15)	1.51	0.14
Beck Anxiety Inventory	3.33 (2.92)	3.38 (3.25)	-0.05	0.96
MFQ				
General Frequency of Forgetting	157.55 (24.6)	168.52 (20.9)	-1.56	0.13
Seriousness of Forgetting	82.24 (21.49)	86.9 (26.58)	-0.49	0.63
Retrospective Forgetting	18.33 (5.57)	18.62 (4.74)	-0.18	0.86
Mnemonics Usage	23.38 (9.56)	22.95 (7.47)	0.16	0.87

[1] Significance level at $p<0.05$. CT = cognitive training; AC = active control; MFQ = Memory Functioning Questionnaire.

Table 6

Mean number of completed daily training tasks in cognitive training (CT) group

	CT Group (n=21)
	Mean (SD)
Brain Age Checks	10.14 (5.39)
Calculations X 20	32.19 (9.61)
Calculations X 100	30.00 (12.30)
Reading Aloud	29.38 (11.93)
Low to High	28.81 (13.88)
Syllable Count	27.62 (13.47)
Head Count	25.57 (13.54)
Triangle Math	18.10 (10.45)
Time Lapse	16.05 (10.77)
Voice Calculation	10.48 (8.38)

Table 7

Growth model trends in performance on daily training tasks over time[1]

Training Task	b	SE b	p	Δ Model Fit[2]
Calculations X 20				
Time	-0.25	0.06	<0.001*	-
*Time*Time*	0.03	0.01	0.002*	$\chi^2(1) = 9.81, p < 0.01$
Calculations X 100				
Time	-0.2	0.08	0.03*	
*Time*Time*	0.04	0.03	0.16	-
Reading Aloud				
Time	0.87	0.28	0.002*	-
*Time*Time*	-0.09	0.04	0.02*	$\chi^2(1) = 5.49, p < 0.05$
Low to High				
Time	0.85	0.39	0.04*	
*Time*Time*	-0.16	0.14	0.26	-
Syllable Count				
Time	-0.12	0.05	0.02*	
*Time*Time*	0.03	0.02	0.14	-
Head Count				
Time	0.59	0.18	0.002*	-
*Time*Time*	-0.05	0.03	0.04*	$\chi^2(1) = 4.12, p < 0.05$
Triangle Math				
Time	-0.19	0.05	<0.001*	
*Time*Time*	0.04	0.03	0.19	-
Time Lapse				
Time	-0.22	0.09	0.02*	
*Time*Time*	0.08	0.03	0.12	-
Voice Calculation				
Time	5.22	5.23	0.33	-

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[1] Significant linear (i.e., *Time*) and quadratic (i.e., *Time*Time*) trends reported. No significant cubic (i.e., *Time*Time*Time*) trends were observed. [2] Calculated based on change in -2 log likelihood with addition of one parameter in successive models. *Significant at $p < 0.05$.

Table 8

Total number of completed card games in active control group (n=21)

	Mean (SD)	Median[1]
Basic		
Old Maid	12.10 (12.49)	6.0
Spit	25.19 (36.00)	8.0
I Doubt It	4.10 (5.25)	2.0
Sevens	31.10 (41.02)	19.0
Memory	20.29 (19.59)	16.0
Pig	15.24 (19.88)	8.0
Intermediate		
Blackjack	14.9 (13.65)	13.0
Hearts	7.62 (7.25)	7.0
President	4.52 (10.13)	1.0
Rummy	13.05 (13.44)	8.0
Seven Bridge	3.05 (5.83)	0.0
Last Card	6.90 (6.79)	4.0
Last Card Plus	2.62 (3.4)	1.0
Advanced		
Five Card Draw	7.19 (13.66)	2.0
Texas Hold’em	5.00 (10.8)	0.0
Nap	2.76 (3.91)	2.0
Spades	8.57 (10.06)	7.0
Contract Bridge	1.57 (3.2)	0.0

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[1] Median values included due to frequency of outliers across card games.

Table 9

Effects of training on neuropsychological outcome measures.

	Time[1]			**Group**[2]			**Time X Group**[3]		
	F value (df=1,40)	*p*	η^2	F value (df=1,40)	*p*	η^2	F value (df=1,40)	*p*	η^2
RBMT									
Immediate recall	9.57	**<0.01**	0.19	1.08	0.31	0.03	1.44	0.23	0.04
Delayed recall	13.57	**<0.01**	0.25	0.18	0.67	0.01	0.14	0.71	0.003
RAVLT									
Immediate recall total	8.61	**<0.01ǂ**	0.18	0.89	0.35	0.02	0.004	0.95	<0.001
Short-delay recall	6.88	**<0.05ǂ**	0.15	3.03	0.09	0.07	0.06	0.81	0.001
Delayed recall	8.05	**<0.01ǂ**	0.17	0.93	0.34	0.02	0.32	0.57	0.01
Recognition accuracy	1.57	0.22	0.04	0.15	0.71	0.004	0.05	0.83	0.001
BVMT									
Immediate recall	3.47	0.07	0.08	0.31	0.58	0.01	0.23	0.64	0.01
Delayed recall	0.61	0.44	0.02	0.86	0.36	0.02	0.81	0.37	0.02
Delayed discrimination	1.98	0.17	0.05	1.04	0.31	0.03	0.001	0.98	<0.001
Digit Span LDSF	2.60	0.12	0.06	1.48	0.23	0.04	0.58	0.45	0.01
WMS-III Spatial Span									
Longest span forward	10.75	**<0.01**	0.21	1.97	0.17	0.05	0.43	0.52	0.01
Longest span backward	5.41	**<0.05**	0.12	0.30	0.59	0.01	0.02	0.89	0.001

