Video Game Interventions to Improve Cognition in Older Adults

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VIDEO GAME INTERVENTIONS TO IMPROVE COGNITION IN OLDER ADULTS

by

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ABSTRACT
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Cognitive abilities decline as part of the normal aging process. Various non-pharmacological interventions are being studied in an effort to ameliorate this cognitive decline. Some of these interventions include computerized cognitive training, such as neuropsychological software (i.e., brain training games) and video games. This study sought to determine if a visual art intervention, a relatively unstudied but potentially beneficial intervention, would elicit cognitive gains.

Twenty-five individuals (M_{age} = 86, $M_{education}$ = 16.2) were quasi-randomly assigned to an experimental digital art intervention, Art Academy™, or an active control condition, Tetris™. Participants played their assigned game at least twenty minutes per day for six weeks. Comprehensive neuropsychological assessments were administered before and after the intervention. Outcome measures were in the form of residualized change scores were calculated by regressing the pre-test scores onto the post-test scores to reduce effects of baseline and other non-treatment factors.

Compared to the Tetris group, the digital art group improved on aspects of a list-learning test, visual memory test, a scanning and sequencing task, a psychomotor task, a mental rotation task, and a composite score of all cognitive change (Total Change Score). The Tetris™ group improved on a math fluency task, and both groups improved on the delayed recall of a story memory task. However, the Art Academy™ group also engaged in the intervention for significantly more minutes of overall play time than the Tetris group, potentially confounding the results. Two groups were created via a median split based on the duration of gameplay: High Gameplay and Low Gameplay. The High Gameplay group showed greater improvement on visual memory, verbal memory, a measure of executive functioning, as well as the Total Change Score.

The study suggests that playing a digital art video game could be a viable intervention to improve cognitive functioning in older adults. However, future research is also needed because the confounding of total gameplay time with group, a metric that other studies rarely report, precludes strong conclusions about the specific training effects.

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Introduction

The normal ageing process involves a certain degree of cognitive decline. This reduction in cognitive functioning is thought to being as early as the age of 20 to 30 (Salthouse, 2009) and is associated with a number of adverse outcomes including a decrease in independence (Greiner, Snowdon, & Schmitt, 1996), increased rates of depression and anxiety (Bierman, Comijs, Jonker, & Beekman, 2007), and increased risks of falls (Muir, Gopaul, & Montero Odasso, 2012). Important to functional independence, older adults perform particularly poorly on memory tasks, specifically on tasks that assess working and long-term memory.

Working memory (WM) is the system that temporarily stores information so that it can be processed and manipulated (A. Baddeley, 1992). It is capacity limited, such that only a certain amount of information can be stored and manipulated at a given time (Cowan, 2001; G. A. Miller, 1956). Working memory declines with age (Light & Anderson, 1985; Wingfield, Stine, Lahar, & Aberdeen, 1988), which is particularly apparent as task-complexity increases (Dobbs & Rule, 1989; Van der Linden, Bredart, & Beerten, 1994). Performance on long-term memory (LTM) tasks among older adults indicates deficits in initial acquisition and information processing (encoding; Troyer, Hafliger, Cadieux, & Craik, 2006), as well as at the retrieval stage, which is the process of locating and accessing previously encoded information (Luo & Craik, 2008), of LTM.

In addition to WM and LTM, other important cognitive processes, such as processing speed (PS) and executive functioning (EF), are also subject to age-related declines (Robbins et al., 1998; Salthouse, 1996; Sweeney, Rosano, Berman, & Luna, 2001; West, 1996). Processing speed is the ability to automatically process information and can be thought of as cognitive efficiency. It is particularly susceptible to aging, with declines beginning as early as 30 years of age (Salthouse, 2009). Executive functioning is an umbrella term that subsumes a larger number of higher-order cognitive processes, such as inhibition, judgment and decision-making, attentional control, and task switching. Compared to young adults, older adults perform worse on tasks that measure EF (Allain et al., 2005) and this decrease in performance is theorized to be the underlying mechanism that leads to the wide-spread cognitive decline observed with age (MacPherson, Phillips, & Della Sala, 2002).

Although evidence strongly shows that cognitive abilities decline with age, it is also somewhat reversible. For example, memory performance differences disappear when older adults process words they are supposed to remember by using visual imagery, a deeper form of processing, rather than more passive and shallow forms of rehearsal such as repetition (Troyer et al., 2006). Working memory performance can improve with the implementation of specific strategies. In a classic case study, an individual was able to increase his recall of digits from 7 digits to 79 after training by chunking - combining the information into smaller, more meaningful groups (Ericcson, Chase, & Faloon, 1980). Despite the decreases in cognition due to aging, these studies show that older adults are capable of skill acquisition and strategy training to ameliorate normal cognitive decline.

Cognitive Training

Cognitive training (CT) is a type of approach that has been used to improve cognition and alleviate the effects of aging. This therapy consists of guided practice on various tasks to improve or maintain functioning of a particular cognitive domain (Clare

& Woods, 2004). CT differs from another cognitive intervention known as cognitive rehabilitation (Bahar-Fuchs, Clare, & Woods, 2013; Clare & Woods, 2004), although the terms have often been used interchangeably. Cognitive rehabilitation and CT rely on a number of the same approaches (e.g., teaching specific strategies to solve problems), but the overall goals of the two interventions are different. Cognitive rehabilitation adopts a compensatory approach and builds treatment around an individual's preserved cognitive abilities to improve everyday functioning, rather than specifically trying to improve functioning of cognitive skills.

Under the supervision of a trained professional, traditional CT protocols teach strategies to improve performance in various cognitive domains. To increase LTM performance, for example, older adults may be taught various mnemonic devices, such as the method of loci (Bower, 1970) and the face-name mnemonic (J. A. Yesavage & Rose, 1984). There is ample empirical support for the efficacy of mnemonic and memory training in older adults (Gross et al., 2012; Rebok, Carlson, & Langbaum, 2007; cf. Zehnder, Martin, Altgassen, & Clare, 2009). An empirically supported strategy called "chunking" has also been shown to improve WM (Ericcson et al., 1980). In addition to strategy training, traditional CT protocols may also involve tasks that adapt in difficulty as the person's abilities improve through practice. For example, both healthy elders and those with mild cognitive impairments who repeatedly practiced a short-term memory task with a divided attention component outperformed those in an active control group on verbal WM tasks after a two-week intervention (Carretti, Borella, & De Beni, 2007; Carretti, Borella, Fostinelli, & Zavagnin, 2013). In general, traditional CT therapies are effective at improving performance in a wide variety of cognitive domains. However, the benefits are typically domain-specific, meaning they are specifically relative to the tasks that were trained, rarely generalizing to other untrained domains (Sitzer, Twamley, & Jeste, 2006; Twamley, Jeste, & Bellack, 2003).

Computerized Cognitive Training

While traditional paper-pencil CT methods are effective, they may be costly, ranging from $15 per hour for a bachelors-level trainer up to $100 per hour for an occupational therapist (Wadley et al., 2006). However, the proliferation of low-cost computers has made possible CT approaches that are individualized, adaptive, and multi-domain. That is, computerized CT can be done anytime without the presence of a trained professional, which allows for greater flexibility in training protocols (Kueider, Parisi, Gross, & Rebok, 2012). The proliferation of this CT media allows underserved and dependent populations access to an intervention they would normally not be able to obtain due to high costs or unavailability of reliable transportation. Lastly, computerized CT provides immediate feedback and automatically adjusts task difficulty to ensure the intervention is sufficiently challenging and increasing adherence to the training protocol (Kueider et al., 2012). Computerized CT consists of classic cognitive training, neurological software, and video games.

Classic cognitive training. Classic CT consists of the repeated practice of standardized tasks focusing on a single cognitive domain. An example of this type of training is speed of processing training, in which individuals repeatedly discriminate between one of two objects briefly presented in the center of a computer screen while also locating an object in the periphery (Ball et al., 2002; Belchior et al., 2013). A review of a 21 studies utilizing this form of CT suggests that this intervention is as effective as, or better than, traditional "paper-pencil" forms of CT (Kueider et al., 2012). A major initiative known as the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study demonstrated the efficacy and long-term benefits of both traditional and computerized classic cognitive training (Ball et al., 2002). In this large, randomized control trial, healthy older adults were assigned to one of four groups: an episodic memory training group that was taught to use mnemonic devices; a reasoning training group; a computerized speed of processing training group; or, a no-contact control group. After 10 hours of training, each experimental group exhibited significant improvements from baseline on measures that assessed the respective cognitive processes that were the targets of training. These effects were robust and evident even 10 years after the intervention (Rebok et al., 2014). Indeed, those in the intervention groups also reported fewer problems performing instrumental activities of daily living (e.g., answering a telephone, medication management, cooking) than the individuals in the control group ten years later.

Neuropsychological software. Another form of computerized CT is neuropsychological software, or brain training. This relatively young field has become a multi-billion dollar industry with companies such as Lumosity™, Brain Age™, and Brain Fitness™ becoming household names. These types of programs train multiple cognitive domains, give instant feedback, adjust difficulty to the players' ability and can be played on a computer or a video game console (Kueider et al., 2012). Despite brain training's popularity, discrepant findings exist about this intervention's ability to improve cognitive abilities.

Many studies examining the efficacy of brain training programs have demonstrated cognitive gains in the domains that were specifically trained (cf.Boot et al., 2013; Owen et al., 2010). However, there is conflicting evidence about whether such training protocols result in transfer effects, or improved cognitive performance in domains beyond those directly trained. For example, older adults who played an auditory perception training game, Brain Fitness, improved in everyday problem solving and visual perceptual reasoning abilities (Strenziok et al., 2014). Likewise, older adults who played Brain Age™, showed improvements in executive functioning (Nouchi et al., 2012). However, other studies have failed to find evidence of transfer effects (e.g., Ackerman, Kanfer, & Calderwood, 2010; Owen et al., 2010). For example, in a large online study young and older adults were randomly allocated to either one of two experimental groups, each designed to reflect popular brain training paradigms, or to an active control group that required internet searches to answer vague questions (Owen et al., 2010). After the six-week intervention, both experimental groups demonstrated performance improvements in the tasks that were trained. The active control group, however, showed similar improvements in performance for benchmark measures that were not directly trained in either experimental group, suggesting there was no evidence of a transfer effect of either intervention. In sum, there is conflicting evidence of whether transfer effects occur after using neuropsychological software.

In addition to dubious transfer effects in computerized CT programs, disparate findings have been found across studies that examined identical brain training interventions. For example, in a four-week intervention, healthy older adults who played the brain training game, Brain Age™, showed improvements in measures of executive functioning and processing speed compared to an active control condition (Nouchi et al., 2012). In a similar study conducted in our lab, English (2012) found that a six-week intervention using Brain Age™ produced improvements in short- and long-term verbal memory, visual WM, and math fluency, but it also produced those improvements in the active control group that played video poker games. Our study utilized alternate forms and split-half versions of neuropsychological measures in the baseline and post-test sessions in order to assure that effects were due to intervention rather than practice. Thus, although some outcome measures differed across these two studies that may explain the different findings, our study suggested that the active control condition was sufficient to improve cognition in multiple domains. This interpretation is consistent with the results of a meta-analysis, in which the improvements due to brain training interventions were no greater than improvements evident from playing other video games (Toril, Reales, & Ballesteros, 2014). Finally, adding further complexity to this small literature, another study failed to find any significant improvements in a wide range of cognitive domains after participants played Brain Age-2™ for twelve weeks (Boot et al., 2013). The lack of effects might be due to the longer schedule (e.g., 1 hour/day versus 15 minutes/day; Nouchi et al., 2012) and more demanding intervention (i.e., high levels of participant-reported frustration) employed in this study versus prior studies. Thus, taken together, it is unclear what cognitive domains, if any, are trained while playing Brain Age™, and whether the training is more specific than simply providing cognitive engagement..

Video Games. The last form of computerized CT is video games. Video games have an advantage over paper-pencil and traditional, computerized CT because they are designed to be fun and engaging (Zelinski & Reyes, 2009) by creating positive experiences and allowing the player opportunities to overcome obstacles. Cognitive benefits may arise incidentally from engaging in these games (e.g., Belchior et al., 2013). Furthermore, they are ideal for creating “flow” for users (Sherry, 2004), which is the optimal experience that occurs when engaging in leisure and work activities (Csikszentmihalyi & LeFevre, 1989). Flow is characterized by intense focus and an integration of action and awareness, which can cause a distortion of time, an increase in self-efficacy, and the perception that an activity is intrinsically rewarding (Nakamura & Csikszentmihalyi, 2014). For example, compared to solving math problems on paper, older adults reported feeling a higher level of excitement and “flow” when doing the same problems on a Nintendo DS (Nacke, Nacke, & Lindley, 2009). Furthermore, consistent with Flow Theory (Csikszentmihalyi & LeFevre, 1989) video games may be adaptive in difficulty to a players skill, which results in higher self-reported flow and higher levels of engagement. Thus, video games are ideal for CT because they may increase the likelihood of gameplay and intervention compliance (Belchior et al., 2013; Zelinski & Reyes, 2009).

Playing certain video games can improve processing speed (Dye, Green, & Bavelier, 2009; Nouchi et al., 2012), visual attention (Belchior et al., 2013; Green & Bavelier, 2003, 2006), WM (Colzato, van den Wildenberg, Zmigrod, & Hommel, 2013), spatial abilities (Feng, Spence, & Pratt, 2007), attentional allocation (Dye et al., 2009), and executive function (Basak, Boot, Voss, & Kramer, 2008; Nouchi et al., 2012). While there is ample support to suggest that video games are effective in improving cognitive abilities in older adults (Achtman, Green, & Bavelier, 2008; Green & Bavelier, 2008; Kueider et al., 2012; Toril et al., 2014), video games widely differ in overall goals, gameplay experience, and complexity. Simple video games, for example, require few cognitive processes to successfully play (Toril et al., 2014). In these games, movement and functions of the characters are generally limited. In the classic arcade game, Pac Man, the character's movement is limited to one of four directions and the visual scene rarely changes. On the other hand, action video games are much more intricate and require multisensory, complex processes. These require players to rapidly process and discriminate information, divide attention among multiple stimuli, and make fast and frequent decisions in order to adapt behaviors to current challenges (Belchior et al., 2013; Zelinski & Reyes, 2009). For example, in the game, Medal of Honor, the player has to perform complex and synchronized movements with a keyboard or handheld controller to successfully navigate a three dimensional playing field while simultaneously engaging opponents and avoiding attacks.

Due to the complexity and multisensory engagement, action video games have been frequently studied as potential interventions to improve cognition in older adults (e.g., Basak et al., 2008; Belchior et al., 2013; Boot et al., 2013). Yet, there is evidence that simple video games are as effective at improving various cognitive domains as action video games in older adults. For example, older adults who played ten hours of the simple video game, Tetris™, had similar increases in selective visual attention as older adults who played an action video game or individuals who participated in a computerized speed of processing intervention for the same amount of time (Belchior et al., 2013). Also, a recent meta-analysis found that the cognitive benefits of playing action video games are not greater than the benefits of playing simple video games (Toril et al., 2014). This may be due to the fact that older adults have difficulty in acquiring the skills to successfully play action video games, whereas simple video games are easier to grasp (Belchior et al., 2013). It is uncertain, however, if action video games are a superior form of CT, compared to simple video games, once mastery of gameplay occurs. Nonetheless, the current evidence suggests that older adults may benefit more from interventions of simple video games compared to more advanced video games.

Another genre of video games is “serious” video games. Unlike simple or action video games, the purpose of serious video games is to learn or practice a new skill (Toril et al., 2014). The interaction of the player with the virtual environment in these types of video games facilitates the learning of a new skill by allowing the player to create cognitive links with similar real-world situations (Ypsilanti et al., 2014). An example of a serious video game is a flight simulator, which allows players to practice a certain skill-set, such as landing a plane on a runway. While it is not the intention of the games, it is possible that older adults who play serious games may show cognitive benefit from engagement in these activities. Skill acquisition is known to alter brain structure and functioning (Doyon & Benali, 2005). For example, older adults who were taught to juggle showed transient gray matter growth in the hippocampus and nucleus accumbens (Boyke, Driemeyer, Gaser, Buchel, & May, 2008). While theoretical evidence suggests that skill acquisition from playing serious video games may be beneficial, there have been few, if any studies that have investigated the cognitive benefits of older adults playing serious video games (Ypsilanti et al., 2014)

Cognitive Stimulation

Another intervention found to prevent cognitive decline is cognitive stimulation (CS). Cognitive Stimulation consists of the engagement in a range of activities, such as word games, puzzles, and other activities, in order to improve general cognition and social functioning (Woods, Aguirre, Spector, & Orrell, 2012). Whereas CT focuses on improving specific cognitive domains, CS therapy consists of engagement in a wide-range of non-specific activities to produce improvements in general cognition (Bahar-Fuchs et al., 2013).

Cognitive Stimulation is based on the idea that cognitive activity can ameliorate the effects of aging in both healthy adults and adults with degenerative disorders. For example, crossword puzzle participation has been found to delay the onset of dementia by 2.54 years (Pillai et al., 2011). Additionally, compared to individuals who did not participate, those who engaged in mental activities, such as reading books and newspapers, completing crossword puzzles, writing, studying, painting, or drawing, had a decreased risk for developing dementia (Wang, Karp, Winblad, & Fratiglioni, 2002). In addition to mitigating cognitive decline that naturally occurs with age, CS therapy can be beneficial for those who have suffered major cognitive impairments due to the onset of dementia; these benefits remained up to three months after the intervention was discontinued (see Woods et al., 2012 for a review). Together, the existing research on CS therapy suggests that engaging your brain in middle and late life is crucial for maintaining cognitive function in late life and may even result in improvements in cognition after cognitive decline has begun.

Art as Cognitive Stimulation. Although it has not been validated, creating visual artwork may result in global brain activation and be a form of CS. Evidence from lesion studies suggest that the creation of visual artwork relies heavily on the right-hemisphere of the brain (Schnider, Regard, Benson, & Landis, 1993). However, visual artistry also requires the use of the dorsolateral prefrontal cortex for planning and organizing a portrait as well as the cingulate cortex for emotional modulation (Miller & Hou, 2004). A neuroimaging study found that creativity, a construct essential for the creation of novel artwork, is associated with the cortical thickness in specific areas of both the right and left hemispheres of the brain (Jung et al., 2010). Furthermore, qualitative research suggests that artistic creativity contributes to successful aging by fostering and encouraging the development of problem-solving skills that are applicable to everyday problems (Fisher & Specht, 2000; Flood & Phillips, 2007). Together, creating visual art may be sufficient to produce global improvements in cognition.

Activities such as painting and drawing are some of the numerous mental activities associated with both reduction in dementia risk and the delay of dementia onset (Stern & Munn, 2010; Wang et al., 2002). However, these observational studies usually lump leisure and mental activities together to create a single, composite of activities. This method makes it difficult to discern the exact effect creating visual art has on reducing the risk of dementia. The existing literature regarding the cognitive effects of creating visual art is scant. Most of this information comes from case studies where individuals with chronic cognitive deficits show recovery after the incorporation of art therapy into treatment (e.g., Kim, Kim, Lee, & Chun, 2008).

To the best of our knowledge there have only been two studies published using a visual art intervention to improve cognition. In one study, college-aged students were randomly assigned to one of four groups where they were asked to either view an inkblot followed by producing an original piece of artwork, replicate an inkblot as closely as possible, merely view an inkblot, or write about a class from high school (Rosier, 2010).

The students who created an original piece of artwork outperformed the other groups in a short-term memory task that was completed after the brief intervention. This study suggests that creating a novel piece of art may lead to benefits in processing, which leads to increases in memory performance. The second study examined cognitive functioning in older adults after four weeks of either a theater art intervention, visual art intervention, or no intervention (Noice, Noice, & Staines, 2004). After the intervention, the theater arts group performed significantly better on a problem-solving task than both the visual arts group and the no-contact control group. However, the “visual art” intervention merely consisted of a group of individuals examining artwork in different media and speculating about the artist’s intention. That is, they observed and evaluated art but did not create art. These two studies suggest that merely viewing or discussing artwork is insufficient to produce cognitive gains. Yet, gains may occur when there is active engagement in producing art. While this research is very limited, these findings suggest that a visual art intervention might be useful to mitigate the cognitive decline in older adults.

Methodological limitations of CT. There are a number of methodological limitations across studies that make it difficult to determine the efficacy of CT interventions (Boot, Blakely, & Simons, 2011). One limitation is that there is rarely consistency across studies in the number of training sessions, length of training session, and the duration of interventions. When CT interventions are being replicated and the results are inconsistent (e.g., Boot et al., 2013; English, 2012; Nouchi et al., 2012), it is uncertain if these differences are due to the intervention protocols or other extraneous factors. Also, studies do not use the same outcome measure, or not all outcome measures are reported (Boot et al., 2011). Again this makes direct comparisons and study replications difficult when inconsistent results are found. Thus, what is needed is a study that examines the efficacy of multiple interventions that uses a wide-range of well-validated cognitive tests as outcome measures.

Present Study

The present study sought to determine if engaging in a visual art intervention elicits cognitive benefits in healthy older adults. Individuals were randomly assigned to an experimental group or an active control group, which controlled for any non-specific effects of engagement. Those allocated to the experimental group played a video game called, Art Academy™. This is a serious video game, in that it is designed to teach the player a skill (Toril et al., 2014). Specifically, Art Academy™ taught individuals how to draw and paint. Within the video game, a virtual tutor instructed art lessons, such as how to analyze a visual scene for patterns and how to blend colors to create the illusion of depth. This intervention served two purposes: 1) it was one of the first randomized control trials examining the cognitive benefits of an art intervention with older adults; 2) it was one of the first studies that examined how skill acquisition via a digital medium (i.e., a serious video game) affects cognition in older adults.

The individuals who were randomly assigned to the active control group played the classic arcade game, Tetris™. Similar to a mental rotation task, in this game, polygons appear at the top of the screen and the player has to rotate the blocks and make them fit together to form a line with no gaps. Tetris™ was selected as an active control because it has been used as an active control in other studies (Belchior et al., 2013; Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Nouchi et al., 2012). Also, previous research with older adults found that playing Tetris™ caused improvement in simple reaction time performance (Goldstein et al., 1997) and selective visual attention performance (Belchior et al., 2013), but there was no evidence of transfer effects to global cognitive functioning, psychomotor speed, working memory, or executive functioning. Since the effects of playing Tetris™ in older adults have already been documented and could be anticipated, it was thought to be sufficient to control for active engagement, particularly in the visual domain, in the present study.

As a secondary aim, the results of the present study were also compared to the results found for the Brain Age™ software training by English (2012), whose active control (video poker) was as effective as the intervention. Herein, significant improvements for Brain Age™ training, above and beyond improvements for the Tetris™ group (i.e., a new active control), can be attributed to the actual intervention.

Finally, the intervention length and the outcome measures of the present study were the same as the comprehensive and well-validated outcome measures used in our previous study (English, 2012). Thus, this study overcame the methodological limitations of CT studies that were outlined and allowed us to analyze the differential effects of four different video game interventions (i.e., Art Academy™, Brain Age™, Tetris™, video poker).

Specific Aims and Hypotheses

Aim 1: To determine if a six-week intervention will produce improvements in gameplay performance for either the experimental group or the active control group.

It was important to determine if either intervention produced improvements in gameplay. A failure to demonstrate gameplay advancement might signal that the game was either too difficult or not engaging enough for the participant. Furthermore a lack of improvement in gameplay would likely yield a failure for cognitive growth or a transfer effect to occur. While there was no precedent to determine if gameplay would improve for Art Academy™, gameplay performance for Tetris™ has improved in previous studies (Nouchi et al., 2012).

Hypothesis 1: *When analyzed separately, improvements in gameplay would occur for both the Tetris™ and Art Academy™ groups.*

Aim 2: To determine if a digital art video game, Art Academy™, resulted in improvements in one or more cognitive domains (i.e., "transfer") after a six-week intervention.

Creating visual art is an activity that requires the artist to visually analyze a scene for shapes and patterns, similar to an abstract reasoning task. Despite relying heavily on right hemispheric brain functions (Schnider et al., 1993), creating visual art also relies on other brain areas, such as the dorsolateral prefrontal cortex and cingulate cortex (Miller & Hou, 2004). This suggests that widespread brain activation may occur, which may produce improvements in cognitive domains that were not specifically trained (i.e., transfer effects). Tetris™ was used to control for engagement (Belchior et al., 2013; Nouchi et al., 2012), thus for sufficient evidence that Art Academy™ causes improvements in an area of cognition, changes from baseline to post-testing had to significantly exceed the changes seen by those playing Tetris™.

Hypothesis 2: (a) *Art Academy™ teaches players to analyze and search for shapes and patterns within a visual scene. Thus, we hypothesized that cognitive improvements beyond those in the active control group would occur in visual abstract reasoning performance. (b) Also, due to the continuous and systematic visual engagement of a* *visual scene, performance improvements, beyond the active control group were expected for visual working memory. (c) However, Art Academy™ was not expected to be sufficient to elicit transfer effects beyond the visual domain (e.g., tests of verbal memory, digit span, etc.)*

Aim 3: To explore the differential effects that playing Art Academy™, Tetris™, Brain Age™, and video poker has on cognition in older adults.

In determining the differential effects of playing the various video games, it is important to determine if the improvements in story memory, visual working memory, and math fluency that were evident in English's (2012) study for Brain Age™ were due specifically to training or due simply to engagement. That is, because video poker playing, which was intended to be an active control, elicited the same degree of improvement on these tests as did those who played Brain Age™, training effects are not clearly distinguishable from engagement effects. Moreover, Brain Age™ specifically trains math fluency and working memory, but it does not directly train episodic memory, suggestive of a transfer effect.

In studies with older adults, playing Tetris™ led to improvement in simple reaction time (Goldstein et al., 1997) and selective visual attention (Belchior et al., 2013), but there was no evidence of transfer effects to global cognitive functioning, psychomotor speed, working memory, or executive functioning (Belchior et al., 2013; Goldstein et al., 1997; Nouchi et al., 2012). Thus, in the current study, playing Tetris™ for six weeks was not expected to improve story memory, visual working memory, or math fluency. Thus, the improvements in working memory and math fluency in the Brain Age™ group were expected to exceed any change in the Tetris™ group, suggesting successful training effects with Brain Age™. Additionally, improvement in episodic memory after Brain Age™ training was expected to exceed any change in performance in the Tetris™ group, suggesting a transfer effect from Brain Age™ training.

Hypothesis 3: (a) *It was hypothesized that the improvements in math fluency and visual working memory would be significantly greater for Brain Age™ than for Tetris™. (b) Tetris™ trains mental rotation. This training may generalize to improvements in visual search abilities. We expected that visual search performance (Trail Making Test Part A) would be better for the Tetris™ group than the Brain Age™ group.* (c) *We expected that the improvement in story memory performance would be greater for Brain Age™ than for Tetris™, suggesting a transfer effect.*

Method

Recruitment

Potential participants were recruited using existing lists of individuals who have volunteered for past studies and indicated willingness for future studies. Potential participants were screened by telephone to determine if they meet inclusionary criteria before baseline testing was scheduled.

Inclusionary criteria. Inclusionary criteria for the study (comparable to those used by English, 2012) required that participants be over the age of 50, living independently, and in good general physical and cognitive health (i.e., no prior diagnosis of Mild Cognitive Impairment or dementia; MMSE score greater than 24). Prospective participants were excluded from the study if they had poor eyesight and were unable to read small print with the use of corrective lenses. Potential participants were also excluded if they have significant video game playing experience (e.g., played more than one hour of video games per week over the past two years; Nouchi et al., 2012) or if they have previously played Art Academy™.

Interventions

Art Academy™. Art Academy™ is a video game for Nintendo DS™ that teaches the player to draw and paint with step-by-step tutorials. The game provides 10 lessons, each building on the other and introducing increasingly complex concepts and techniques. The player can go at his/her own pace and repeat lessons as necessary. The game also offers a “free paint” mode in which the player can draw or paint whatever they like. There is also a multimedia library with hundreds of pictures that the player can use as a model. To paint, the player directly interacts with the Nintendo DS’s touchscreen. The Nintendo’s stylus acts as a pencil or paintbrush. Each stroke of the stylus against the touchscreen results in a pencil or paintbrush mark on the digital “canvas.”

Gameplay guidelines were given to the participants (Appendix A). The guidelines asks the participants to do two art lessons a week for the first four weeks and then one art lesson for weeks five and six. When not doing lessons, the participants were instructed to draw whatever they pleased. Once a week, the participants’ progress was assessed (see Assessing Gameplay Performance). Participants were instructed to track the duration of daily gameplay as well as the activities completed.

Tetris™. Based on the classic 1980s arcade game, in Tetris™ one of four different polygons, which can be rotated in a number of directions, falls down into the playing field. The objective is to manipulate the shapes in such a way that they form a horizontal line with no gaps. If this occurs, the horizontal line disappears and any blocks on top fall down. As gameplay progresses, the rate at which the polygons fall increases.

The game ends when the shapes stack together and touch the top of the playing field. Participants were instructed to track how long they play the video game each day and at the end of each week and which game mode they played. On the seventh day of each week, the participants were instructed to record the highest score they obtained on that given day.

Assessing Gameplay Performance

Assessing gameplay improvement in Art Academy™. Unfortunately, there is little empirical precedent to objectively assess skill acquisition in subjects who have undergone visual art training. Clark (1989) developed the Clark's Drawing Abilities test to identify children who may be well-suited for a gifted and talented education program. The task requires the child to make four pre-selected pictures. To assess artistic performance as objectively as possible, a scoring criterion was developed that was based on observable characteristics of the drawing. These characteristics were: "(1) sensory properties (line, shape, texture, value); (2) formal properties (rhythm, balance, unity, composition); (3) expressive properties (mood, originality), and (4) technical properties (technique, correctness of solution)" (Clark, 1989, p. 100). Each of these 12 properties were rated on a five-point Likert-type scale and added together to create a score ranging from 5 to 60 points. The scoring criteria used in the present study are adapted from these scoring criteria.

Art Academy™ comes equipped with a number of still-life pictures, which can serve as models for the player to draw. As part of the gameplay protocol for Art Academy™, participants drew a still-life image at the end of each training week (Day 7 of 7). In collaboration with a professional artists from Wisconsin, a still-life image of a water lily (Figure 1) was selected to serve as a model that the participants will draw each week. This image was selected because it is a single object that is not overly complex; yet, this image has a number of features, such as color blending and shading that requires some artistic competency to replicate. Thus, the image is not too complex nor is it too easy to draw, which will reduce the probability of a floor or ceiling effect from occurring.

Figure 1.
Water Lily Used to Assess Gameplay Improvements for Art Academy™

Note. The water lily, seen on the top screen, serves as a model for the participant to draw on the touch-sensitive pad of the Nintendo DS.

The participants' weekly drawings of the water lily were deidentified and complied into a large power point presentation. Each of the drawings of the water lily were presented in a random order to a professional artist. In an adaption of the rating system created by Clark (1989), each iteration of the water lily will be judged on the same 12 properties (rhythm, shape, etc.) as well as an additional property, color. These 13 properties were rated on a five-point Likert-type scale and the 13 scores were combined to create one total score. In sum, each subject was instructed to draw six iterations of the water lily at each weeks end. Each iteration was judged by 13 different observable qualities to create a single score ranging from 13 to 65.

Assessing gameplay improvements in Tetris™. Participants were asked to record the highest score attained on the final day of each week (Day 7 of 7). Previous studies have assessed gameplay performance for Tetris™ by examining pre-post changes for the very first game played and the final game played at the end of the intervention (Nouchi et al., 2012). However, since these games are played outside of the laboratory, extraneous factors (e.g., distractions or fatigue) may interfere and artificially influence a participant's performance on either the initial or final gameplay session. For greater accuracy, and to follow a methodology similar to English (2012), the participant's highest scores at the end of each week will be assessed for growth over the duration of the intervention.

Neuropsychological Outcome Measures

In order to examine transfer effects of the intervention and active control, the main outcome variables will be a number of well-validated neuropsychological measures (Table 1). The present study will use the same measures (with a few additions) used by

English (2012) for a number of reasons: 1) the measures that were used assessed the performance of a large number of cognitive domains (see below for more details) 2) it will allow for a direct comparison of the cognitive changes for individuals who played Brain Age™ or video poker from English's (2012) study 3) we hypothesize that Art Academy™ effects will be limited to the visual domain. There is no precedent and little existing literature that can guide these hypotheses. All of these neuropsychological

Table 1.
Neuropsychological Outcome Measures

Measures
Premorbid Intelligence and Mental Status
Mini-Mental State Examination
North American Adult Reading Test
Memory
Rivermead Behavioral Memory Test- Story subtest
Rey Auditory Verbal Learning Test
Brief Visual Memory Test- Revised
Spatial Span
Executive Function
Controlled Oral Word Association Test
Semantic Fluency
Trail Making Test – Part B
Psychomotor Speed
Digit Symbol Coding
Attention
Digit Span
Trail Making Test – Part A
Reasoning Measures
WAIS-III Similarities
WAIS-III Matrix Reasoning
Math Fluency
WJ ACH III Math Fluency
Visuospatial Abilities
Mental Rotation

Note. WAIS – III = Wechsler Adult Intelligence Scale 3rd Edition; WJ ACH III = Woodcock-Johnson Test of Achievement 3rd edition.

measures are well validated and widely used across the country in both clinical and research settings.

To try and reduce any possible practice effect, alternate forms of the neuropsychological measures were used, as possible. In some cases, when alternate versions of the test were unavailable a split-half method, where the odd-numbered questions will be administered at baseline and the even-numbered questions will be administered at post-testing, will be used. The following is a brief summary of the primary neuropsychological measures that will be administered:

Premorbid intelligence and mental status.

Mini Mental State Examination. To assess mental status, the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) was administered at baseline testing. The MMSE is widely used clinical screening instrument that assesses a wide range of cognitive domains (e.g, orientation, attention, language, memory, visuospatial construction) via 11 categories of questions. The highest possible score is 30 points; participants in the present study must obtain a score of at least 24 to be included in the study. The internal consistency of the MMSE ranges from 0.31 to 0.96 depending on the sample (Strauss, Sherman, Spreen, & Spreen, 2006). The MMSE also has modest to high correlations with other cognitive screeners, such as the Dementia Rating Scale and the Clock Drawing Test (Strauss et al., 2006).

Memory measures.

Rivermead Behavioral Memory Test. The Rivermead Behavioral Memory Test – 3rd edition (RBMT; B. Wilson, Cockburn, Baddeley, & Hiorns, 1989) consists of 11 subtests that assess memory performance in areas that are typically affected in individuals who suffer from head injuries (Sunderland, Harris, & Baddeley, 1983) and were designed to be ecologically valid. In the present study, only the Story subtest, which assesses verbal memory abilities, was used. In this subtest, a prose passage is read aloud and the participant is instructed to recall the details of the story immediately and 20-30 minutes later. Form 1 will be used in the baseline session and Form 2 will be used in the post-testing session. Depending on the subtest, alternate form reliability for the RBMT ranged from 0.67 to 0.88 (B. Wilson et al., 1989). Outcome measure is the amount of information correctly recalled immediately after the initial presentation (RBMT Immediate) and after the delay (RBMT Delayed).