WAIS-III									
Digit Symbol total correct	0.05	0.83	0.001	0.10	0.75	0.003	0.25	0.62	0.01
Symbol copy total correct	0.84	0.36	0.02	0.18	0.67	0.01	0.60	0.44	0.02
Symbol copy time	2.24	0.14	0.05	1.87	0.18	0.05	0.002	0.96	<0.001
Similarities total	0.64	0.43	0.02	0.02	0.89	0.001	1.44	0.24	0.04
Math Fluency correct	17.4	**<0.001**	0.30	0.15	0.70	0.004	3.05	0.09	0.07
Math Fluency time	5.73	**<0.05**	0.13	0.99	0.33	0.02	3.04	0.09	0.07
COWAT total	0.41	0.53	0.01	1.20	0.28	0.03	2.80	0.10	0.07
Semantic Fluency[4]	2.27	0.14	0.05	0.60	0.44	0.02	0.05	0.83	0.001
Trails A/C Time	0.02	0.89	<0.001	0.04	0.85	0.001	0.02	0.89	<0.001
Trails A/C errors	1.36	0.25	0.03	3.91	0.06	0.09	1.36	0.25	0.03
Trails B/D Time	1.91	0.18	0.05	0.49	0.49	0.01	1.21	0.28	0.03
Trail B/D errors	1.26	0.27	0.03	0.02	0.89	<0.001	3.12	0.09	0.07

[1] Main effects of time from pre-test to post-test. [2] Main effects of group: CT group (n=21) and AC group (n=21). [3] Interaction effects. [4] Animal naming total scores used for session one and boy's names total score used for session two. ǂPerformance significantly decreased from pre-test to post-test. RBMT = Rivermead Behavioral Memory Test; RAVLT = Rey Auditory Verbal Learning Test; BVMT = Brief Visuospatial Memory Test; LDSF = Longest digit span forward; WMS-III = Wechsler Memory Scale-third edition; WAIS-III = Wechsler Adult Intelligence Scale-third edition; COWAT = Controlled Oral Word Association Test.

Table 10

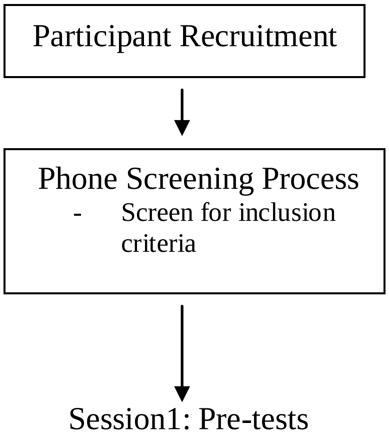
Supplementary repeated measures analyses of training effects in cognitive training (CT) and active control (AC) groups.[1]

	CT Group (n=21)				AC Group (n=21)			
	Pre-test Mean (SD)	Post-test Mean (SD)	p	η^2	Pre-test Mean (SD)	Post-test Mean (SD)	p	η^2
RBMT								
Immediate recall	7.85 (3.08)	10.07 (3.43)	**<0.01**	0.29	9.4 (3.95)	10.38 (2.81)	0.17	0.09
Delayed recall	7.21 (2.96)	9.29 (2.93)	**<0.05**	0.29	7.71 (3.32)	9.41 (2.10)	**<0.05**	0.22
WMS-III Spatial Span								
Longest span forward	5.29 (1.06)	5.86 (1.06)	**<0.05**	0.18	4.76 (1.0)	5.62 (1.36)	**<0.05**	0.24
Longest span backward	4.90 (1.14)	5.24 (1.0)	0.11	0.12	4.71 (1.10)	5.1 (1.18)	0.12	0.12
Math Fluency correct	125.48 (26.25)	137.67 (27.85)	**<0.01**	0.41	132.0 (22.96)	137.0 (26.67)	0.06	0.16
Math Fluency time	176.14 (9.97)	169.52 (18.14)	**<0.05**	0.26	177.57 (5.20)	176.14 (9.61)	0.61	0.01
RAVLT‡								
Immediate recall total	51.67 (10.45)	48.38 (8.97)	0.06	0.16	49.05 (7.71)	45.9 (10.31)	**<0.05**	0.20
Short-delay recall	10.86 (3.43)	9.86 (2.71)	0.07	0.16	9.4 (3.38)	8.2 (3.11)	0.09	0.15
Delayed recall	9.86 (3.73)	8.33 (3.38)	**<0.05**	0.21	8.7 (3.13)	7.67 (3.50)	0.11	0.13

---

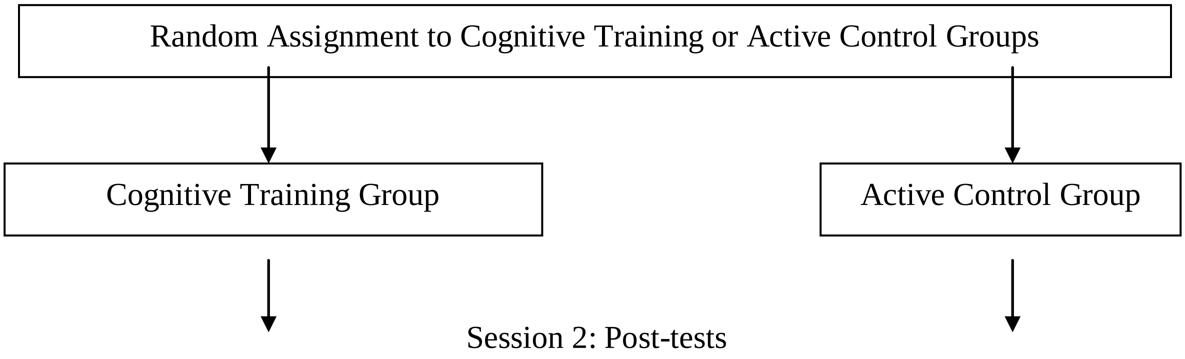
[1] Post hoc repeated measures ANOVAs conducted for each group separately. DVs that exhibited significant Time main effects from omnibus analyses were selected. ‡ Indices selected from RAVLT that exhibited significant decreases in performance in omnibus analyses. RBMT = Rivermead Behavioral Memory Test; RAVLT = Rey Auditory Verbal Learning Test; WMS-III = Wechsler Memory Scale-third edition.

Figure 1. Overview of study design.



Neuropsychological Measures	*Self-Report Measures*
- Mini-Mental Status Exam	- Geriatric Depression Scale (GDS)
- Rey Auditory Verbal Learning Test (Form 1)	- Beck Anxiety Inventory
- Brief Visuospatial Memory Test (Form 1)	- Memory Factors Questionnaire (MFQ)
- Rivermead Behavioral Memory Test (Form 1)	
- Controlled Oral Word Association Test (FAS version)	
- Semantic Fluency: Animal Naming	
- Trails A and B/Trails C and D (i.e., counterbalanced)	
- R-BANS Digit Span (Form A)	
- WMS-III Spatial Span (Form A)	
- Digit-Symbol Coding (WAIS-III Version)	
- Symbol Copy	
- WJ Math Fluency (Form 1)	
- WAIS-III Similarities (Form A)	

(Figure 1 continued)



Neuropsychological Measures	*Self-Report Measures*
- Rey Auditory Verbal Learning Test (Form 4) - Brief Visuospatial Memory Test (Form 4) - Rivermead Behavioral Memory Test (Form 2) - Controlled Oral Word Association Test (PRW version) - Semantic Fluency: Boy’s Names - Trails A and B/Trails C and D (i.e., counterbalanced) - R-BANS Digit Span (Form B) - WMS-III Spatial Span (Form B) - Digit-Symbol Coding (WAIS-IV Version) - Symbol Copy - WJ Math Fluency (Form 2) - WAIS-III Similarities (Form B)	- Geriatric Depression Scale (GDS) - Beck Anxiety Inventory (BAI) - Exit Questionnaire

Figure 2. Participant flow.

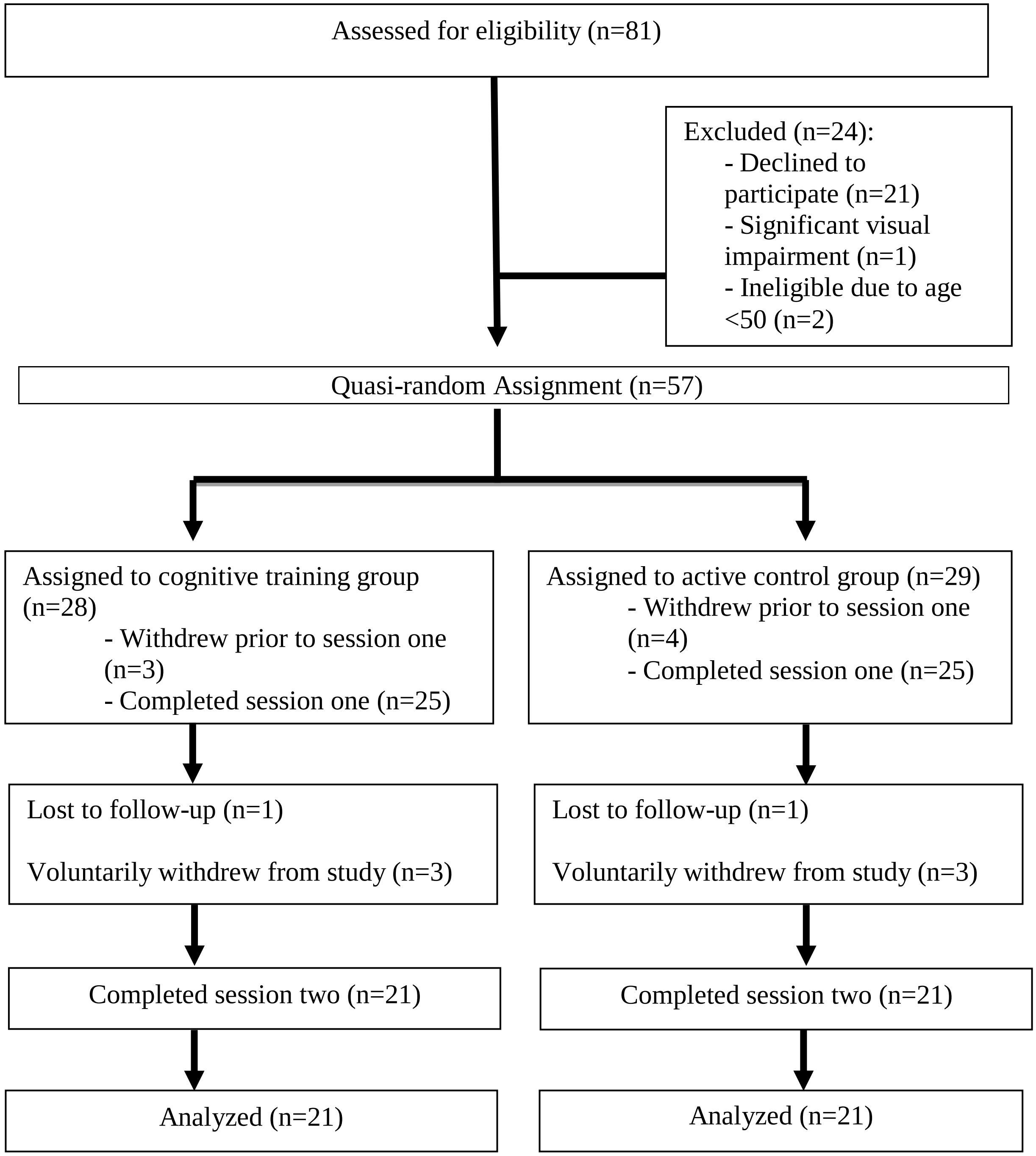
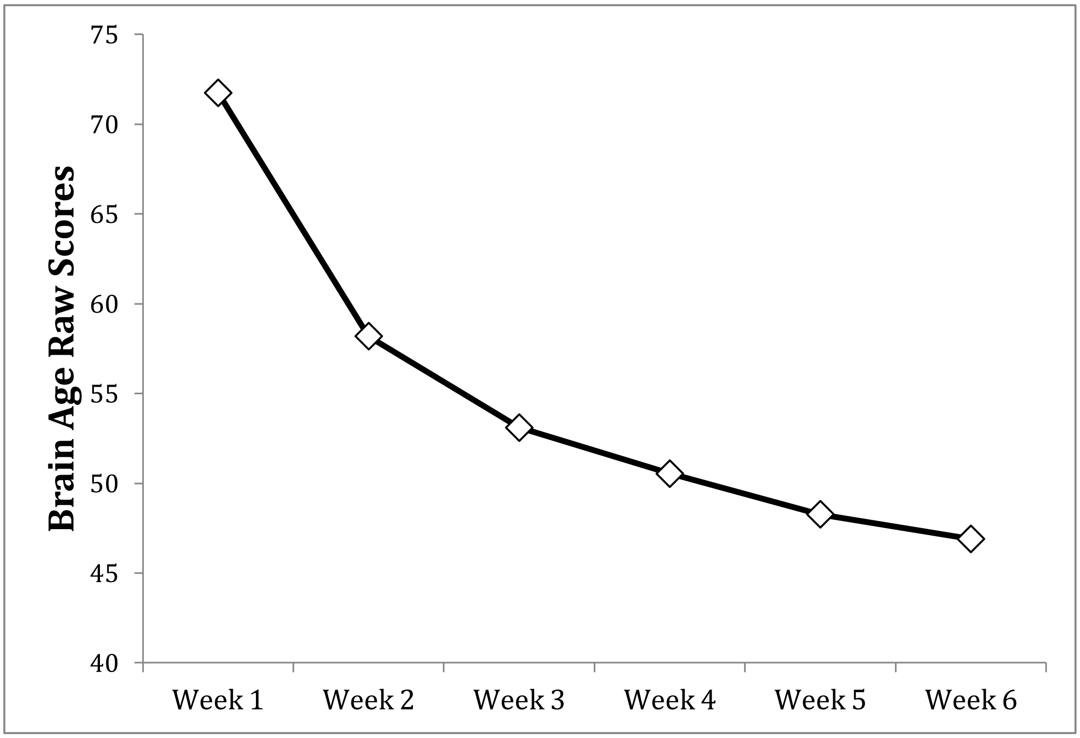
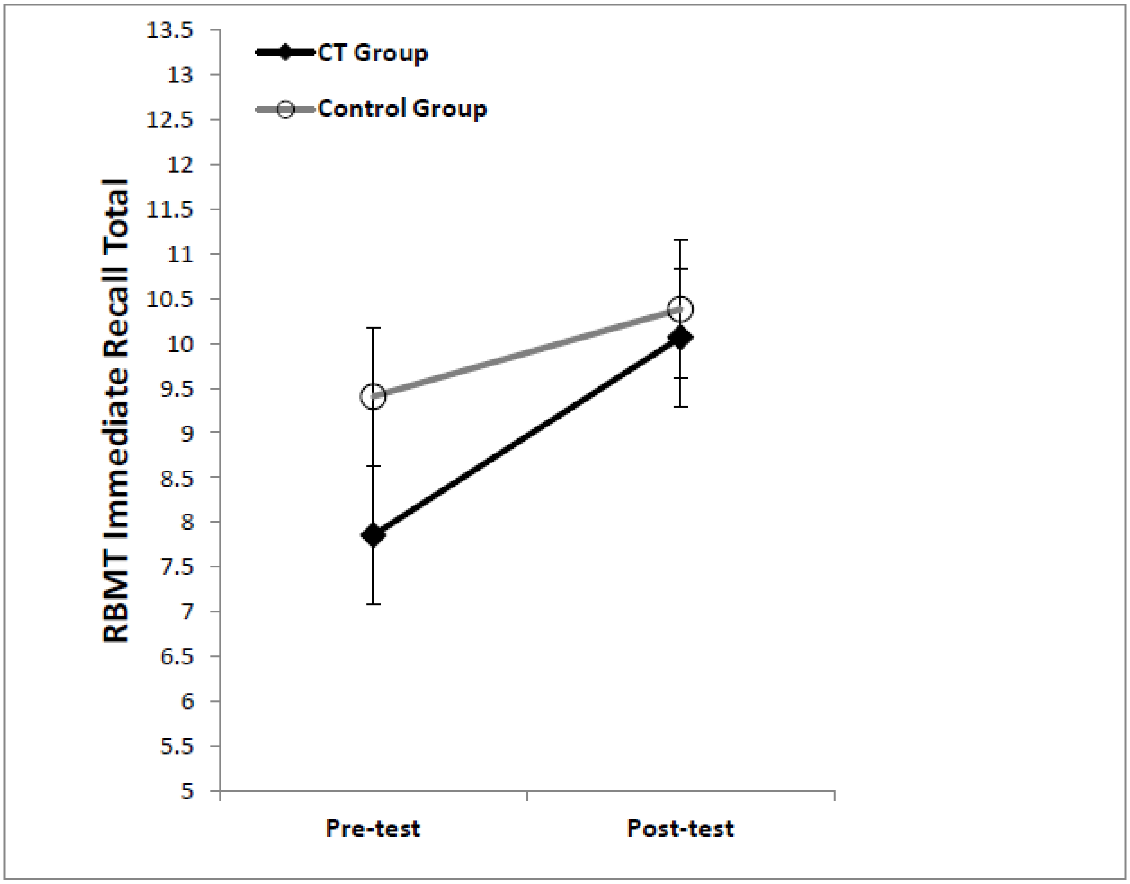