Rey Auditory Verbal Learning Test. The Rey Auditory Verbal Learning Test (RAVLT; Rey, 1958) is a list-learning test, which assess both short-term and long-term verbal episodic memory. It is well-validated and is widely used in both research and clinical applications (Woodard, Dunlosky, & Salthouse, 1999). In this test, fifteen unrelated items are read aloud at a rate of one word per second over five trials. Free recall follows each presentation of the target words. An interference trial of different words follows the initial five-trial presentation. Short-term recall of the initial, target words takes place immediately following the interference trial. Delayed recall occurs 20 to 30 minutes later. Finally, a 30-word recognition trial occurs after the delayed recall trial. The RAVLT has a high internal reliability (coefficient alpha is about 0.90). There is variability in the reported alternate form reliability, however, most of the reliability coefficients reported fall above the marginal range (>.60; Strauss et al., 2006). Despite the marginal-or-above reliability, practice effects are reduced when different forms of the test are given (Crawford, Stewart, & Moore, 1989), thus Form 1 will be used at baseline testing and Form 2 will be used at post-testing for the following study. The number of words recalled after the first stimulus presentation (RAVLT Trial 1), the total number of words recalled over the five learning trials (RAVLT Immediate Total), the number of correctly recalled words during the interference trial (RAVLT List B), the number of target words recalled immediately after the interference trial (RAVLT Short Delay), target words recalled after a 20 minute delay (RAVLT Long Delay), and the number of target words identified among foils (RAVLT Discrimination) will be used as outcome measures.

Brief Visual Memory Test-Revised. The Brief Visual Memory Test- Revised (BVMT;Benedict, 1997) consists of three trials in which six geometric designs are presented for ten seconds. After each stimulus presentation the participant is instructed to replicate the geometric designs in their correct spatial locations. To assess long-term recall, the participant is asked to draw the designs in their correct location without any visual prompts after a 30-minute delay. There are six equivalent alternate forms of the BVMT (Strauss et al., 2006). Form 1 and Form 4 will be administered at pre-test and post-testing, respectively. Outcome measures included the total number of correctly recalled designs across the three learning trials (BVMT Immediate), correct designs recalled after the delay (BVMT Delay), and the number of correctly identified objects among foils (BVMT Discrimination).

Executive functioning measures.

Controlled Oral Word Association Test. The Controlled Oral Word Association Test (COWA) is a measure of verbal fluency, thought to assess one aspect of executive functioning (Benton, Hamsher, & Rey, 1989). In this test, participants are given a letter of the alphabet and are instructed to say as many unique words as possible in 60 seconds, excluding repetitions, minor modifications (e.g., the same word with a different prefix, suffix or tense), and proper nouns. The letters are F, A, and S for one form and C, F, and L for the other. High internal consistency is reported for the letter group F, A, and S ($r = 0.83$) as well as the letters C, F, and L ($r = 0.83$; Ruff, Light, Parker, & Levin, 1996). There is a high correlation between the two verbal fluency tasks and are about equivalent with one another (Strauss et al., 2006). At baseline testing the FAS version will be administered and the CFL version will be administered at post-testing. Outcome measure for the present study is the total number of unique words across all three trials.

Semantic Fluency. The semantic fluency condition immediately follows the letter fluency condition. Depending on the version, the participant is asked to name as many unique animals or boys names as possible in 60 seconds. Correlations among the various semantic category forms are moderately high (.66-.71). Test-retest reliability is typically above .70 (Strauss et al., 2006) and small, but reliable practice effects occur when the test is repeated over a short period of time (B. A. Wilson, Watson, Baddeley, Emslie, & Evans, 2000). Switching categories during repeated testing can reduce this practice effect. Therefore, the “animals” version will be administered at baseline testing and the “boys names” version will be administered at Post-testing.

Trail Making Test. The Trail Making Test (TMT) has been used as an outcome measure in a number of CT studies (e.g., Nouchi et al., 2012; Wolinsky, Vander Weg, Howren, Jones, & Dotson, 2013). The TMT consists of two parts: Trails A and Trails B (Reitan, 1958). Trails A assess psychomotor speed and visual search abilities, while Trails B is an ecologically valid measure of executive functioning (Burgess, Alderman, Evans, Emslie, & Wilson, 1998). In Trails A, the numbers 1 through 25 are dispersed among a single piece of paper. The participant has to start at “1” and draw a continuous line, as fast as possible, sequentially connecting the numbers until “25” is reached. In Trails B, numbers and letters are randomly dispersed around a page. The participant, beginning with “1” must alternate between connecting the numbers and letters both sequentially and in alphabetical order until the number 13 is reached. In both trials, immediate feedback is provided if the participant makes an error. Trails A and B have alternate forms, Trails C and D, respectively. The alternate form reliability is 0.80 for Trails A and C and 0.78 for Trails B and D (DesRosiers & Kavanagh, 1987). However, Trails D has been found to be slightly more difficult than the alternate form, Trails B (LoSasso, Rapport, Axelrod, & Reeder, 1998). Given that all of the trials are not equivalent in difficulty, the order of administration for Trials A/B and Trials C/D will be counterbalanced during baseline and post-test sessions. The outcome measures are the number of seconds to complete each trial (Trails A, Trails B).

Working memory measures.

Digit Span. Digit span performance has been used in a number of CT studies (e.g., Nouchi et al., 2013) to assess verbal working memory. The present study will use the digit span subtest from the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS;Randolph, 1998). In the Digit Span subtest, numbers are read aloud to the participant at a rate of one word per second. The task continues until either ceiling level of functioning is reached or nine digits are correctly recalled. Form 1 of the RBANS digit span will be used in baseline and Form 2 will be used during post-testing. Alternate form reliability for the RBANS is good (.77; Wilk et al., 2004). The main outcome measure is the total number of trials where the digit sequence is correctly recalled (Digit Span).

Spatial Span. The Wechsler Memory Scale – III Spatial Span subtest (Wechsler, 1997) will be used to assess visual working memory abilities. In the forward condition of this test, the examiner touches a series of unmarked blocks and the participant has to touch the blocks in the exact same sequences as the examiner. In the backwards condition, the examiner touches the blocks in a certain sequence and the participant has to touch the blocks in the reverse order as the examiner. Since alternate forms of this test are not available, the original test was split in half to create two versions. Two outcome measures, the longest span correctly recalled forward (Spatial Span Forward) and the longest span correctly recalled backwards (Spatial Span Backwards) was used in the present study.

Psychomotor speed measures.

Digit Symbol Coding. Psychomotor speed was be assessed using the Digit Symbol Coding subtest of the WAIS-III (Wechsler, 1997) and the WAIS-IV (Wechsler, 2008). This test has been used to assess processing speed in a similar CT study (Nouchi et al., 2012). In this test, nine simple figures are paired with numbers and presented at the top of the page for the participant to use as a reference. The rest of the page has two adjacent boxes with numbers in the top box and the bottom boxes are left empty. The participant has 120 seconds to copy the symbol that corresponds with the numbers. The WAIS-III version was used during the baseline testing and the WAIS-IV version was used during Post-testing. The main outcome measure is the total number of boxes that were filled (Digit Symbol Coding).

***Digit Symbol Copy*.** This test, used to assess graphomotor speed, consists of simple figures in the top of two boxes. The adjacent, bottom box is empty and the participant is instructed to copy the symbol from above into the empty box as quickly as possible for 90 seconds. The outcome measures from this test is the total number of symbols correctly drawn in the empty boxes (Digit Symbol Copy Total) and the total amount of time needed to complete the form (Digit Symbol Copy Completion Time).

Reasoning measures.

WAIS-III Similarities. In the WAIS-III Similarities subtest (Wechsler, 1997), the participant is asked to describe how to word pairs are alike (e.g., horse and tiger). Abstract answers are score higher than concrete responses. This is thought to test verbal abstract reasoning and has been assessed in other CT studies as well (Ball et al., 2002; Owen et al., 2010). The original items from the subtest were split in half to create two versions of the test for pre- and post-testing. The WAIS-III has excellent split-half reliability (.98) when averaged across all thirteen subtests (Wechsler, 1997).

WAIS-III Matrix Reasoning. The WAIS-III Matrix Reasoning subtest (Wechsler, 1997) measures nonverbal abstract reasoning. In this subtest, an abstract design with a piece missing is presented to the subject. The subject must identify, from choices below, the piece that best completes the pattern of the abstract design. The original subtest was split into two tests for Pre- and Post-testing. Again, the WAIS-III has excellent split-half reliability (Wechsler, 1997). Outcome measure is the total number of correct items (Matrix Reasoning).

Math fluency measures.

Woodcock Johnson Test of Achievement -III Math Fluency. Math fluency, a skill highly trained in Brain Age™ was assessed using the Math Fluency subtest of the Woodcock-Johnson Test of Achievement – 3rd edition (Woodcock, McGrew, & Mather, 2001). In this subtest, the participant is asked to answer as many simple mathematic questions as they can in three minutes. Form A will be used during Pre-test and Form B will be used for Post-testing. The alternate form reliability ranges, depending on the age group from 0.80 to 0.96 (Woodcock et al., 2001). Outcome measures include the number of correctly completed problems (Math Fluency Total) and how long it took to complete the task (Math Fluency Completion Time).

Visuospatial abilities

Mental rotation. Playing Tetris™ has led to improvements in mental rotation performance in older adults (Boot et al., 2013). Based on the seminal task created by Cooperau and Shepard (1973) and alphanumeric stimulus of either a “2” or the capital letter “R” is presented in the center of a computer screen. The original or a mirror-image of the stimulus was randomly presented at either 0, 45, 90, 135, 180, 225, 270, or 315 degrees. The participant has five seconds to decide if the alphanumeric stimuli is a normal or mirror image. If no response is given, the trial is considered incorrect and the next trial begins. Outcome measures include the percentage of correctly responses given (Mental Rotation Accuracy) and the reaction time of correct responses (Mental Rotation Reaction Time).

Emotional functioning measures.

Geriatric Depression Scale. The Geriatric Depression Scale (GDS;Jerome A Yesavage & Sheikh, 1986) will be used to assess self-reported levels of depression. This is essential to measure because elevated levels of depression places older adults at a higher risk for cognitive decline (Steffens et al., 2007). Furthermore cognitive interventions have also been shown to reduce depression in older adults (Kurz, Pohl, Ramsenthaler, & Sorg, 2009). The GDS asks fifteen yes-no questions regarding the subject’s mood. In non-clinical populations, the internal consistency has a Crombach’s alpha value ranging from .71 to .84 (Strauss et al., 2006).

Beck Anxiety Inventory. To assess current levels of anxiety, the Beck Anxiety Inventory (BAI;Beck & Steer, 1993) will be administered at baseline and post-testing session. The BAI is a 21-item self-report questionnaire and assesses for common symptoms of anxiety, such as numbness, dizziness, and nervousness.

Design

In the present study, participants were quasi-randomly assigned to either the experimental training group, Art Academy™, or the active control group, Tetris™. Similar to our previous study (English, 2012) the intervention lasted six weeks and participants played their assigned game for at least 20 minutes (no more than 45 minutes) per day over the six-week period, making the total amount of gameplay approximately 14 hours over the course of the intervention. This amount of gameplay is similar to other research studies (e.g., Nouchi et al., 2012) and a meta-analysis has shown that efficacy of video game gameplay is no different for short or long interventions (Toril et al., 2014).

However, shorter interventions may have an advantage over longer interventions by potentially reducing attrition rates.

Prior to the intervention, all participants underwent baseline testing to assess premorbid cognitive functioning. After the six-week intervention, a post-testing session (no more than one week after completion of the intervention) took place so that cognitive functioning could be reassessed.

Data Analyses

All analyses were done using the Statistical Pack for the Social Sciences (SPSS) version 22. Alpha levels of $p < .05$ will be set as criterion for statistical significance.

Aim 1. Aim 1 will determine if a six-week intervention will produce improvements in gameplay performance for either an experimental group (*Art Academy*™) or an active control group (*Tetris*™).

Hypothesis 1: *When analyzed separately, improvements in gameplay will occur for both the Tetris™ and Art Academy™ groups.*

To ensure comparability of intervention compliance between the two groups, two independent-sample *t*-tests were conducted on the total number of minutes the games were played and the number of days the games were played.

To address this hypothesis the "total score" for the Tetris™ group and the subjective ratings of artistic performance for Week 1 and Week 6 were analyzed. To evaluate gameplay performance for Art Academy™, the 13 Likert-type scales rated by the professional artist was combined to create a single score. Since the gameplay score for Art Academy™ is an ordinal measure, based on combined Likert scales, a Freidman's test, which is the nonparametric alternative to a repeated-measures Analysis of Variance

(ANOVA), was performed. A planned comparison, using a Wilcoxon signed-rank test, was done to assess the total score of the drawing from Week 1 and Week 6. The purpose of this analysis was to determine if the performance on the drawing task improved by the end of the intervention for the Art Academy™ group.

To assess gameplay performance for the Tetris™ group, a one-way repeated measures ANOVA examining the highest score obtained at the end of each week was done. A planned contrast comparing the total score for the first week (Week 1) and the last week (Week 6) was completed. As with Art Academy™, the main interest is to determine if gameplay performance was significantly better at the end of the intervention compared to the beginning of the intervention. No direct comparison of relative gameplay improvement between groups was done as this is not a specific aim of the study.

Aim 2. The purpose of Aim 2 is to determine if playing Art Academy™ causes improvements in cognitive functioning beyond those achieved by the active control group, Tetris™.

> Hypothesis 2: (a) *Art Academy™ teaches players to analyze and search for shapes and patterns within a visual scene. Thus, we hypothesize that cognitive improvements beyond those in the active control group will occur in visual abstract reasoning performance. (b) Also, due to the continuous and systematic visual engagement of a visual scene, performance improvements, beyond the active control group are expected for visual working memory. (c) However, Art Academy™ is not expected to be sufficient to elicit transfer effects beyond the visual domain (e.g., tests of verbal memory, digit span).*

To address the hypotheses, a difference score for each neuropsychological outcome variable was created by calculating a residualized change score by regressing the post-test scores onto the baseline scores. This method controls incidental differences at baseline more effectively than a simple change score (Veldman & Brophy, 1974) and has been used in other intervention studies (Prochaska, Velicer, Nigg, & Prochaska, 2008). The residualized change scores that had a Mahalanobis D^2 with a cumulative probability of 0.001 or less were considered outliers and removed. This resulted in the removal of three data points (0.56% of the dataset), and these data points were not replaced.

To determine if Art Academy™ resulted in broad, generalizable effects, a Multivariate Analysis of Variance (MANOVA) analyzing all of the neuropsychological outcome measures was performed. The MANOVA had group (Art Academy™ and Tetris™) as the between-subjects independent variable and the residualized change scores of the neuropsychological measures as the dependent variables. Additionally, it is specifically expected that Art Academy™ will result in an improvement in visual abstract reasoning and working memory. Therefore, these univariate analyses were be examined, regardless of the outcome of the omnibus MANOVA. Furthermore, since there is limited empirical research to determine if broad, cognitive generalizations would occur, all of the univariate analyses were examined *post-hoc*, even if the omnibus MANOVA failed to reach significance.

To assess the total cognitive change, the residuals for all the neuropsychological measures were summed to create a Total Change score. Linear transformations on the change scores were done, when necessary, so that positive values represented better performance.

Aim 3. Aim 3 will combine the data from the present study with the data from English's (2012) study to examine the differential effects of playing video games on cognition in older adults.

Hypothesis 3: (a) *It is hypothesized that the improvements in math fluency and visual working memory will be significantly greater for Brain Age™ than for Tetris™. (b) Tetris™ trains mental rotation. This training may generalize to improvements in visual search abilities. We expect that the visual search (Trail Making Test Part A) will be better for the Tetris™ group than the Brain Age™ group.* (c) *We expect that the improvement in story memory performance will be significantly greater for Brain Age™ than for Tetris™, suggesting a transfer effect.*

Our previous study (English, 2012) found that story memory, visual working memory, and math fluency improved for the Brain Age™ group. However, these improvements did not surpass the improvements of the active control (video poker). Since we were only interested in analyzing the improvements of the Brain Age™ group compared to the active control of the present study (Tetris™), five independent-samples t-tests analyzing the residualized change scores for these neuropsychological outcome measures were conducted. Furthermore, another independent sample *t*-test will be conducted to determine if there are differences in improvements for the residualized change score for a visual search task (Trail Making Test Part A).