Figure 3. CT group Brain Age scores weeks 1 through 6[1]



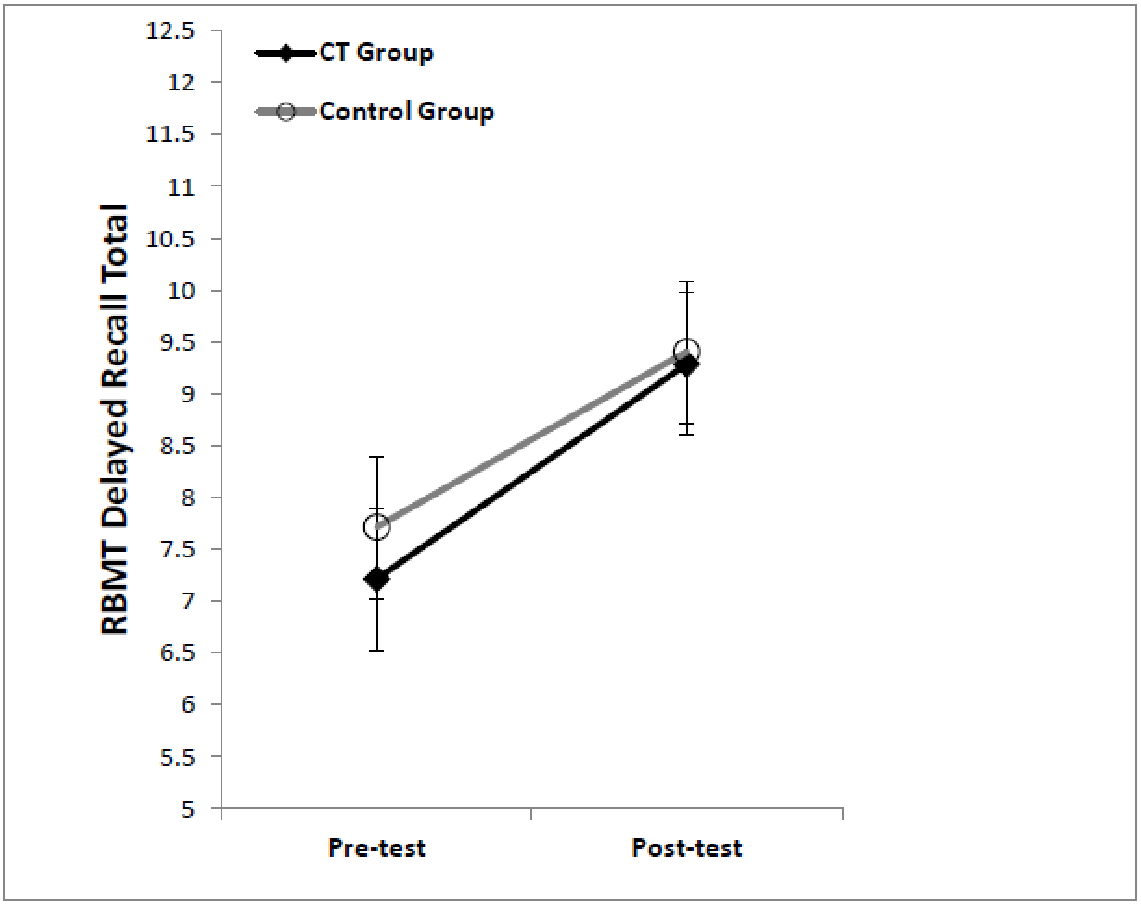
Note: [1]Mean Brain Age scores were calculated for all CT group (n=21) participants for each of the six weeks of study.

Figure 4. RBMT immediate recall performance by group.



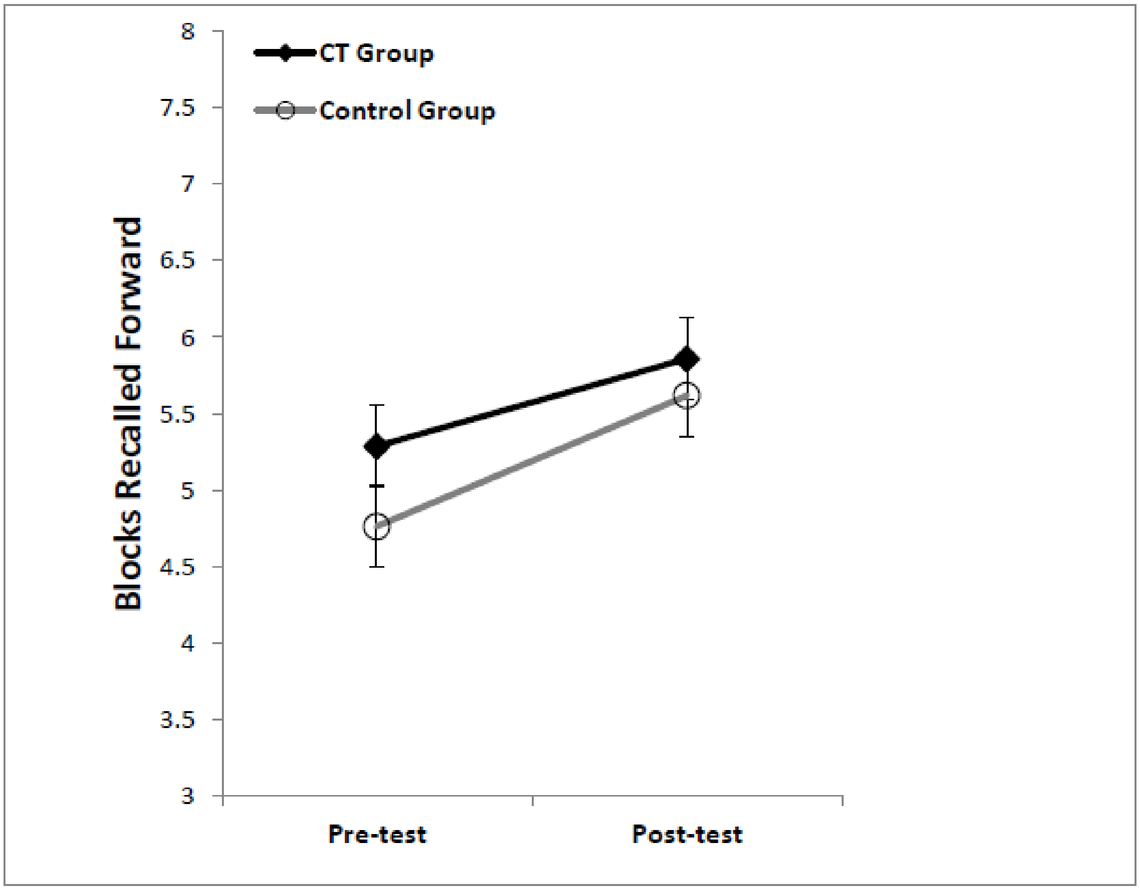
Note: Significant main effect of Time, p<0.01. Error bars represent SEM.

Figure 5. RBMT delayed recall performance by group.