Results

Participants

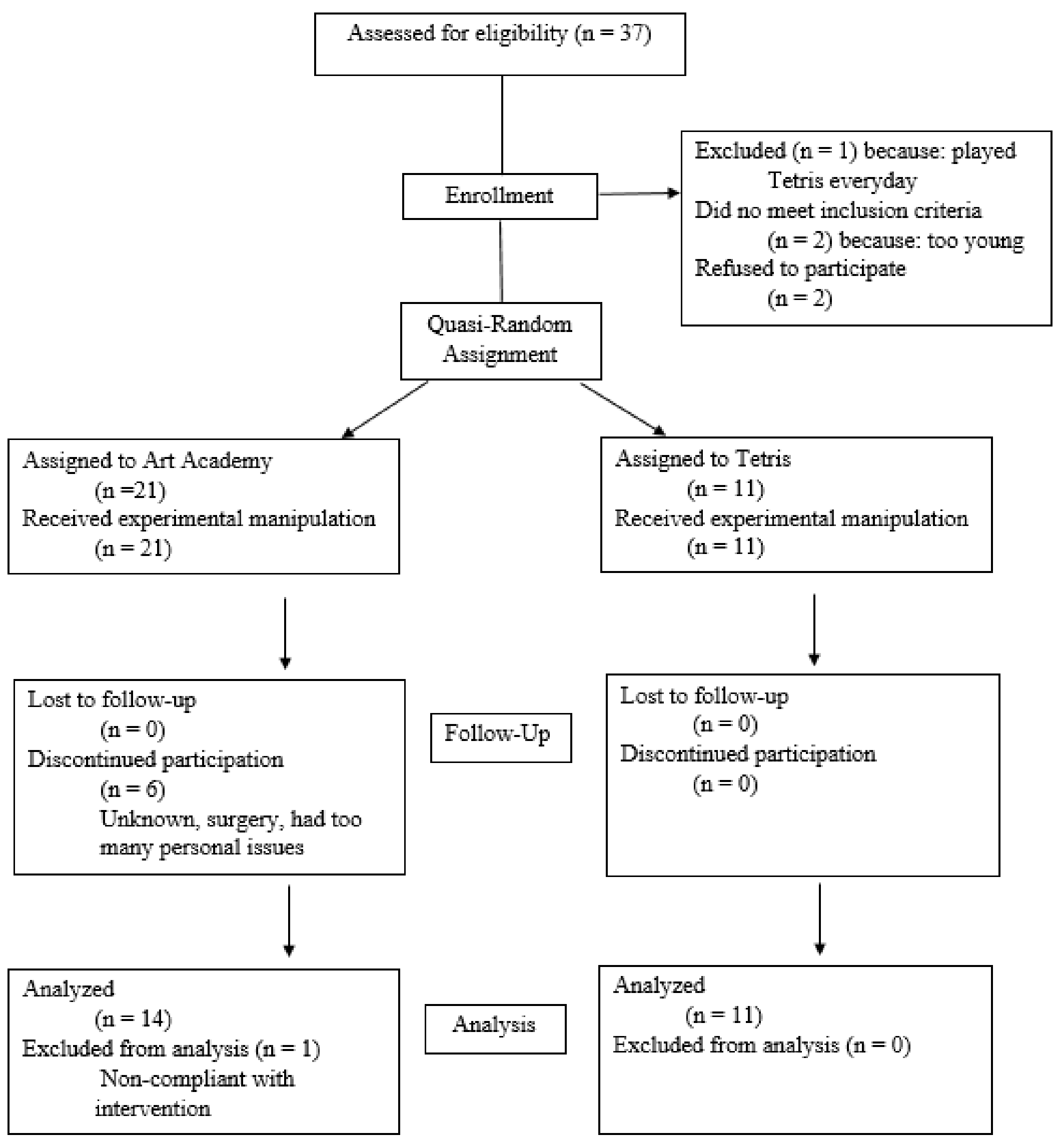
Thirty-seven individuals were recruited and assessed for eligibility to participate in the present study (see Figure 2 for participant flow). Twenty-one individuals were quasi-randomized to the experimental condition and eleven individuals were assigned to the control condition. Six individuals from the Art Academy™ condition withdrew from the study and one individual's data were not analyzed due to non-compliance with the protocol. No individuals from the Tetris group withdrew and all their data were analyzed. The number of individuals who withdrew or were noncompliant to the treatment condition were greater in the Art Academy™ condition than the Tetris™ condition ($\chi^2(1) = 4.69$, $p = 0.03$). The participants who withdrew from the study or were noncompliant were younger ($t(26.58) = -2.36$, $p = 0.03$), but were similar in every other demographic.

The final sample in the present study consisted of twenty-five predominantly female older adults ($M_{age} = 66.16$, SD = 10.82; female n = 19, 76%), who were primarily Caucasian (n = 22, 88%), currently employed (n = 14, 56%) and highly educated ($M_{education} = 16.20$, SD = 2.31; see Table 2). The participants were similar in age ($F(3,66) = 0.305$, $p = .822$), education ($F(3,66) = 1.869$, $p = .144$), sex distribution ($\chi^2(3) = .517$, $p = .915$), race ($\chi^2(12) = 9.62$, $p = .649$), and employment status ($\chi^2(3) = 1.58$, $p = .665$) to those included in the earlier study by English (2012). The four groups did, however, differ in baseline MMSE ($F(3, 66) = 4.63$, $p = 0.005$), with the Tetris™ group having higher scores than the Brain Age group ($M_{difference} = 1.385$, $p = .008$). However, given the intentional ceiling effect on this dementia screening tool, this difference was not considered meaningful.

Aim 1: Assessing Change in Gameplay Performance

Participants in the active control condition played an average of 975.18 minutes (range: 715-1183, SD = 176.31) and 39.10 days (range: 28 – 42, SD = 4.06). The participants in the experimental condition played an average of 1331.93 minutes (range: 530-1895, SD = 391.33) and 35.14 days (range: 17-42; SD = 8.60). The two groups did

Figure 2.
Participant Flow



not differ in the number of days the games were played ($t(19.29) = -1.516$, $p > .05$), but the average session lengths were greater for the experimental group ($t(17.35) = 5.259$, $p < .001$), giving this group a greater amount of exposure (in minutes) to the intervention ($t(23) = 2.80$, $p = .010$). This difference in gameplay is explored in a later section.

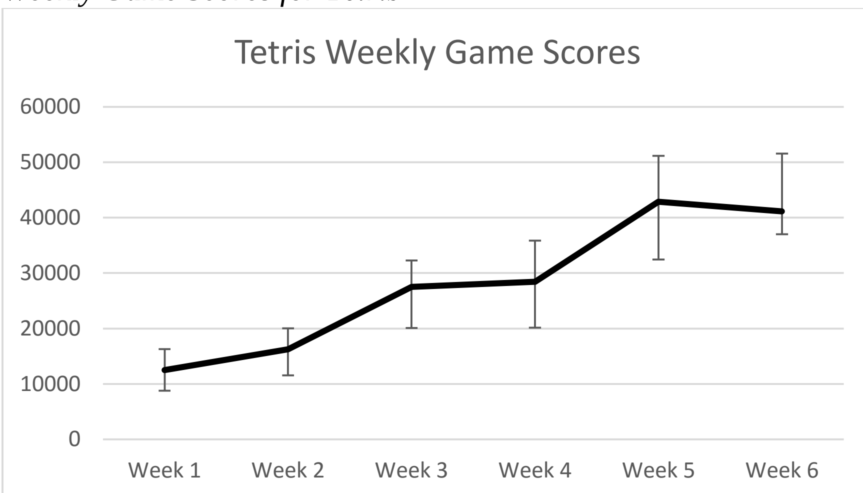
Table 2.
Mean and Standard Deviation of Sample Demographic Characteristics for Each Condition

	Overal l	Art Academy	Tetris	Brain Age	Virtual Poker
N	67	14	11	21	21
Age	65.13 (9.97)	65.29 (10.42)	11.71 (3.52)	65.33 (10.80)	63.71 (8.21)
Education	16.40 (2.64)	17.07 (2.32)	15.09 (1.87)	15.98 (3.04)	17.05 (2.60)
Female, %	50 (74.62)	10 (71.43)	9 (81.82)	15 (71.43)	16 (76.19)
Race, %					
White	58 (86.57)	13 (92.86)	9 (81.82)	17 (80.95)	19 (90.48)
African American	2 (3.03)	0 (0.0)	0 (0.0)	1 (4.76)	1 (4.76)
Hispanic	3 (4.55)	0 (0.0)	1 (9.10)	1 (4.76)	1 (4.76)
Asian	3 (4.54)	0 (0.0)	1 (9.10)	2 (9.52)	0 (0.0)
Biracial	1 (1.52)	1 (7.70)	0 (0.0)	0 (0.0)	0 (0.0)
Retired, %	29 (43.28)	6 (42.86)	5 (45.45)	11 (52.38)	7 (33.33)
Baseline MMSE	29.22 (1.19)	29.43 (0.76)	**29.91 (.302)****	**28.52 (1.54)****	29.21 (1.20)

Note. MMSE = Mini Mental State Examination; ** = p < .01

Tetris™. A one-way repeated measures ANOVA showed that gameplay performance changed over time ($F(5,25) = 14.15$, $p < .001$, $\eta_p^2 = .739$), see Figure 3 for weekly averages over time), and as hypothesized, gameplay performance improved from the beginning of the intervention (Week 1) to the end (Week 6) suggesting adequate engagement from participants ($t(5) = 8.654$, $p < .001$)[1].

Figure 3.
Weekly Game Scores for Tetris™



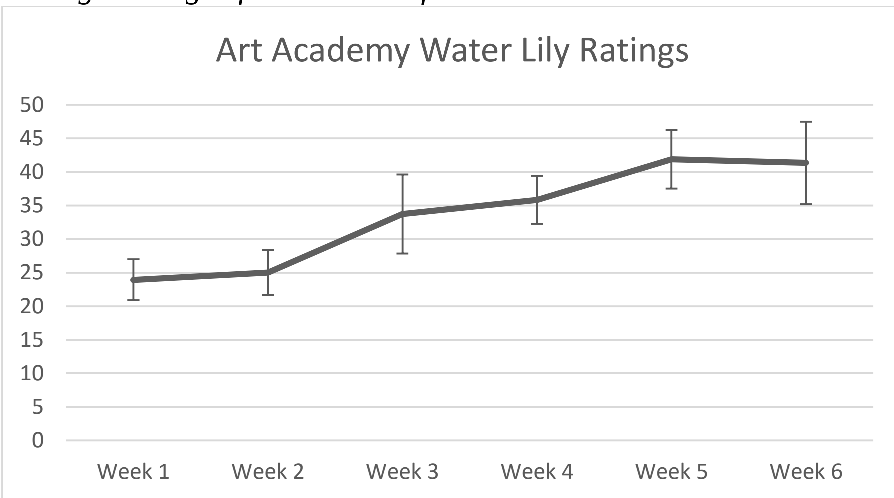
Note. Error bars represent ± 1 standard error

Art Academy™. Analysis of the waterlily ratings revealed a high internal consistency (Cronbach's $\alpha = .987$) and high inter-item correlations (Table 3).

Performance on the weekly waterlily drawings changed over the course of the intervention (Friedman's $\chi^2(5) = 14.99$, $p = 0.010$; see Figure 4). Average ratings from Week 6 were better than Week 1 ($Z = -2.383$, $p = 0.017$), again suggesting adequate engagement from participants[2].

[1] Given that 45% participants did not record their final score for Week 6, Week 1 scores and the final *recorded* score were compared. Final recorded scores were better than initial scores ($t(10) = 4.656$, $p = .001$).

Figure 4.
Average Ratings of Water Lilies for Each Week



Note. Error bars represent ± 1 standard error

Table 3.
Inter-Item Correlation Matrix of Water Lily Ratings

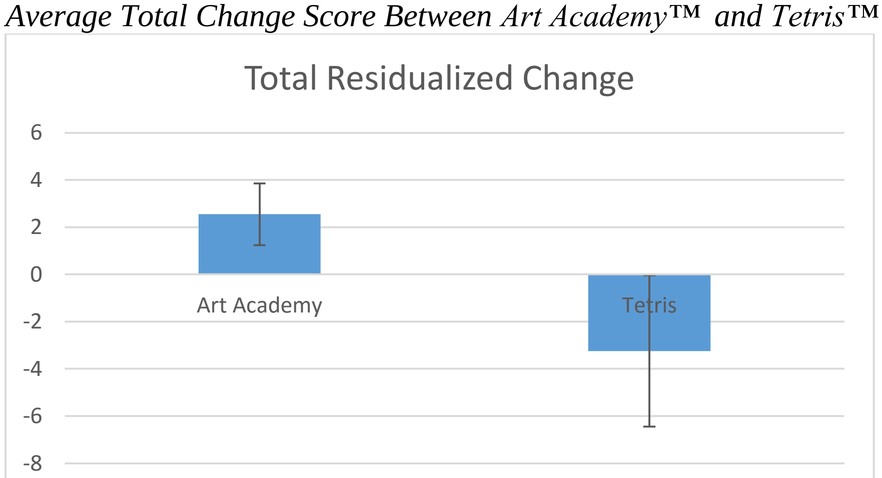
	1	2	3	4	5	6	7	8	9	10	11
1. Shape	-										
2. Texture	.874	-									
3. Color	.775	.865	-								
4. Rhythm	.825	.893	.937	-							
5. Balance	.877	.865	.887	.943	-						
6. Unity	.843	.852	.913	.899	.913	-					
7. Composition	.870	.857	.848	.852	.871	.908	-				
8. Mood	.818	.839	.883	.870	.915	.888	.856	-			
9. Originality	.820	.819	.858	.887	.923	.851	.832	.884	-		
10. Technique	.840	.843	.900	.888	.895	.858	.858	.876	.895	-	
11. Correctness of Solution	.899	.875	.830	.868	.925	.866	.894	.852	.878	.889	-

[2] Not every participant completed the final waterlily for Week 6. This analysis was re-run analyzing the performance of Week 1 and the *last* waterlily that was drawn. This analysis was also significant (Z = -2.703, p = .007)

Aim 2: Comparing Cognitive Change between Art Academy™ and Tetris™

Residualized Change Scores. Table 4 shows the raw pre-test and post-test scores of all of the cognitive measures for each condition. A MANOVA with Art Academy™ and Tetris™ as the independent variables and the residualized change scores of the neuropsychological measures as the dependent variables was not significant (λ = 0.201, (1, 16) = .248, *p* = .938, η_p^2= .799) nor were any of the follow-up univariate analyses (Table 5; all *p*'s > .05). Planned comparisons also failed to reach significance, thus, any gains in visual abstract reasoning or visual working memory were not greater in the experimental condition than the active control. To assess total cognitive change, the residuals for all of the neuropsychological measures were summed to create a Total Change Score (Figure 5). The average total change score was marginally greater for the Art Academy™ group (M = 2.54; SD = 5.01; 95% CI: 2.54 ± 2.90) than the Tetris™ group (M = -3.24; SD = 10.66; 95% CI: -3.24 ± 7.15) suggesting that Art Academy™ led to greater total cognitive improvements than the active control (F(1,23) = 3.26, p = .084).

Figure 5.
Average Total Change Score Between Art Academy™ and Tetris™



Note. Error bars represent ± 1 standard error

Table 4.

Mean and Standard Deviations of Pre-tests and Post-Tests

Measures	Art Academy		Tetris	
	Pre-Test Mean (SD)	Post-Test Mean (SD)	Pre-Test Mean (SD)	Post-Test Mean (SD)
Memory				
RBMT Immediate	10.11(3.08)	11.75 (2.31)	7.77 (3.20)	9.01 (3.25)
RBMT Delay	8.89 (3.59)	10.43 (2.60)	6.96 (3.01)	8.045 (2.81)
RAVLT Trial 1	6.29 (1.82)	5.86 (1.03)	5.82 (1.47)	5.91 (2.67)
RAVLT Immediate Total	50.79 (10.10)	52.36 (8.47)	47.64 (10.13)	46.45 (14.26)
RAVLT Trial B	5.14 (2.07)	6.07 (2.00)	5.27 (2.87)	5.91 (2.43)
RAVLT Short Delay	11.07 (2.50)	11.14 (3.03)	10.45 (3.36)	9.09 (3.81)
RAVLT Long Delay	11.14 (3.06)	10.64 (3.25)	10.18 (3.37)	9.18 (3.79)
BVMT Immediate	19.86 (6.25)	20.57 (7.79)	18.91 (7.84)	20.91 (7.43)
BVMT Delay	7.50 (2.85)	8.36 (2.56)	7.55 (3.08)	7.55 (3.39)
Executive Function				
Letter Fluency	44.00 (11.20)	45.64 (11.48)	41.73 (11.67)	41.64 (13.79)
Semantic Fluency	20.64 (5.71)	22.79 (5.75)	22.18 (5.42)	21.00 (8.37)
Trails B/D	69.08 (15.95)	68.14 (22.78)	72.82 (36.01)	81.27 (50.90)
Psychomotor Speed				
Digit Symbol Coding Total	74.00 (10.87)	71.14 (12.69)	67.55 (19.19)	107.20 (31.49)
Digit Symbol Copy Total	111.15 (24.17)	117.36 (17.13)	109.00 (24.81)	107.20 (31.50)
Digit Symbol Copy Completion Time	88.34 (3.83)	85.38 (6.23)	88.67 (3.64)	86.78 (4.97)

Table 4 Continued.
Mean and Standard Deviations of Pre-tests and Post-Tests

Measures	Art Academy		Tetris	
	Pre-Test Mean (SD)	Post-Test Mean (SD)	Pre-Test Mean (SD)	Post-Test Mean (SD)
Attention/ Working Memory				
Digit Span	10.79 (3.70)	11.57 (3.06)	9.91 (2.21)	10.82 (2.53)
Trails A/C	26.86 (9.05)	23.07 (6.34)	30.27 (13.40)	30.18 (16.06)
Spatial Span Forward	4.93 (0.83)	5.00 (1.36)	5.27 (0.91)	5.27 (1.42)
Spatial Span Backwards	4.64 (0.84)	5.07 (1.07)	5.00 (1.414)	4.82 (1.08)
Reasoning Measures				
Similarities	11.71 (1.54)	11.71 (1.98)	9.64 (2.73)	9.36 (2.25)
Matrix Reasoning	9.07 (1.54)	8.07 (1.98)	8.82 (3.00)	8.18 (2.79)
Math Fluency				
Math Fluency Total	121.07 (22.04)	125.43 (24.00)	101.45 (31.89)	108.18 (33.02)
Visuospatial Abilities				
Mental Rotation Accuracy	93.23 (4.49)	95.32 (4.75)	87.97 (13.24)	92.42 (8.44)
Mental Rotation RT	1514.35(261.59)	1394.45(305.20)	1498.24(429.47)	1506.93(436.93)

Note. RBMT = Rivermead Behavioral Memory Test; RAVLT = Rey Auditory Verbal Learning Test; BVMT = Brief Visual Memory Test; RT = Reaction Time

Table 5.

One-Way ANOVAs of Residualized Change Scores between Art Academy™ and Tetris™

Measure	F (1,23)	*p*
Memory		
RBMT Immediate	.241	.628
RBMT Delayed	2.443	.132
RAVLT Trial 1	.117	.736
RAVLT Immediate Total	1.063	.313
RAVLT Trial B	.154	.698
RAVLT Short Delay	2.393	.136
RAVLT Long Delay	.540	.470
RAVLT Discrimination	.451	.508
BVMT Immediate	.340	.565
BVMT Delay	1.489	.235
BVMT Discrimination	.015	.902
Executive Function		
Letter Fluency	.421	.523
Semantic Fluency	.801	.380
Trails B	.674	.420
Psychomotor Speed		
Digit Symbol Coding	.224	.641
Digit Symbol Copy Total	1.861	.187
Digit Symbol Copy Completion Time	.320	.578
Attention/ Working Memory		
Digit Span Total	.049	.827
Trails A	1.996	.172
Spatial Span Forward	.003	.958
Spatial Span Backwards	2.035	.167
Reasoning Measures		
Similarities	1.469	.238
Matrix Reasoning	.167	.687
Math Fluency		
Math Fluency Total Correct	.164	.689
Math Fluency Completion Time	1.121	.301
Visuospatial Abilities		
Mental Rotation Accuracy	.000	.991
Mental Rotation RT	.867	.361
Residualized Change Score		
Average Total Score	**3.255**	**.084**

Note. RBMT = Rivermead Behavioral Memory Test; RAVLT = Rey Auditory Verbal Learning Test; BVMT = Brief Visual Memory Test. $p < .10$ for bolded items.

Mixed-Methods ANOVA. Additional series of mixed 2 Condition (between) x 2 Time (within) ANOVAs were conducted for each neuropsychological measure (Table 6). Considering the main effect of Time, performance improved from baseline on the RBMT Immediate ($F_{Time}(1,23) = 14.96$, $p < .001$), RBMT Delayed ($F_{Time}(1,23) = 4.46$, $p = .046$), RAVLT Trial B ($F_{Time}(1,23) = 4.72$, $p = 0.040$), Math Fluency Total ($F_{Time}(1,23) = 6.76$, $p = .016$), and Mental Rotation Accuracy ($F(1,23) = 6.744$, $p = .016$). Considering main effects of Condition, performance on the Similarities subtest was greater for Art Academy™ ($F_{Condition}(1, 23) = 7.91$, $p = .010$), but this may be a reflection of greater education. There were no other significant main effects of Time or Condition, nor any significant Condition by Time interactions (all p's > .05).

Follow-up exploratory *t*-tests. Given the study's small sample size and exploratory nature, a series of paired-sample *t*-tests were conducted to elucidate the Pre-Post changes for both conditions (Table 7). Consistent with the mixed-method ANOVAs, both the Art Academy™ group and the Tetris™ group improved on the RBMT Immediate ($t(13) = 2.38$, $p = .033$ and $t(10) = 3.216$, $p = .009$, respectively). However, performance improved on the BVMT Delayed Recall ($t(13) = 2.28$, $p = .040$), Trails A ($t(13) = -2.67$, $p = .020$), RAVLT Trial B ($t(13) = 2.25$, $p = .040$), Digit Symbol Copy Completion Time ($t(12) = -2.321$, $p = .039$), and Mental Rotation Accuracy ($t(13) = -2.67$, $p = .019$) for Art Academy™ , but not for the Tetris™ group (all p's > 0.05). As expected, the Tetris™ group had a greater improvement in Mental Rotation Accuracy than the Art Academy™ group, however the pairwise comparison failed to reach significance due to high performance variability (i.e., high standard errors of the mean).

Although scores decreased similarly for both groups (11.07% and 7.26%) contrary to the hypothesis, performance on Matrix Reasoning significantly declined ($t(13) = -2.65$, $p = .02$) for the experimental group, whereas the Tetris™ group's performance did not ($p > 0.05$). This, however, is likely a reflection of the split-half method and not a true alteration in visual abstract reasoning. Also unexpected, Math Fluency Total Correct only improved for Tetris™ ($t(13) = 2.24$, $p = .049$).

Aim 3: Brain Age Compared to Tetris™ To determine if the significant improvements in story memory, visual working memory, and math fluency that were seen for the Brain Age™ group of English's (2012) study were due to an engagement effect or training, a series of independent sample *t*-tests were conducted comparing the residualized change scores of these outcome measures for Brain Age and Tetris™. In line with the hypotheses, the residualized change scores were marginally better for Spatial Span Backwards ($t(30) = 1.78$, $p = .086$) and Math Fluency Completion Time ($t(20.643) = 2.03$, $p = .055$). Contrary to the hypotheses, there were no differences in the residualized change scores for either verbal memory measures (RBMT Immediate $t(30) = .113$, $p = .991$; RBMT Delay $t(30) = 1.192$, $p = .243$) or Trails A ($t(29) = .081$, $p = .936$). Together, this suggests that Brain Age is only marginally better than an active control at improving performance on tasks it is specifically training and that there is no evidence of a transfer effect.

Additional Analyses

Total Change Score with all games. To understand the differential effects of playing either a digital art video game, a brain training video game, virtual poker, or a simple

Table 6.
Repeated Measure ANOVAs of All Neuropsychological Measures

Measures	Time		Condition		Time X Condition	
	F(1,23)[1]	Partial η2	*F*(1,23)	Partial η2	*F*(1,23)[1]	Partial η2
Memory						
RBMT Immediate	**14.96*****	**.394**	3.70	.139	.26	.011
RBMT Delay	**4.46***	**.162**	4.19	.154	.128	.006
RAVLT Trial 1	.171	.007	.120	.005	.405	.017
RAVLT Immediate Total	.014	.001	1.271	.271	.713	.030
RAVLT Trial B	**4.72***	**.170**	0.00	.000	.165	.007
RAVLT Short Delay	1.604	.065	1.312	.054	2.00	.079
RAVLT Long Delay	1.35	.056	1.04	.043	.150	.006
BVMT Immediate	1.854	.075	.012	.001	.416	.018
BVMT Delay	1.375	.056	.115	.005	1.375	.056
Executive Function						
Letter Fluency	.240	.010	.474	.020	.299	.013
Semantic Fluency	.105	.005	.004	.000	1.258	.052
Trails B	1.367	.059	.330	.015	.789	.035
Psychomotor Speed						
Digit Symbol Coding	.675	.029	.725	.031	.405	.017
Digit Symbol Copy Total	1.203	.285	.618	.029	.261	.060
Digit Symbol Copy Time	**6.750**	**.252***	.208	.010	.325	.016
Attention/ Working Memory						
Digit Span Total	3.593	.135	.529	.022	.019	.001
Trails A	.756	.033	.356	.016	1.994	.083
Spatial Span Forward	.020	.001	.629	.027	.020	.001
Spatial Span Backwards	.452	.019	.017	.001	2.769	.107

Table 6 Continued.

Repeated Measure ANOVAs of All Neuropsychological Measures

Measures	Time		Condition		Time X Condition	
	F(1,23)[1]	Partial η2	*F*(1,23)	Partial η2	*F*(1,23)[1]	Partial η2
Reasoning Measures						
Similarities	.169	.007	**7.907****	**.256**	.169	.007
Matrix Reasoning	4.710	.170	.007	.934	.223	.010
Math Fluency						
Math Fluency Total	**6.764***	**.227**	2.866	.111	.309	.013
Visuospatial Abilities						
Mental Rotation Accuracy	**6.744***	**.235**	.511	.023	.056	.003
Mental Rotation RT	.581	.025	.151	.007	.777	.033
Reasoning Measures						
Similarities	.169	.007	**7.907****	**.256**	.169	.007

Table 7.
Mean Pre-Post Differences in Cognitive Performance

Measures	Art Academy		Tetris	
	t df = 13	*p*	*t* df = 11	*p*
Memory				
RBMT Immediate	2.30	.033	3.22	.009
RBMT Delay	1.66	*ns*	1.45	*ns*
RAVLT Trial 1	-0.84	*ns*	0.14	*ns*
RAVLT Immediate Total	0.84	*ns*	-0.42	*ns*
RAVLT Trial B	2.25	.042	1.02	*ns*
RAVLT Short Delay	0.15	*ns*	-1.39	*ns*
RAVLT Long Delay	-0.78	*ns*	-0.83	*ns*
BVMT Immediate	0.56	*ns*	1.28	*ns*
BVMT Delay	2.28	.040	0.00	*ns*
Executive Function				
Letter Fluency	0.67	*ns*	-0.05	*ns*
Semantic Fluency	1.02	*ns*	-0.59	*ns*
Trails B/D	0.24[a]	*ns*	1.22	*ns*
Psychomotor Speed				
Digit Symbol Coding Total	-0.88	*ns*	-0.25	*ns*
Digit Symbol Copy Total	1.62[a]	*ns*	-0.04[b]	*ns*
Digit Symbol Copy Completion Time	-2.32[a]	.039	-1.48	*ns*
Attention/ Working Memory				
Digit Span	1.26	*ns*	1.46	*ns*
Trails A/C	-2.67	.020	.026[b]	*ns*
Spatial Span Forward	0.21	*ns*	0.00	*ns*
Spatial Span Backwards	1.89	*ns*	-0.61	*ns*
Reasoning Measures				
Similarities	0.00	*ns*	-0.64	*ns*
Matrix Reasoning	-2.64	.020	-0.90	*ns*
Math Fluency				
Math Fluency Total	1.48	*ns*	2.24	.049
Math Fluency Completion Time	-1.10	*ns*	-1.00	*ns*
Visuospatial Abilities				
Mental Rotation Accuracy	2.67	.019	1.40	*ns*
Mental Rotation RT	-2.57	.023	0.06	*ns*

Note. RBMT = Rivermead Behavioral Memory Test; RAVLT = Rey Auditory Verbal Learning Test; BVMT = Brief Visual Memory Test; RT = Reaction Time. *ns* = Not Significant [a] = df = 10. [b] = df = 9 arcade game, a MANOVA with all four video game conditions as independent variables and the residualized change scores of the neuropsychological measures as dependent variables was performed. The omnibus MANOVA was not significant (λ = 0.229, F(3, 66) = .903, p = .668, η_p^2= .338) nor were the planned, univariate one-way ANOVAs (Table 8). The residuals for all of these outcome measures were summed to create a Total Change Score (Figure 6). The average total change score was highest for the Art Academy™ group (M = 2.02; SD = 4.71; 95% CI = 2.02 ± 2.72) followed by the Brain Age group (M = 1.36; SD = 8.08; 95% CI = 1.36 ± 3.68), then the virtual poker group (M = -0.769; SD = 7.11; 95% CI = 0.769 ± 3.24), and the Tetris™ group (M = -3.70; SD = 9.88; 95% CI = 3.70 ± 6.64). However, a one-way ANOVA showed there were no significant differences between these four groups (F(3,66) = 1.516, p = .219). Given the exploratory nature of this study the pairwise comparisons were also examined. However, these comparisons were not significant (all p's < .05).

Accounting for minutes played. Additional analyses were conducted to determine if the difference in the minutes of gameplay between Art Academy™ and Tetris™ affected the results from Aim 2. Gameplay time was correlated with a number of outcome measures (Table 9), including RAVLT Short Delay (r(23) = .444, p < *.05),* BVMT Delayed Recall (r(23) .409, p < .05), Letter Fluency (r(23) = .398, p < .05), Digit Symbol Copy Total (r(23) = .356, p < .05), and the Total Change Score (r(23) = .397, p < .05). In contrast, condition assignment was only correlated with the Total Change Score (r(23) = .355, p < *.10)*, but this association disappeared when controlling for minutes played (r_{Partial}(23) = .056, p = *ns*).Given the association among the number of minutes of

Table 8.

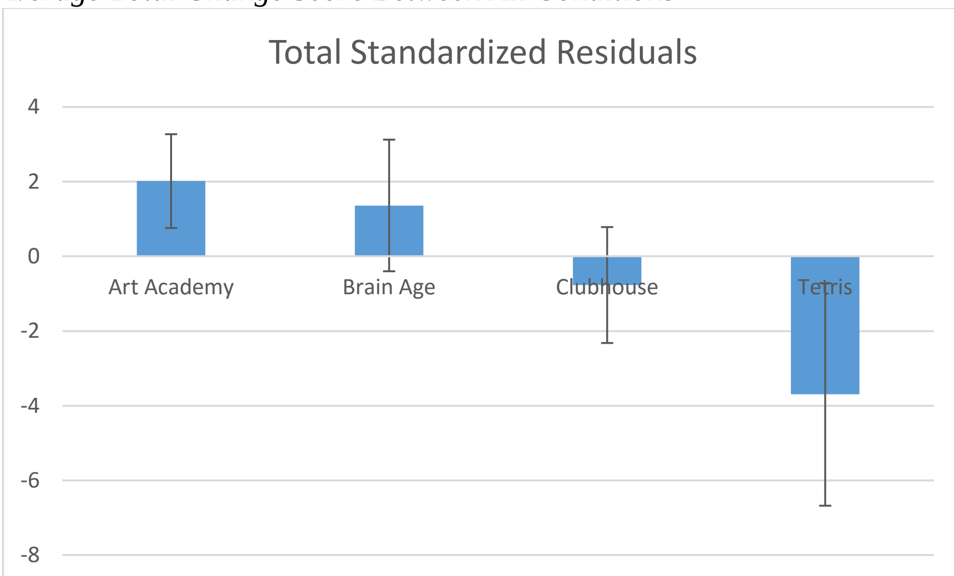
One-way ANOVAs of Residualized Change Scores for All Conditions

Measure	F (3,66)	*p*
Memory		
RBMT Immediate	0.417	.704
RBMT Delayed	1.073	.367
RAVLT Immediate Total	1.636	.190
RAVLT Trial B	1.085	.362
RAVLT Short Delay	1.839	.149
RAVLT Long Delay	.914	.439
RAVLT Discrimination	.876	.459
BVMT Immediate	.562	.642
BVMT Delay	1.173	.327
BVMT Discrimination	.400	.753
Executive Function		
Letter Fluency	.762	.519
Semantic Fluency	1.295	.284
Trails B	1.16	.349
Psychomotor Speed		
Digit Symbol Coding	.252	.859
Digit Symbol Copy Total	.995	.401
Digit Symbol Copy Completion Time	1.208	.315
Attention/ Working Memory		
Digit Span Total	.154	.927
Trails A	.833	.481
Spatial Span Forward	**2.199**	**.097**
Spatial Span Backwards	1.390	.254
Reasoning Measures		
Similarities	.988	.404
Math Fluency		
Math Fluency Total Correct	1.689	.178
Math Fluency Completion Time	1.716	.173
Residualized Change Score		
Average Total Score	1.516	.219

Note. RBMT = Rivermead Behavioral Memory Test; RAVLT = Rey Auditory Verbal Learning Test; BVMT = Brief Visual Memory Test.
$p < .10$ for bolded items.

gameplay and the neuropsychological outcome measures, two groups were produced via a median split (Median = 1119 minutes): a high gameplay group (HG) and a low game group (LG; see Table 10 for demographic characteristics). Both groups were similar in age ($t(23) = 1.28$, $p = .214$), education ($t(23) = -.238$, $p = .814$), sex distribution ($\chi^2(1) = 1.10$, $p = .294$), race ($\chi^2(3) = 3.69$, $p = .297$), employment status ($\chi^2(1) = 1.92$, $p = .165$), and baseline MMSE scores ($t(23) = -0.42$, $p = .679$)

Figure 6.
Average Total Change Score Between All Conditions



Note. Error bars represent ± 1 standard error

A MANOVA with the HG and the LG as the independent variables and the residualized change scores of the neuropsychological measures as the dependent variables was not significant ($\lambda = 0.029$, $F(1, 16) = 2.081$, $p = .502$, $\eta_p^2 = .971$). Exploratory one-way ANOVAs revealed group differences for the BVMT Delayed Recall, Trails B, RAVLT Short Delay, RAVLT Long Delay, Letter Fluency, and the Total Change Score (see Table 11). For these variables, the residuals were greater in the HG, suggesting better performance improvements than the LG in all outcome measures except for Trails B, where performance was worse for the HG (Table 12). Figures 7

Table 9.
Correlation of Condition and Number of Minutes Played with Neuropsychological Outcome Measures

Measure	Condition	Minutes Played
Condition	-	.235
Minutes Played	.235	-
Memory		
RBMT Immediate	.102	.043
RBMT Delayed	.310	.014
RAVLT Trial 1	-.071	-.054
RAVLT Immediate Total	.210	.137
RAVLT Trial B	.082	.242
RAVLT Short Delay	.307	**.444***
RAVLT Long Delay	.151	.256
RAVLT Discrimination	.139	.231
BVMT Immediate	-.121	.059
BVMT Delay	.247	**.409***
BVMT Discrimination	.027	-.107
Executive Function		
Letter Fluency	.134	**.398***
Semantic Fluency	.183	.003
Trails B	-.172	-.149
Psychomotor Speed		
Digit Symbol Coding	-.098	-.233
Digit Symbol Copy Total	.285	**.356**†
Digit Symbol Copy Completion Time	-.126	.059
Attention/ Working Memory		
Digit Span Total	.046	.019
Trails A	-.288	-.298
Spatial Span Forward	-.011	.044
Spatial Span Backwards	.285	.239
Reasoning Measures		
Similarities	.245	.183
Matrix Reasoning	-.085	.103
Math Fluency		
Math Fluency Total Correct	-.084	.040
Math Fluency Completion Time	-.216	-.306
Visuospatial Abilities		
Mental Rotation Accuracy	.002	-.046
Mental Rotation RT	-.191	-.171
Residualized Change Score		
Average Total Score	**.355†**	**.397***

Note. RBMT = Rivermead Behavioral Memory Test; RAVLT = Rey Auditory Verbal Learning Test; BVMT = Brief Visual Memory Test; RT = Reaction Time. †p < .10 *p < .05.

shows the scatterplots of the amount of gameplay and these six outcome variables, stratified by experimental condition.