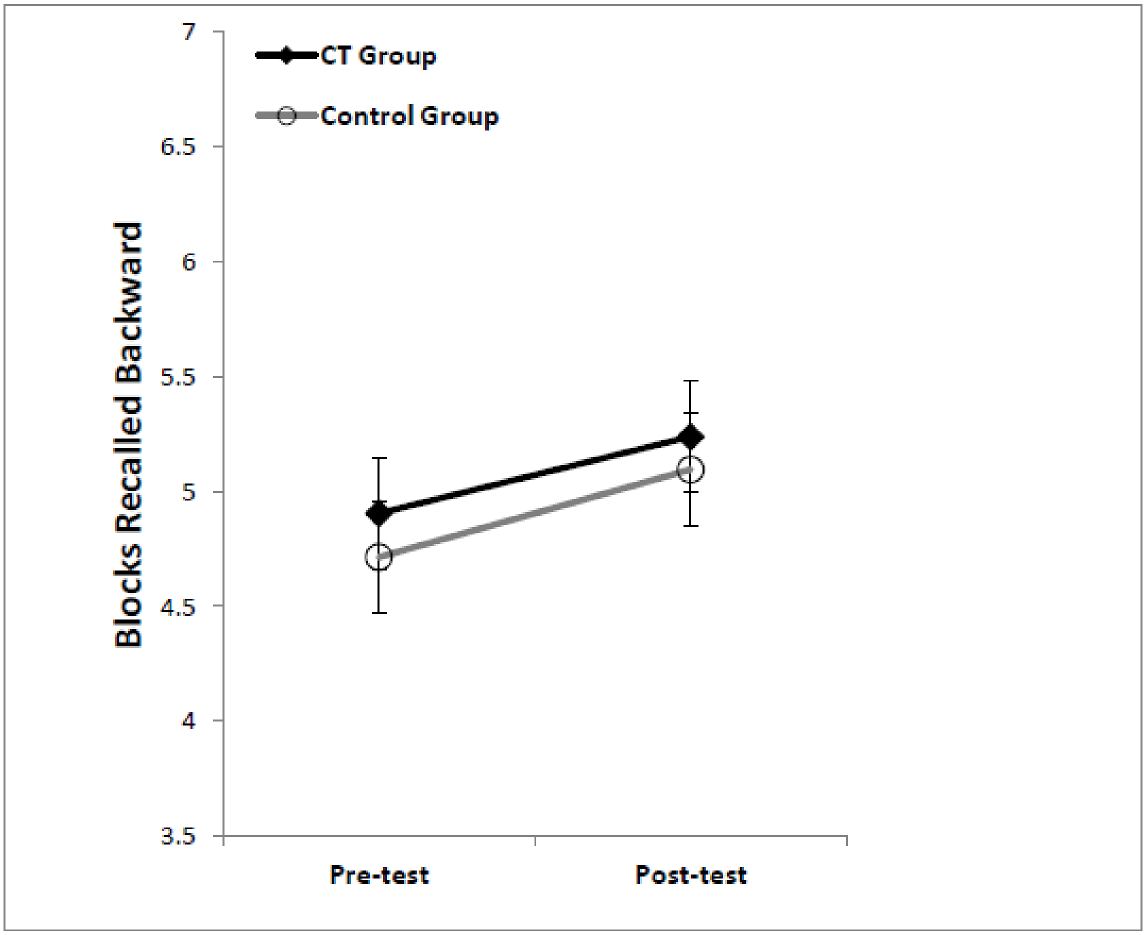
Note: Significant main effect of time, p<0.01. Error bars represent SEM.

Figure 6. Longest spatial span forward (LSSF) performance by group.



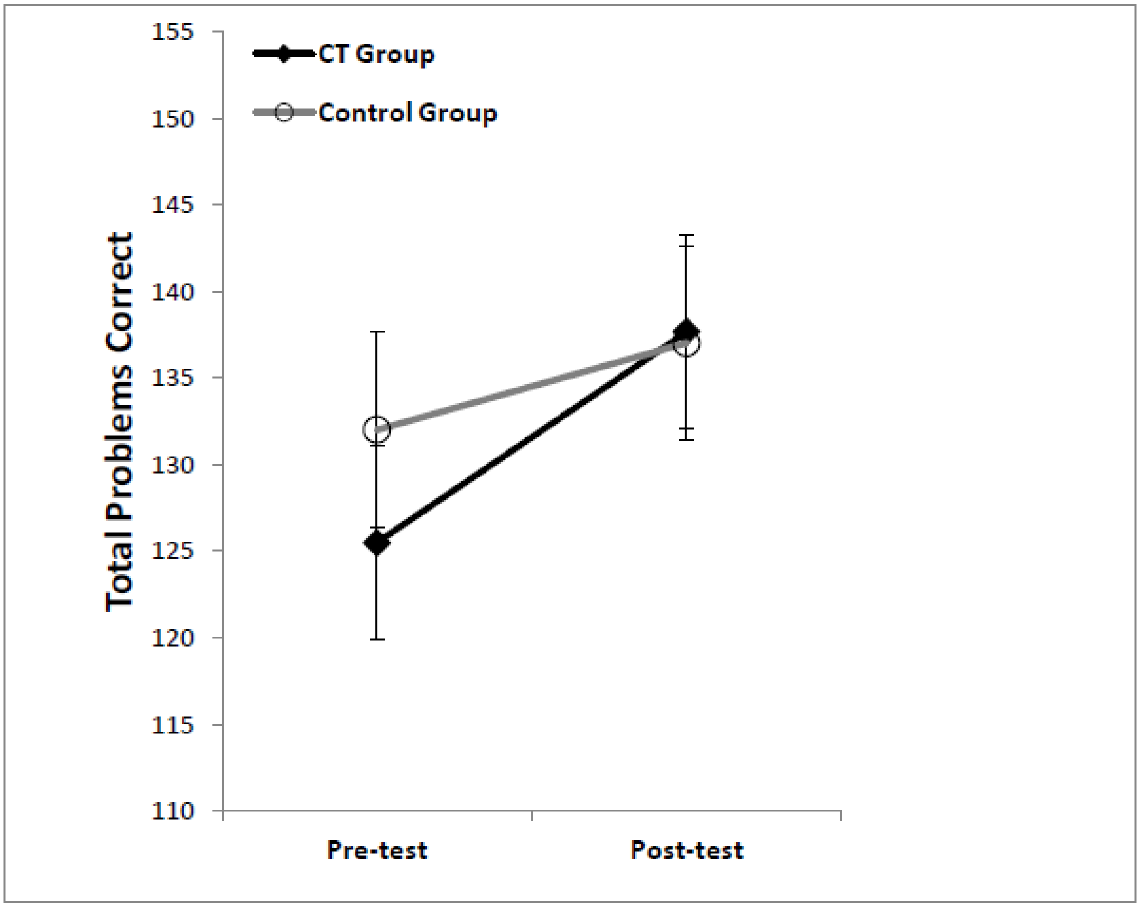
Note: Significant main effect of time, p<0.01. Error bars represent SEM.