To ensure that the duration of gameplay truly accounted for the group differences between the HG and LG for the outcome measures above, a series of hierarchal regressions were performed (Tables 13– 18). The first block of the regressions consisted of demographic information (age and education) and in the next block was duration of gameplay. The last two blocks consisted of assigned condition (Art Academy™ or Tetris™) and a gameplay duration and condition interaction term, respectively (in no instance did the interaction term contribute to the model so it was not reported in the tables). For all but two of the neuropsychological outcome measures tested, the demographic information did not contribute to any of the models. Therefore, the same hierarchal regressions were repeated without the demographic information.

Table 10. *Demographic characteristics of the High and Low Gameplay Groups*

	Overall	High Minutes	Low Minutes
N	25	13	12
Art Academy	14	9	5
Tetris	11	4	7
Minutes Played	1174.96 (358.56)	1438.38 (270.73)	889.58 (172.33)
Age	86 (10.82)	63.54 (9.94)	69.00 (11.42)
Education	16.2 (2.31)	16.31 (1.97)	16.08 (2.71)
Female, %	19 (76%)	11 (85%)	8 (67%)
Race, %			
White	22 (88%)	13 (100%)	9 (75%)
Hispanic	1 (4%)	0 (0%)	1 (8.3%)
Asian	1 (4%)	0 (0%)	1 (8.3%)
Biracial	1 (4%)	0 (0%)	1 (8.3%)
Retired, %	11 (44%)	4 (31%)	7 (58%)
Baseline MMSE	29.64 (.638)	29.58 (.70)	29.58 (0.63)

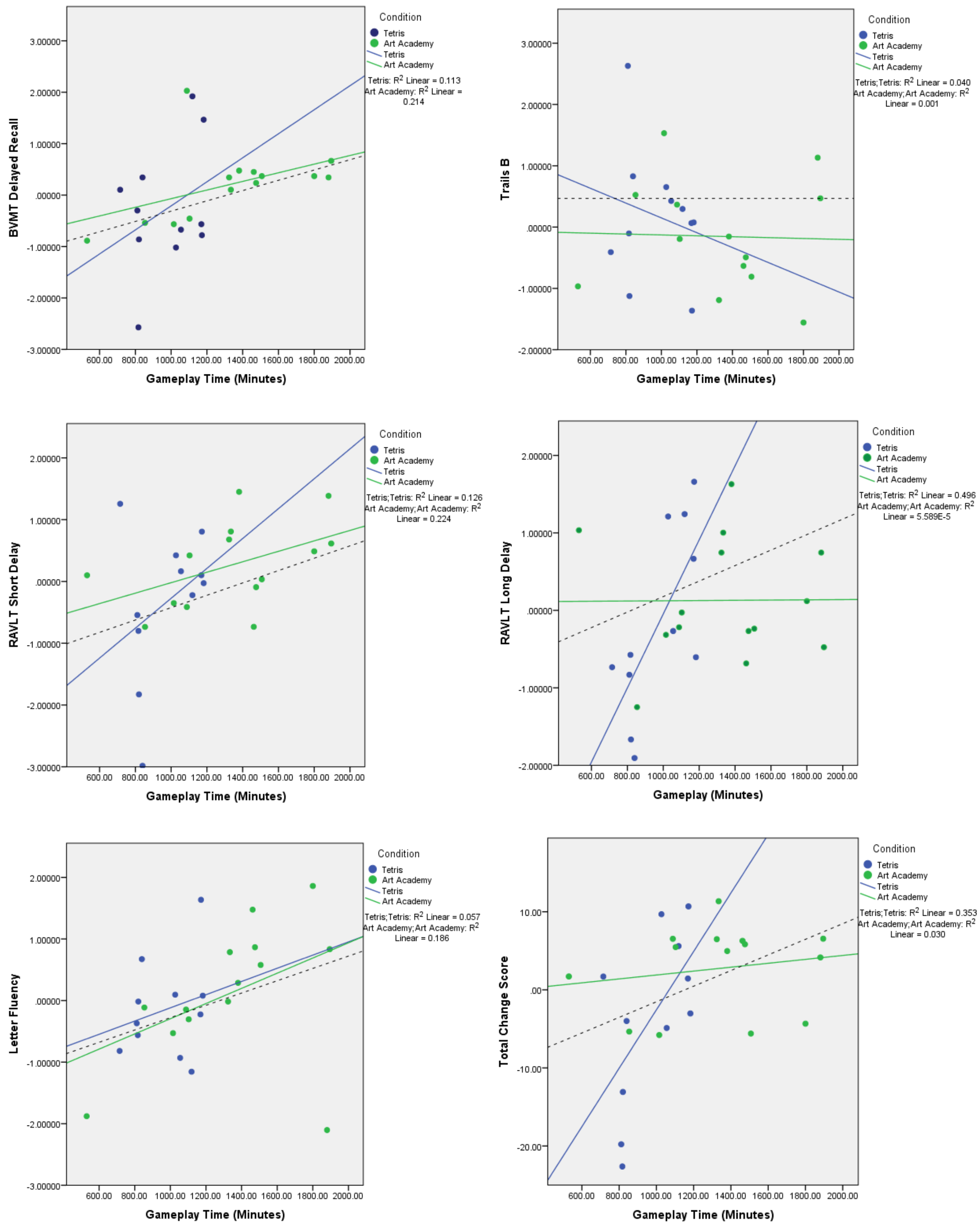
Note. No significant differences in any of the values

Table 12.
Mean Residualized Change Scores and Mean Pre-Post Scores between High Gameplay and Low Gameplay Groups

	High Game Time			Low Game Time		
Measures	Change Score (SD)	Pre-Test Mean (SD)	Post-Test Mean (SD)	Change Score (SD)	Pre-Test Mean (SD)	Post-Test Mean (SD)
RAVLT Short Delay	.336 (.678)	11.92 (2.33)	12.23 (2.35)	-.364 (1.18)	9.58 (2.97)	8.08 (3.55)
RAVLT Long Delay	.303 (.973)	11.54 (2.85)	11.77 (2.42)	-.328 (.961)	9.83 (3.38)	8.08 (3.55)
BVMT Delay	.411 (.779)	7.46 (2.70)	8.69 (2.36)	-.445 (1.05)	7.58 (3.20)	7.25 (3.36)
Letter Fluency	.373 (1.15)	43.38 (8.62)	47.15 (10.27)	-.404 (.628)	42.58 (13.91)	40.33 (14.00)
Trails B/D	.376 (.713)	67.50 (15.01)	62.69 (17.38)	-.376 (1.13)	74.08 (34.86)	86.08 (49.24)
Total Change Score	2.10 (5.06)	-	-	-9.72 (4.88)	-	-

Figure 7.

Scatterplot of Gameplay Time and Residualized Change Scores Stratified by Condition



Note. The dashed line represents the regression equation collapsed across condition

Table 13.
Hierarchal Regressions Predicting the Residualized Change Score of Brief Visual Memory Test – Delayed Recall

	Model 1		Model 2		Model 3[1]	
Variable	B	ß	B	ß	B	ß
Age	-.022	-.242	-.018	-.198	-.018	-.199
Education	.004	.010	-.009	-.021	-.021	-.049
Minutes Played			.001	.386[†]	.001	.353
Condition					.138	.071
Model *F*	.693		1.809		.298	
R^2	.059		.205		.208	
F for change in R^2			3.861[†]		.785	

Regression Models Without Demographic Characteristics

	Model 4		Model 5		Model 6	
	B	ß	B	ß	B	ß
Minutes Played	.001	.409*	.001	.382	.002	.856
Condition			.435	.054	1.637	.847
Minutes X Condition					-.001	-1.122
Model *F*	4.62*		2.24		1.70	
R^2	.167		.169		.196	
F for change in R^2			.058		.684	

Note. [†]$p < .10$ *$p < .05$. **$p < .01$.*** $p < .001$
[1]Interaction assessed but not significant

Table 14.
Hierarchal Regressions Predicting the Residualized Change Score of Trail Making Test – B

	Model 1		Model 2		Model 3[1]	
Variable	B	ß	B	ß	B	ß
Age	.028	.306	.027	.298	.027	.294
Education	-.143	0.344†	-.140	-.336	-.152	-.366
Minutes Played			.000	-.082	.000	-.114
Condition					.134	
Model *F*	3.381†		2.23		1.61	
R^2	.244		.250		.253	
F for change in R^2			.177		.071	

	Regression Models Without Demographic Characteristics					
	Model 4		Model 5		Model 6	
	B	ß	B	ß	B	ß
Minutes Played	.000	-.149	.000	-.08	-.001	-.451
Condition			-.251	-.131	-1.415	-.736
Minutes X Condition					.001	.859
Model *F*	.500		.381		.357	
R^2	.022		.035		.051	
F for change in R^2			.279		.333	

Note. †$p < .10$ *$p < .05$. **$p < .01$.*** $p < .001$
[1]Interaction assessed but not significant

Table 15.

Hierarchal Regressions Predicting the Residualized Change Score of Rey Auditory Verbal Learning Test – Short Delay Recall

	Model 1		Model 2		Model 3[1]	
Variable	B	ß	B	ß	B	ß
Age	-.015	-.167	-.011	-.121	-.011	-.121
Education	.107	.252	.093	.219	.094	.222
Minutes Played			.001	.408*	.001	.412ᵗ
Condition					-.016	-.008
Model *F*	1.24		2.52ᵗ		1.80	
R^2	.102		.265		.265	
F for change in R^2			4.66*		.001	

Regression Models Without Demographic Characteristics

	Model 4		Model 5		Model 6	
	B	ß	B	ß	B	ß
Minutes Played	.001	.444*	.001	.388ᵗ	.002	.886
Condition			.216	.112	1.825	.945
Minutes X Condition					-.002	-1.179
Model *F*	5.664*		2.860ᵗ		2.153	
R^2	.197		.206		.235	
F for change in R^2			.257		.794	

Note. ᵗ$p < .10$ *$p < .05$. **$p < .01$.*** $p < .001$

[1]Interaction assessed but not significant

Table 16.

Hierarchal Regressions Predicting the Residualized Change Score of Rey Auditory Verbal Learning Test – Long Delay Recall

	Model 1[1]		Model 2[1]		Model 3[1]	
Variable	B	*ß*	B	*ß*	B	*ß*
Age	-.023	-.259	-.021	-.237	-.021	-.234
Education	.138	.326	.131	.310	.160	.378†
Minutes Played			.001	.198	.001	.280
Condition					-,340	-.176
Model *F*	2.645†		2.17		1.67	
R^2	.194		.232		.251	
F for change in R^2			1.045		.492	

Regression Models Without Demographic Characteristics

	Model 4		Model 5		Model 6	
	B	*ß*	B	*ß*	B	*ß*
Minutes Played	.001	.256	.001	.241	.005	1.75**
Condition			.058	.030	4.93	2.552*
Minutes X Condition					-.005	-2.886**
Model *F*	1.616		.781		3.471*	
R^2	.256		.258		.331	
F for change in R^2			.016		8.330**	

Note. †p < .10. *p < .05. **p < .01. *** p < .001.

[1]Interaction assessed but not significant

Table 17.
Hierarchal Regressions Predicting the Residualized Change Score of Letter Fluency

	Model 1[1]		Model 2[1]		Model 3[1]	
Variable	B	ß	B	ß	B	ß
Age	-.023	-.255	-.019	-.212	-.019	-.211
Education	-.500	-.118	-.063	-.150	-.059	-.140
Minutes Played			.001	.387	.001	.399
Condition					-.050	-.026
Model *F*	.850		1.951		1.397	
R^2	.072		.218		.218	
F for change in R^2			3.93[†]		.010	

	Regression Models Without Demographic Characteristics					
	Model 4		Model 5		Model 6	
	B	ß	B	ß	B	ß
Minutes Played	.001	.398*	.001	.444[†]	.001	.392
Condition			-.173	-.090	-.338	-.175
Minutes X Condition					.000	.121
Model *F*	4.339*		2.168		1.383	
R^2	.159		.165		.165	
F for change in R^2			.158		.008	

Note. [†]$p < .10$. *$p < .05$. **$p < .01$. *** $p < .001$.
[1]Interaction assessed but not significant

Table 18.
Hierarchal Regressions Predicting the Total Change Score

Variable	Model 1[1] B	Model 1[1] ß	Model 2[1] B	Model 2[1] ß	Model 3[1] B	Model 3[1] ß
Age	-.454	-.554***	-.427	-.521***	-.426	-.521**
Education	1.537	.400**	1.444	.376**	1.461	.381*
Minutes Played			.007	.297*	.007	.302†
Condition					-.193	-.011
Model *F*	12.029***		10.887***		7.78***	
R^2	.522		.609		.609	
F for change in R^2			4.631*		.004	

Regression Models Without Demographic Characteristics

	Model 4 B	Model 4 ß	Model 5 B	Model 5 ß	Model 6 B	Model 6 ß
Minutes Played	.010	.397*	.007	.292	.037	1.514*
Condition			3.64	.208	39.37	2.251*
Minutes X Condition					-.035	-2.891*
Model *F*	4.302*		2.577†		4.001*	
R^2	.158		.190		.364	
F for change in R^2			.875		5.740*	

Note. †$p < .10$. *$p < .05$. **$p < .01$. *** $p < .001$.
[1]Interaction assessed but not significant

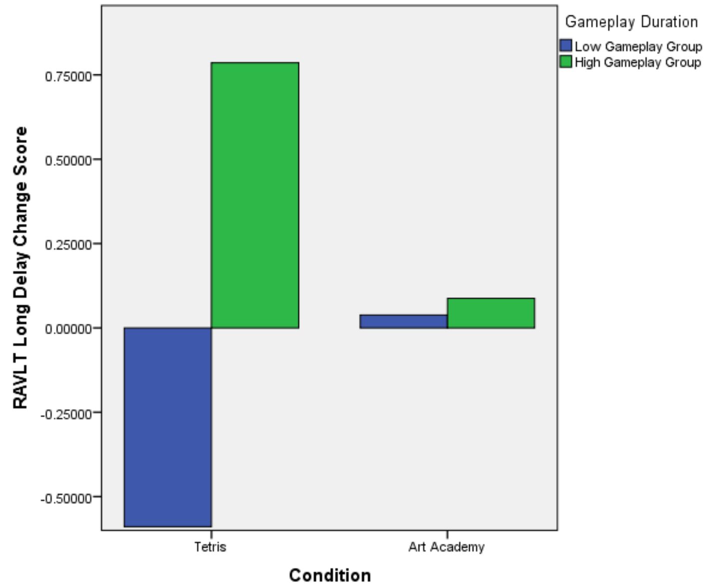
BVMT Delayed Recall. Regarding the delayed recall on the BVMT, the only model that predicted the residualized change scores was the number of minutes played (Model 4). As gameplay time increased, performance increased on this measure.

Trail Making Test – Part B. In predicting the change scores for Trails B, Model 1, containing only demographic information was trending. Of the demographic predictors, education was trending suggesting that as education increased, performance changes decreased. Together this suggests that individuals with lower educational attainment improved more on this measure than individuals with higher educational attainment, and that neither gameplay duration nor video game condition affected performance changes. Perhaps, individuals with higher educational attainment performed closer to ceiling level of functioning and had less of an opportunity to improve performance.

RAVLT Short Delay Recall. Only Model 4, containing amount of gameplay predicted the change scores for the RAVLT short delay recall. As the duration of gameplay increased, performance on this measure increased.

RAVLT Long Delay Recall. In predicting change scores for the RAVLT Long Delay Recall, only Model 6 was significant. For this model, the number of minutes played, experimental condition, and the interaction of these two variables were significant. Analysis of the standardized β's suggests that RAVLT performance increases as gameplay time increases. It also suggests that those in the Art Academy™ condition showed more improvement, on average, than the Tetris™ group. However, the amount of change was greater for the Tetris™ group as gameplay time increased (See Figure 13).

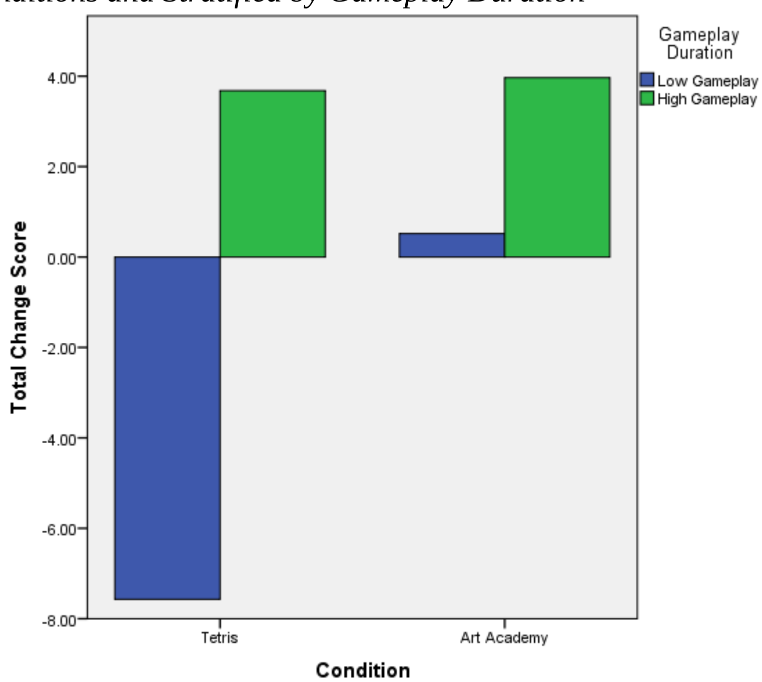
Figure 13.
Bar Chart of the Average Residualized Change Score for the RAVLT Long Delay Recall between Conditions and Stratified by Gameplay Duration



Letter Fluency. In predicting the change scores for Letter Fluency, only Model 4, containing the amount of gameplay, was significant. This suggests that change scores increased as time of gameplay increased.