Figure 7. Longest spatial span backward (LSSB) performance by group.



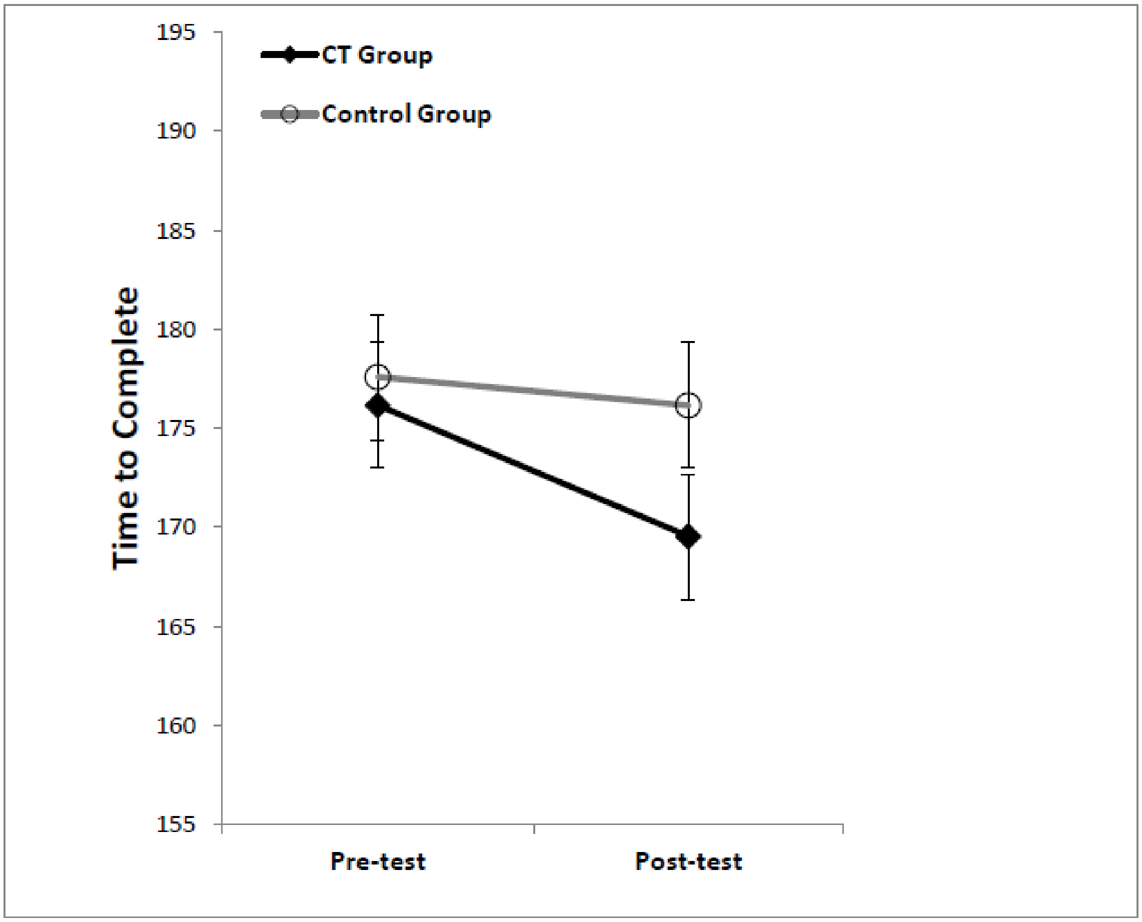
Note: Significant main effect of time, p<0.05. Error bars represent SEM.

Figure 8. WJ-III Math Fluency accuracy performance by group.



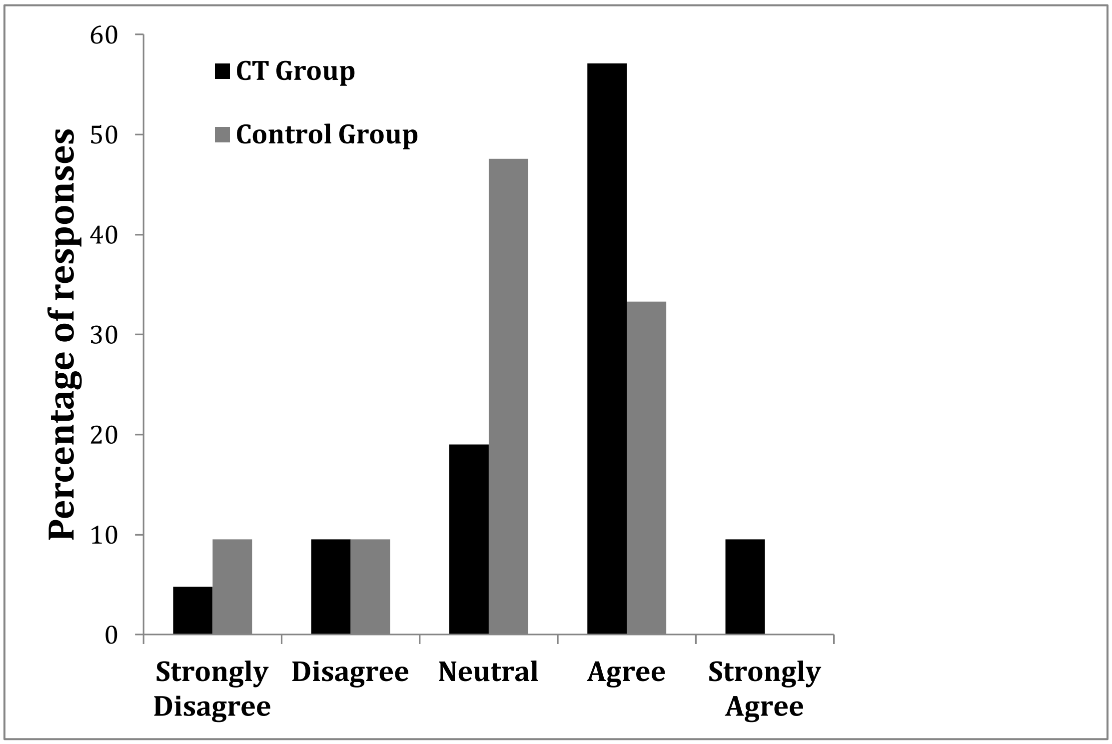
Note: Significant main effect of time, p<0.001. Error bars represent SEM.