Total Change Score. Finally, Models 1, 2, 3, 4, and 6, all predicted the Total Change Score. In Model 1, both demographic variables predicted the outcome variable, with Total Change Scores decreasing with age, but increasing with education. Minutes of gameplay predicted the Total Change Score when controlling for demographic information (Model 2) and improved the amount of variability explained by the model. Even though the model was significant, experimental condition was not a significant predictor when controlling for demographics and minutes of gameplay (Model 3). When demographic information was dropped from the prediction equation (i.e., given the lack of prediction and small sample size), minutes of gameplay, experimental condition, and the interaction of these two variables predicted the Total Change score (Model 6). This model suggests that the Total Change score increases as time of gameplay increases. In addition, Art Academy™ contributed significantly more to the Total Change Score than Tetris™ when controlling for minutes played. However, the interaction indicated that the amount of improvement in Total Change Score was greater in the Tetris™ group as minutes of gameplay increased (See Figure 14). Even thought they had the same number of predictors, Model 6 explained far less variance than Model 2 (34% versus 61% of the variance). Thus, the participant's demographic information and minutes of gameplay was a better predictor of the Total Change Score than minutes of gameplay, experimental condition, and the interaction of both.

Figure 14.
Bar Chart of the Average Residualized Change Score for the Total Change Score between Conditions and Stratified by Gameplay Duration



Discussion

Observational studies and case reports suggest that creating artwork can ameliorate cognitive decline and delay dementia onset (e.g., Kim et al., 2008; Stern & Munn, 2010; Wang et al., 2002). However, to the best of our knowledge, this is the first ever randomized-controlled study that examined the direct influences of creating visual artwork on cognition in an older adult sample. We hypothesized that playing the games would significantly increase game performance for both Art Academy™ (experimental condition) and Tetris™ (active control). We also hypothesized that Art Academy™ would lead to greater cognitive improvements in abstract reasoning and visual working memory than Tetris™, while Art Academy™ was not likely to produce transfer effects to non-visual domain cognitive performance (e.g., verbal memory). We also hypothesized that when comparing these two tasks with data from a prior study that compared Brain Age software with video poker to examine cognitive training, that Brain Age would produce superior effects on math fluency and story memory versus Tetris™, and that Tetris™ would produce better gains in Trail-making Part A than Brain Age.

The results of the study indicated that a six-week intervention of creating digital artwork using Art Academy™ or Tetris™ for at least 20 minutes a day did lead to improved game play (Aim 1). Moreover, this intervention was sufficient to induce improvement in cognitive functioning (Aim 2). Specifically, older adults who took part in the digital art intervention showed improvement in visual memory, aspects of verbal memory, visual scanning and sequencing, psychomotor speed, and mental rotation, while the active control (Tetris™) did not show similar improvements.

While Art Academy™ induced cognitive gains, none of the specific hypotheses from Aim 2 were supported. Playing Art Academy™ resulted in improvements in visual memory, but not visual working memory as anticipated. Contrary to our hypothesis, the Art Academy™ group *declined* in visual abstract reasoning. As mentioned, both groups similarly declined, suggesting the decline was due to the split-half testing method as opposed to an actual decline in cognitive performance. Also contrary to our hypotheses but encouraging nonetheless, the improvement on a verbal memory test suggests that playing Art Academy™ may have resulted in a transfer effect. Furthermore, relative to the active control, the digital art intervention resulted in greater, overall cognitive improvement. These results are in line with the existing, though scant, literature that the creation of visual art can improve cognition and ameliorate cognitive decline.

Art Academy™ is a "serious video game," teaching the player a specific skill (Toril et al., 2014). The effects of playing a serious video game in an older adult population has not been examined, but research has shown that skill acquisition should elicit transient cognitive changes (e.g., Boyke et al., 2008). Traditional, non-digital arts and crafts activities have been typically conceptualized as a form of cognitive stimulation (Woods et al., 2012), and theoretical evidence suggests that engaging in these activities should ameliorate cognitive decline (Wang et al., 2002). It is uncertain, however if the additional cognitive demand of operating a digital device occluded or enhanced cognitive change. That is, would the participants who played Art Academy™ still show the same pattern and amount of cognitive growth if the art intervention was paper-and-pencil rather than digital? Given that most of the cognitive changes were limited to the visual domain suggests that the art intervention was responsible for these changes. It is however, uncertain whether the change in verbal memory performance (i.e., the transfer effect) was related to the increased demand of using a digital device.

The third aim of the study was to compare the findings of our previous study (English, 2012) and determine if neuropsychological software (i.e., Brain Age) was an effective intervention. In line with our hypotheses, those who played the brain training video game improved on the specific tasks that were trained (i.e., visual working memory and math fluency), but transfer effects were not evident. This finding is in line with a recent meta-analysis, which found that neuropsychological software was no better than other video games at inducing cognitive changes (Toril et al., 2014). Also, the MANOVA and all univariate ANOVAs comparing the findings of the present study with our previous study (English, 2012) failed to reach significance. This seems to suggest that no single video game is superior to another in inducing cognitive gains.

However, all of these results are confounded by a disparate amount of intervention exposure between the two groups of the present study. While both groups played their respective video games for the same number of days, the average session lengths were greater for the Art Academy™ group through self-choice to play longer. Thus, the total intervention exposure (in minutes) was greater for the experimental group. Additional analyses examined the effects of video game exposure on cognitive change. When dichotomous groups (High Gameplay and Low Gameplay) were created based on the total minutes of exposure to the intervention, the HG group showed greater cognitive change regardless of type of intervention on the delayed recall of a visual memory task (BVMT Delayed Recall), recall of a verbal list after a short delay (RAVLT Short Delay), the delayed recall of a verbal list after a long delay (RAVLT Long Delay), letter fluency, and total cognitive improvement (Total Change Score).

Follow-up regression analyses examined the unique influences of gameplay duration on each of tasks that showed significant effects in omnibus analyses. For visual memory recall, recall of verbal material after a short delay and letter fluency, gameplay exposure significantly predicted cognitive change, whereas demographic information and experimental condition did not. Demographic information was the only predictor of change for a visual scanning and set-shifting task. While duration of gameplay significantly predicted the total cognitive change, demographic information explained much more of the variability in this outcome measure. Importantly, recall of a verbal list after a long delay was significantly predicted by gameplay duration, experimental condition, and their interaction. Analysis of the beta values showed the Art Academy™ group improved more, on average, than the Tetris™ group, but gameplay duration hardly affected the amount of improvement for the experimental condition. However, after a certain amount of gameplay, Tetris™ produced more improvement on the verbal measure than Art Academy™.

It is important to note that there was not a significant difference in the composition of the HG and LG, with nearly an equal number of individuals from Art Academy™ and Tetris™ in each group. Given the results described above, it seems that, under the right conditions, performance increases for measures of verbal memory, visual memory, and executive functioning can occur regardless of the video game played. This is especially important as both Art Academy™ and Tetris™ mainly tap into visual domain. The performance increases is verbal memory and executive functioning suggest a transfer effect. This, however, contradicts the findings of Aim 3 that Brain Age only improved tasks that were trained but transfer effects were not evident. Unfortunately, English (2012) did not ask participants to record the number of minutes played in each session, rather only the number of days played. Thus, these results may be confounded by amount of gameplay.

Similarly, most video game studies took place in a laboratory setting under the supervision of the experimenters (e.g., Ball et al., 2002; Basak et al., 2008; Belchior et al., 2013) who can monitor gameplay duration and protocol adherence. However, at-home studies (e.g., Ackerman et al., 2010; Nouchi et al., 2012; Owen et al., 2010) rarely report the actual duration of participants' gameplay. For example, Nouchi and colleagues (2012) reported only that, "participants performed the games for about 15 minutes" (pg. 2). Thus, it is possible that the significant effects of the experimental intervention may be influenced by gameplay time. Similarly Ackerman and colleagues (2010) report giving participants diaries to record the date and times of gameplay over the four week intervention, but these data were not analyzed or reported (Ackerman et al., 2010). Boot and colleagues did ask participants to track gameplay duration. The individuals randomly assigned to the brain training program played much longer than those assigned to the action video game (M = 56 hours vs. M = 22 hours, respectively; Boot et al., 2013). Neither of the experimental groups had any cognitive improvements after the study, but interestingly, there was no relationship between compliance and cognitive outcomes. The authors contend that this lack of cognitive improvement was related high levels of frustration from playing the game and a lack of belief that the games could improve cognition.

The participants' attitudes towards Art Academy™ might explain why the average amount of gameplay was higher for this group. It is possible that the game was viewed as more intellectually demanding and required more time to master. This could potentially explain the higher attrition rate for this group compared to the control group. The greater intellectual demand might also explain why this group showed evidence of a transfer effect. On the other hand, playing Art Academy™, may also have produced more "flow" than Tetris™, resulting in a temporal distortion (Nakamura & Csikszentmihalyi, 2014). Future research should investigate this possibility.

The confounding of gameplay duration with type of game is a clear limitation to the study. While effects were seen in both the experimental group and active control, it is uncertain if these changes were due to training effects or active engagement. Had gameplay duration been equal across conditions and one video game improved relative to the other, a training effect could have been more conclusively concluded. However, the participants in the HG group, consisting of both Tetris™ and Art Academy™ players, improved on verbal memory, visual memory, and executive functioning relative to the LG group. This suggests an engagement effect. Yet, a training effect cannot be ruled out. Also, English (2012) only reported the number of days the games were played. Thus, the comparison of Tetris™ and Brain Age in Aim 3 may be similarly confounded, making the training effect versus engagement effects impossible to discern. Thus, the current literature on the effectiveness of brain training programs is nearly as nebulous as at the outset of the study. In hindsight, having the participants complete their interventions in a laboratory setting would have given us stricter control over intervention exposure as was done in other studies (e.g., Ball et al., 2002). However, it is known that social contact can ameliorate cognitive decline (Fratiglioni, Wang, Ericsson, Maytan, & Winblad, 2000). Despite the limitation in intervention exposure, the present study is beneficial because the participants played their video games at home, in isolation, removing the social component from the intervention. Thus, cognitive gains from the study were likely due to the intervention itself and not from confounding factors, such as social facilitation.

Another limitation of the study is its small sample size. Unfortunately, despite multiple preventative measures in place (e.g., weekly phone calls and check-ins), there was a high attrition rate for the Art Academy™ group. Despite the small sample size and low power, differences between the HG and LG group were evident, suggesting the robustness of a video game intervention. Our sample was also heterogeneous, consisting of mostly healthy, highly educated Caucasian females who were still employed. This limits the generalizability of our results. However, these highly educated older adults were likely performing at near ceiling level of functioning. The fact that significant findings emerged lends evidence to the robustness of the engagement effects of video games. A final limitation of the study is the lack of a reliability index for the judgment of the water lilies. Although this process was entirely exploratory and novel in nature, the lack of a reliability index calls into question the validity of the findings from Aim 1.

Future research should continue this project to gather more participants. A strict 20-minute time limit would be experimentally wise toward reducing confounds. This would also allow clarification of the distinction between a training effect versus an engagement effect. It would also be valuable to expand this training protocol to an older, retired sample with lesser advanced education. This could possibly produce much more robust effects than ones of the present study. A follow-up examination will give further consideration for the individuals who dropped out of the study. Understanding the behavioral and cognitive characteristics of these individuals may elucidate the type of person who would most benefit from a digital art intervention.

This study found that the number of minutes of gameplay may be important in producing cognitive change. However, it is uncertain if the pattern of intervention exposure is an important part of this equation. For example, would the results be similar if participants played the 14 hours of the intervention in a few short bursts, or over a period of time. Classic learning theory would suggest that short, repeated exposures would be most beneficial (AD Baddeley & Longman, 1978). Furthermore, a meta-analysis found that short video game interventions tend to be better than long interventions (Toril et al., 2014). However, to our knowledge, the same intervention with different training paradigms has never been examined. A future study design could recruit undergraduates to perform a cognitive training protocol for the same amount of time, but with different training intervals (e.g., all at once and broken up into two sessions). Understanding which training paradigm yields the greatest benefits could be useful in guiding training protocols for future studies.

The present study is the first randomized-controlled study to examine the potential cognitive benefits of a digital art intervention in an older adult sample. Although definitive conclusions about the specific cognitive benefits of creating visual art could not be reached, this study does provide evidence of the utility of such a task. Our findings give sufficient reason to continue investigating a visual art program as a cognitive intervention to ameliorate cognitive decline.

BIBLIOGRAPHY

Achtman, R., Green, C., & Bavelier, D. (2008). Video games as a tool to train visual skills. *Restorative neurology and neuroscience, 26*(4, 5), 435-446.

Ackerman, P. L., Kanfer, R., & Calderwood, C. (2010). Use it or lose it? Wii brain exercise practice and reading for domain knowledge. *Psychol Aging, 25*(4), 753-766. doi:10.1037/a0019277

Allain, P., Nicoleau, S., Pinon, K., Etcharry-Bouyx, F., Barre, J., Berrut, G., . . . Le Gall, D. (2005). Executive functioning in normal aging: a study of action planning using the Zoo Map Test. *Brain Cogn, 57*(1), 4-7. doi:10.1016/j.bandc.2004.08.011

Baddeley, A. (1992). Working memory. *Science*, *255*(5044), 556-559.

Baddeley, A., & Longman, D. (1978). The influence of length and frequency of training session on the rate of learning to type. *Ergonomics*, *21*(8), 627-635.

Bahar-Fuchs, A., Clare, L., & Woods, B. (2013). Cognitive training and cognitive rehabilitation for mild to moderate Alzheimer's disease and vascular dementia. *Cochrane Database Syst Rev, 6*, CD003260. doi:10.1002/14651858.CD003260.pub2

Ball, K., Berch, D. B., Helmers, K. F., Jobe, J. B., Leveck, M. D., Marsiske, M., . . . Vital Elderly Study, G. (2002). Effects of cognitive training interventions with older adults: a randomized controlled trial. *JAMA, 288*(18), 2271-2281.

Basak, C., Boot, W. R., Voss, M. W., & Kramer, A. F. (2008). Can training in a real-time strategy video game attenuate cognitive decline in older adults? *Psychol Aging, 23*(4), 765-777. doi:10.1037/a0013494

Beck, A. T., & Steer, R. A. (1993). *Beck Anxiety Inventory Manual*. San Antonio, TX: Harcourt Brace and Company.

Belchior, P., Marsiske, M., Sisco, S. M., Yam, A., Bavelier, D., Ball, K., & Mann, W. C. (2013). Video game training to improve selective visual attention in older adults. *Comput Human Behav, 29*(4), 1318-1324.

Benedict, R. H. (1997). *Brief visuospatial memory test--revised: professional manual*. Odessa, FL: Psychological Assessment Resources, Inc.

Benton, A. L., Hamsher, K. D., & Rey, G. J. (1989). *Multilingual Aphasia Examination (MAE)*. San Antonio, TX: The Psychological Corporation.

Bierman, E. J., Comijs, H. C., Jonker, C., & Beekman, A. T. (2007). Symptoms of anxiety and depression in the course of cognitive decline. *Dement Geriatr Cogn Disord*, *24*(3), 213-219. doi:10.1159/000107083

Boot, W. R., Blakely, D. P., & Simons, D. J. (2011). Do action video games improve perception and cognition? *Front Psychol, 2*, 226. doi:10.3389/fpsyg.2011.00226

Boot, W. R., Champion, M., Blakely, D. P., Wright, T., Souders, D. J., & Charness, N. (2013). Video games as a means to reduce age-related cognitive decline: attitudes, compliance, and effectiveness. *Front Psychol, 4*, 31. doi:10.3389/fpsyg.2013.00031

Boot, W. R., Kramer, A. F., Simons, D. J., Fabiani, M., & Gratton, G. (2008). The effects of video game playing on attention, memory, and executive control. *Acta psychologica*, *129*(3), 387-398.

Bower, G. H. (1970). Analysis of a mnemonic device: Modern psychology uncovers the powerful components of an ancient system for improving memory. *American Scientist, 58*(5), 496-510.

Boyke, J., Driemeyer, J., Gaser, C., Buchel, C., & May, A. (2008). Training-induced brain structure changes in the elderly. *J Neurosci, 28*(28), 7031-7035. doi:10.1523/JNEUROSCI.0742-08.2008

Burgess, P. W., Alderman, N., Evans, J., Emslie, H., & Wilson, B. A. (1998). The ecological validity of tests of executive function. *J Int Neuropsychol Soc, 4*(6), 547-558.

Carretti, B., Borella, E., & De Beni, R. (2007). Does strategic memory training improve the working memory performance of younger and older adults? *Exp Psychol, 54*(4), 311-320. doi:10.1027/1618-3169.54.4.311

Carretti, B., Borella, E., Fostinelli, S., & Zavagnin, M. (2013). Benefits of training working memory in amnestic mild cognitive impairment: specific and transfer effects. *Int Psychogeriatr, 25*(4), 617-626. doi:10.1017/S1041610212002177

Clare, L., & Woods, R. T. (2004). Cognitive training and cognitive rehabilitation for people with early-stage Alzheimer's disease: A review. *Neuropsychological Rehabilitation*, *14*(4), 385-401.

Clark, G. (1989). Screening and identifying students talented in the visual arts: Clark's Drawing Abilities Test. *Gifted Child Quarterly*, *33*(3), 98-105.