Figure 9. WJ-III Math Fluency time scores by group.



Note: Significant main effect of Time ($p < 0.05$). Means displayed based on untransformed data. Error bars represent SEM.

Figure 10. Ratings of subjective memory improvement as a result of Nintendo DS usage by group.



Note: Participants' responses to the statement *"I believe that my memory has improved as a result of using the Nintendo DS on a daily basis."*

Appendix A

Rating Scale – Week One

Please rate your experience using the Nintendo DS this past week according to the following questions:

1) How enjoyable was it to use the Nintendo DS?

←--→
1 2 3 4 5 6 7 8 9 10
Not at all enjoyable *Moderately enjoyable* *Extremely enjoyable*

2) How entertaining was it to use the Nintendo DS?

←--→
1 2 3 4 5 6 7 8 9 10
Not at all entertaining *Moderately entertaining* *Extremely entertaining*

3) How intellectually engaging was it to use the Nintendo DS?

←--→
1 2 3 4 5 6 7 8 9 10
Not at all engaging *Moderately engaging* *Extremely engaging*

4) How difficult was it to use the Nintendo DS?

←--→
1 2 3 4 5 6 7 8 9 10
Not at all difficult *Moderately difficult* *Extremely difficult*

5) How mentally challenging was it to use the Nintendo DS?

←--→
1 2 3 4 5 6 7 8 9 10
Not at all challenging *Moderately challenging* *Extremely challenging*

Appendix B

Exit Questionnaire

Please rate your experience using the Nintendo DS over the past six weeks according to the following questions:

6) How enjoyable was it to use the Nintendo DS?

←--→

1 2 3 4 5 6 7 8 9 10

Not at all enjoyable *Moderately enjoyable* *Extremely enjoyable*

7) How entertaining was it to use the Nintendo DS?

←--→

1 2 3 4 5 6 7 8 9 10

Not at all entertaining *Moderately entertaining* *Extremely entertaining*

8) How intellectually engaging was it to use the Nintendo DS?

←--→

1 2 3 4 5 6 7 8 9 10

Not at all engaging *Moderately engaging* *Extremely engaging*

9) How difficult was it to use the Nintendo DS?

←--→

1 2 3 4 5 6 7 8 9 10

Not at all difficult *Moderately difficult* *Extremely difficult*

10) How mentally challenging was it to use the Nintendo DS?

←--→

1 2 3 4 5 6 7 8 9 10

Not at all challenging *Moderately challenging* *Extremely challenging*

Please rate your agreement with the following statements:

11) I believe that my memory has improved as a result of using the Nintendo DS on a daily basis.

1 = Strongly Disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly Agree

12) I feel that my general mental ability has improved as a result of using the Nintendo DS on a daily basis.

1 = Strongly Disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly Agree

13) I feel that I successfully completed all of the daily at-home activities for this study.

1 = Strongly Disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly Agree

14) I would consider purchasing a Nintendo DS system to use on my own in the future.

1 = Strongly Disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly Agree

10) I enjoyed participating in this study.

1 = Strongly Disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly Agree

Please also answer the following questions:

11) How often have you participated in research studies?

0 = Never
1 = Once or Twice
2 = Several Times
3 = Quite a bit
4 = Frequently

12) How often have you participated in studies about memory?

0 = Never
1 = Once or Twice
2 = Several Times
3 = Quite a bit
4 = Frequently

13) Would you be willing to be contacted as a potential participant for a possible follow-up to this study in 6 to 12 months? **YES / NO**

14) Would you be willing to be contacted as a potential participant for other “Successful Aging” studies? **YES / NO**

Please provide any comments or feedback about this study below:

Appendix C

Available "Daily Training" Tasks

Calculations X 20. Participants solve 20 simple arithmetic problems as rapidly as possible writing out their answers using the stylus pen.

Calculations X 100. Identical to *Calculations X 20* except 100 problems are presented.

Reading Aloud. Participants read a passage of dense prose aloud and time to read the entire piece is recorded.

Low to High. Numbers appear momentarily on the screen and boxes then appear in place of the numbers. Participants tap the boxes in the chronological order of the numbers.

Syllable Count. Participants read a passage on the screen and count the number of syllables it contains and write out their answer using the stylus pen.

Head Count. Participants watch people go in and out of a house for several rounds. At the end of the brief period participants must guess the number of people left inside the house.

Triangle Math. Participants solve three rows of arithmetic problems. First the top row is completed then the answers from the top row are solved to complete the third row.

Time Lapse. Two clocks appear on the screen and participants must determine the amount of time that has passed in terms of hours and minutes between the two clocks.

Voice Calculation. Participants solve arithmetic problems and speak their answers into the microphone on the DS console.

Appendix D

Tests Used in the "Brain Age Check"

Calculations X 20. Participants solve 20 simple arithmetic problems as rapidly as possible, writing out their answers using the stylus pen.

Stroop Test. Modeled after the neuropsychological measure. Names of colors appear in various colors (e.g., "Red" appears in green lettering) and participants must name the colors of the words without saying the words.

Word Memory. 30 words appear simultaneously and participants are allowed two minutes to memorize as many words as possible. At the end of the study period, participants are allowed another two minutes to write out as many words as possible from memory.

Speed Counting. Participants count aloud from 1 to 120 and touch the "Done" button when finished.

Connect Maze. Modeled after Trails B. Participants connect dots of a "maze" switching back and forth between letters and numbers each time (e.g., A to 1 to B).

Number Cruncher. Numbers of various types appear scattered across the display screen. Participants read and answer questions about the display as quickly as possible (e.g., "How many red numbers are there?").

Appendix E

Available Card Games

Basic Card Games.

Old Maid, Spit, I Doubt It, Sevens, Memory, Pig.

Intermediate Card Games.

Blackjack, Hearts, President, Rummy, Bridge, Last Card, Last Card Plus.

Advanced Card Games.

Five Card Draw, Texas Hold’em, Nap, Spades, Contract Bridge