Colzato, L. S., van den Wildenberg, W. P., Zmigrod, S., & Hommel, B. (2013). Action video gaming and cognitive control: playing first person shooter games is associated with improvement in working memory but not action inhibition. *Psychol Res*, *77*(2), 234-239. doi:10.1007/s00426-012-0415-2

Cooperau, L. A., & Shepard, R. N. (1973). The time required to prepare for a rotated stimulus. *Mem Cognit, 1*(3), 246-250. doi:10.3758/BF03198104

Cowan, N. (2001). The magical number 4 in short-term memory: a reconsideration of mental storage capacity. *Behav Brain Sci, 24*(1), 87-114; discussion 114-185.

Crawford, J. R., Stewart, L. E., & Moore, J. W. (1989). Demonstration of savings on the AVLT and development of a parallel form. *J Clin Exp Neuropsychol, 11*(6), 975-981. doi:10.1080/01688638908400950

Csikszentmihalyi, M., & LeFevre, J. (1989). Optimal experience in work and leisure. *J Pers Soc Psychol, 56*(5), 815-822.

DesRosiers, G., & Kavanagh, D. (1987). Cognitive Assessment in Closed Head Injury: Stability, Validity and Parallel Forms for Two Neuropsychological Measures of Recovery. *International Journal of Clinical Neuropsychology*.

Dobbs, A. R., & Rule, B. G. (1989). Adult age differences in working memory. *Psychol Aging, 4*(4), 500-503.

Doyon, J., & Benali, H. (2005). Reorganization and plasticity in the adult brain during learning of motor skills. *Curr Opin Neurobiol, 15*(2), 161-167. doi:10.1016/j.conb.2005.03.004

Dye, M. W., Green, C. S., & Bavelier, D. (2009). The development of attention skills in action video game players. *Neuropsychologia, 47*(8-9), 1780-1789. doi:10.1016/j.neuropsychologia.2009.02.002

English, S. (2012). *Cognitive Training with Healthy Older Adults: Investigating the Effectiveness of Brain Age Software for Nintendo* (Dissertation), Marquette University, Milwaukee, WI.

Ericcson, K. A., Chase, W. G., & Faloon, S. (1980). Acquisition of a memory skill. *Science, 208*(4448), 1181-1182.

Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychol Sci, 18*(10), 850-855. doi:10.1111/j.1467-9280.2007.01990.x

Fisher, B. J., & Specht, D. K. (2000). Successful aging and creativity in later life. *Journal of Aging Studies, 13*(4), 457-472.

Flood, M., & Phillips, K. D. (2007). Creativity in older adults: A plethora of possibilities. *Issues in Mental Health Nursing, 28*(4), 389-411.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). “Mini-mental state”: a practical method for grading the cognitive state of patients for the clinician. *Journal of psychiatric research, 12*(3), 189-198.

Fratiglioni, L., Wang, H.-X., Ericsson, K., Maytan, M., & Winblad, B. (2000). Influence of social network on occurrence of dementia: a community-based longitudinal study. *The Lancet, 355*(9212), 1315-1319.

Goldstein, J., Cajko, L., Oosterbroek, M., Michielsen, M., Van Houten, O., & Salverda, F. (1997). Video games and the elderly. *Social Behavior and Personality: an international journal, 25*(4), 345-352.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*(6939), 534-537. doi:10.1038/nature01647

Green, C. S., & Bavelier, D. (2006). Effect of action video games on the spatial distribution of visuospatial attention. *J Exp Psychol Hum Percept Perform, 32*(6), 1465-1478. doi:10.1037/0096-1523.32.6.1465

Green, C. S., & Bavelier, D. (2008). Exercising your brain: a review of human brain plasticity and training-induced learning. *Psychol Aging, 23*(4), 692-701. doi:10.1037/a0014345

Greiner, P. A., Snowdon, D. A., & Schmitt, F. A. (1996). The loss of independence in activities of daily living: the role of low normal cognitive function in elderly nuns. *Am J Public Health, 86*(1), 62-66.

Gross, A. L., Parisi, J. M., Spira, A. P., Kueider, A. M., Ko, J. Y., Saczynski, J. S., . . . Rebok, G. W. (2012). Memory training interventions for older adults: a meta-analysis. *Aging Ment Health, 16*(6), 722-734. doi:10.1080/13607863.2012.667783

Jung, R. E., Segall, J. M., Jeremy Bockholt, H., Flores, R. A., Smith, S. M., Chavez, R. S., & Haier, R. J. (2010). Neuroanatomy of creativity. *Hum Brain Mapp, 31*(3), 398-409. doi:10.1002/hbm.20874

Kim, S.-H., Kim, M.-Y., Lee, J.-H., & Chun, S.-i. (2008). Art therapy outcomes in the rehabilitation treatment of a stroke patient: A case report. *Art Therapy, 25*(3), 129-133.

Kueider, A. M., Parisi, J. M., Gross, A. L., & Rebok, G. W. (2012). Computerized cognitive training with older adults: a systematic review. *PLoS One, 7*(7), e40588. doi:10.1371/journal.pone.0040588

Kurz, A., Pohl, C., Ramsenthaler, M., & Sorg, C. (2009). Cognitive rehabilitation in patients with mild cognitive impairment. *Int J Geriatr Psychiatry, 24*(2), 163-168. doi:10.1002/gps.2086

Light, L. L., & Anderson, P. A. (1985). Working-memory capacity, age, and memory for discourse. *J Gerontol, 40*(6), 737-747.

LoSasso, G. L., Rapport, L. J., Axelrod, B. N., & Reeder, K. P. (1998). Intermanual and alternate-form equivalence on the trail making tests. *J Clin Exp Neuropsychol, 20*(1), 107-110. doi:10.1076/jcen.20.1.107.1487

Luo, L., & Craik, F. I. (2008). Aging and memory: a cognitive approach. *Can J Psychiatry, 53*(6), 346-353.

MacPherson, S. E., Phillips, L. H., & Della Sala, S. (2002). Age, executive function, and social decision making: a dorsolateral prefrontal theory of cognitive aging. *Psychol Aging, 17*(4), 598-609.

Miller, & Hou, C. E. (2004). Portraits of artists: emergence of visual creativity in dementia. *Arch Neurol, 61*(6), 842-844. doi:10.1001/archneur.61.6.842

Miller, G. A. (1956). The magical number seven plus or minus two: some limits on our capacity for processing information. *Psychol Rev, 63*(2), 81-97.

Muir, S. W., Gopaul, K., & Montero Odasso, M. M. (2012). The role of cognitive impairment in fall risk among older adults: a systematic review and meta-analysis. *Age Ageing, 41*(3), 299-308. doi:10.1093/ageing/afs012

Nacke, L. E., Nacke, A., & Lindley, C. A. (2009). Brain training for silver gamers: effects of age and game form on effectiveness, efficiency, self-assessment, and gameplay experience. *Cyberpsychol Behav, 12*(5), 493-499. doi:10.1089/cpb.2009.0013

Nakamura, J., & Csikszentmihalyi, M. (2014). The concept of flow *Flow and the Foundations of Positive Psychology* (pp. 239-263): Springer.

Noice, H., Noice, T., & Staines, G. (2004). A short-term intervention to enhance cognitive and affective functioning in older adults. *J Aging Health, 16*(4), 562-585. doi:10.1177/0898264304265819

Nouchi, R., Taki, Y., Takeuchi, H., Hashizume, H., Akitsuki, Y., Shigemune, Y., . . . Kawashima, R. (2012). Brain training game improves executive functions and processing speed in the elderly: a randomized controlled trial. *PLoS One, 7*(1), e29676. doi:10.1371/journal.pone.0029676

Owen, A. M., Hampshire, A., Grahn, J. A., Stenton, R., Dajani, S., Burns, A. S., . . . Ballard, C. G. (2010). Putting brain training to the test. *Nature, 465*(7299), 775-778. doi:10.1038/nature09042

Pillai, J. A., Hall, C. B., Dickson, D. W., Buschke, H., Lipton, R. B., & Verghese, J. (2011). Association of crossword puzzle participation with memory decline in persons who develop dementia. *J Int Neuropsychol Soc, 17*(6), 1006-1013. doi:10.1017/S1355617711001111

Prochaska, J. J., Velicer, W. F., Nigg, C. R., & Prochaska, J. O. (2008). Methods of quantifying change in multiple risk factor interventions. *Prev Med, 46*(3), 260-265. doi:10.1016/j.ypmed.2007.07.035

Randolph, C. (1998). *Repeatable Battery for the Assessment of Neuropsychological Status (RBANS)*: Psychological Corporation San Antonio, TX.

Rebok, G. W., Ball, K., Guey, L. T., Jones, R. N., Kim, H. Y., King, J. W., . . . Group, A. S. (2014). Ten-year effects of the advanced cognitive training for independent and vital elderly cognitive training trial on cognition and everyday functioning in older adults. *J Am Geriatr Soc, 62*(1), 16-24. doi:10.1111/jgs.12607

Rebok, G. W., Carlson, M. C., & Langbaum, J. B. (2007). Training and maintaining memory abilities in healthy older adults: traditional and novel approaches. *J Gerontol B Psychol Sci Soc Sci, 62 Spec No 1,* 53-61.

Reitan, R. M. (1958). Validity of the Trail Making Test as an indicator of organic brain damage. *Perceptual and motor skills, 8*(3), 271-276.

Rey, A. (1958). *L'examen clinique en psychologie*. Oxford, England: Presses Universitaries De France.

Robbins, T. W., James, M., Owen, A. M., Sahakian, B. J., Lawrence, A. D., McInnes, L., & Rabbitt, P. M. (1998). A study of performance on tests from the CANTAB battery sensitive to frontal lobe dysfunction in a large sample of normal volunteers: implications for theories of executive functioning and cognitive aging. Cambridge Neuropsychological Test Automated Battery. *J Int Neuropsychol Soc, 4*(5), 474-490.

Rosier, J. T. (2010). Art and memory: an examination of the learning benefits of visual-art exposure.

Ruff, R. M., Light, R. H., Parker, S. B., & Levin, H. S. (1996). Benton Controlled Oral Word Association Test: reliability and updated norms. *Arch Clin Neuropsychol, 11*(4), 329-338.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychol Rev, 103*(3), 403-428.

Salthouse, T. A. (2009). When does age-related cognitive decline begin? *Neurobiol Aging, 30*(4), 507-514. doi:10.1016/j.neurobiolaging.2008.09.023

Schnider, A., Regard, M., Benson, D. F., & Landis, T. (1993). Effects of a right-hemisphere stroke on an artist's performance. *Cognitive and Behavioral Neurology, 6*(4), 249-255.

Sitzer, D. I., Twamley, E. W., & Jeste, D. V. (2006). Cognitive training in Alzheimer's disease: a meta-analysis of the literature. *Acta Psychiatr Scand, 114*(2), 75-90. doi:10.1111/j.1600-0447.2006.00789.x

Steffens, D. C., Potter, G. G., McQuoid, D. R., MacFall, J. R., Payne, M. E., Burke, J. R., . . . Welsh-Bohmer, K. A. (2007). Longitudinal magnetic resonance imaging vascular changes, apolipoprotein E genotype, and development of dementia in the neurocognitive outcomes of depression in the elderly study. *Am J Geriatr Psychiatry, 15*(10), 839-849. doi:10.1097/JGP.0b013e318048a1a0

Stern, C., & Munn, Z. (2010). Cognitive leisure activities and their role in preventing dementia: a systematic review. *Int J Evid Based Healthc, 8*(1), 2-17. doi:10.1111/j.1744-1609.2010.00150.x

Strauss, E., Sherman, E. M. S., Spreen, O., & Spreen, O. (2006). *A compendium of neuropsychological tests : administration, norms, and commentary* (3rd ed.). Oxford ; New York: Oxford University Press.

Strenziok, M., Parasuraman, R., Clarke, E., Cisler, D. S., Thompson, J. C., & Greenwood, P. M. (2014). Neurocognitive enhancement in older adults: comparison of three cognitive training tasks to test a hypothesis of training transfer in brain connectivity. *Neuroimage, 85 Pt 3*, 1027-1039. doi:10.1016/j.neuroimage.2013.07.069

Sunderland, A., Harris, J. E., & Baddeley, A. D. (1983). Do laboratory tests predict everyday memory? A neuropsychological study. *Journal of verbal learning and verbal behavior, 22*(3), 341-357.

Sweeney, J. A., Rosano, C., Berman, R. A., & Luna, B. (2001). Inhibitory control of attention declines more than working memory during normal aging. *Neurobiol Aging, 22*(1), 39-47.

Toril, P., Reales, J. M., & Ballesteros, S. (2014). Video game training enhances cognition of older adults: a meta-analytic study. *Psychol Aging, 29*(3), 706-716. doi:10.1037/a0037507

Troyer, A. K., Hafliger, A., Cadieux, M. J., & Craik, F. I. (2006). Name and face learning in older adults: effects of level of processing, self-generation, and intention to learn. *J Gerontol B Psychol Sci Soc Sci, 61*(2), P67-74.

Twamley, E. W., Jeste, D. V., & Bellack, A. S. (2003). A review of cognitive training in schizophrenia. *Schizophr Bull, 29*(2), 359-382.

Van der Linden, M., Bredart, S., & Beerten, A. (1994). Age-related differences in updating working memory. *Br J Psychol, 85 (Pt 1)*, 145-152.

Veldman, D. J., & Brophy, J. E. (1974). Measuring teacher effects on pupil achievement. *Journal of Educational Psychology, 66*(3), 319.

Wadley, V. G., Benz, R. L., Ball, K. K., Roenker, D. L., Edwards, J. D., & Vance, D. E. (2006). Development and evaluation of home-based speed-of-processing training for older adults. *Arch Phys Med Rehabil, 87*(6), 757-763. doi:10.1016/j.apmr.2006.02.027

Wang, H. X., Karp, A., Winblad, B., & Fratiglioni, L. (2002). Late-life engagement in social and leisure activities is associated with a decreased risk of dementia: a longitudinal study from the Kungsholmen project. *Am J Epidemiol, 155*(12), 1081-1087.

Wechsler, D. (1997). *Wechsler Memory Scale- Third Edition: Administration and Scoring Manual*. San Antonio, TX: The Psychological Corporation.

Wechsler, D. (2008). *Wechsler Adult Intelligence Scale - Fourth Edition: Administration and Scoring Manual*. San Antonio, TX: The Psychological Corporation.

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychol Bull, 120*(2), 272-292.

Wilk, C. M., Gold, J. M., Humber, K., Dickerson, F., Fenton, W. S., & Buchanan, R. W. (2004). Brief cognitive assessment in schizophrenia: normative data for the Repeatable Battery for the Assessment of Neuropsychological Status. *Schizophr Res, 70*(2-3), 175-186. doi:10.1016/j.schres.2003.10.009

Wilson, B., Cockburn, J., Baddeley, A., & Hiorns, R. (1989). The development and validation of a test battery for detecting and monitoring everyday memory problems. *J Clin Exp Neuropsychol, 11*(6), 855-870. doi:10.1080/01688638908400940

Wilson, B. A., Watson, P. C., Baddeley, A. D., Emslie, H., & Evans, J. J. (2000). Improvement or simply practice? The effects of twenty repeated assessments on people with and without brain injury. *J Int Neuropsychol Soc, 6*(4), 469-479.

Wingfield, A., Stine, E. A., Lahar, C. J., & Aberdeen, J. S. (1988). Does the capacity of working memory change with age? *Exp Aging Res, 14*(2-3), 103-107. doi:10.1080/03610738808259731

Wolinsky, F. D., Vander Weg, M. W., Howren, M. B., Jones, M. P., & Dotson, M. M. (2013). A randomized controlled trial of cognitive training using a visual speed of processing intervention in middle aged and older adults. *PLoS One, 8*(5), e61624. doi:10.1371/journal.pone.0061624

Woodard, J. L., Dunlosky, J. A., & Salthouse, T. A. (1999). Task decomposition analysis of intertrial free recall performance on the Rey Auditory Verbal Learning Test in normal aging and Alzheimer's disease. *J Clin Exp Neuropsychol, 21*(5), 666-676. doi:10.1076/jcen.21.5.666.872

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson III Tests of Achievement: Administration Manual*. Itasca, IL: Riverside Publishing.

Woods, B., Aguirre, E., Spector, A. E., & Orrell, M. (2012). Cognitive stimulation to improve cognitive functioning in people with dementia. *Cochrane Database Syst Rev, 2*, CD005562. doi:10.1002/14651858.CD005562.pub2

Yesavage, J. A., & Rose, T. L. (1984). The effects of a face-name mnemonic in young, middle-aged, and elderly adults. *Exp Aging Res, 10*(1), 55-57. doi:10.1080/03610738408258543

Yesavage, J. A., & Sheikh, J. I. (1986). 9/Geriatric Depression Scale (GDS) recent evidence and development of a shorter violence. *Clinical gerontologist, 5*(1-2), 165-173.

Ypsilanti, A., Vivas, A. B., Räisänen, T., Viitala, M., Ijäs, T., & Ropes, D. (2014). Are serious video games something more than a game? A review on the effectiveness of serious games to facilitate intergenerational learning. *Education and Information Technologies, 19*(3), 515-529.

Zehnder, F., Martin, M., Altgassen, M., & Clare, L. (2009). Memory training effects in old age as markers of plasticity: a meta-analysis. *Restor Neurol Neurosci, 27*(5), 507-520. doi:10.3233/RNN-2009-0491

Zelinski, E. M., & Reyes, R. (2009). Cognitive benefits of computer games for older adults. *Gerontechnology, 8*(4), 220-235.

Appendix A

Week 1

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Lesson 1	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Lesson 2	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Draw Water Lily

Week 2

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Lesson 3	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Lesson 4	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Draw Water Lily

Week 3

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Lesson 5	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Lesson 6	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Draw Water Lily

Week 4

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Lesson 7	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Lesson 8	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Draw Water Lily

Week 5

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Lesson 9	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Draw Water Lily

Week 6

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Lesson 10	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Free Draw -Or- Continue Lesson	Draw Water Lily