

AN EXAMINATION OF THE EFFECT OF A COMMERCIALY AVAILABLE
COGNITIVE TRAINING PROGRAM ON SPEED-OF-PROCESSING

by

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A DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in the Department of Psychology
in the Graduate School of
The University of Alabama

TUSCALOOSA, ALABAMA

2014

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Abstract

This study examined the effect of a commercially available cognitive training product, *Brain Age*, on the objective and subjective cognitive abilities of 40 older adults. Of particular interest was the effect on speed-of-processing, as this type of training was implied by the game design. A 2 (time of measurement) x 2 (group) design was used to compare a weekly-contact control to a group playing the game three times a week for 30 minutes at a time over a four week period. The game play intervention showed significant improvement over the controls and within participants on a Stroop Color-Word test, a skill directly trained in the game. No other significant effects were found on objective or subjective cognitive measures, though some trends in the data suggest the possibility of small effects on some measures. Within the game play group, frequency and time spent playing did not significantly affect scores. These findings suggest that the effect of commercial products is largely isolated to skills trained and expectations about the benefits of these products should be modest.

List of Abbreviations and Symbols

d	Cohen's d : difference between two means divided by a standard deviation for the data
F	Fisher's F ratio: A ratio of two variances
f	Cohen's f statistic: measure of effect size for use in ANOVA
M	Mean: the sum of a set of measurements divided by the number of measurements in the set
n	Statistical notation for sample size
η_p^2	Partial eta-squared: measure of effect size for use in ANOVA
p	Probability of obtaining a test statistic as extreme as the observed value, assuming that the null hypothesis is true
r	Pearson product-moment correlation
SD	Standard deviation
t	Ratio of the departure of an estimated parameter from its notional value and its standard error
$<$	Less than
$=$	Equal to
\pm	Plus or minus

Acknowledgments

To all those who have helped me along the way, it is finally time you received my gratitude in writing. First, I want to thank my chair, Forrest Scogin. When you interview for schools and they tell you it is about fit, you may doubt them, but I can fully endorse that statement at this time. Working with you has brought me both knowledge and enjoyment. To the members of my committee, Rebecca Allen, Sheila Black, Frances Connors, and Avani Shah, thank you for your guidance and support in completing this project. To those students who have helped me along the way: Lisa Mieskowski, Elizabeth DiNapoli, Ernest Wayde, Kristy Shoji, Caite Tighe, Jordan Williams, Mike LaRocca, and Adriana Hyams. Truly I would not be here without your assistance. My sincere wish is that others help you along your way as you have helped me. To Grant Harris, many thanks to your help and support throughout the entire school experience. I do believe we have made it. To my family and friends, thanks for unending support during my long journey through school and life. I am not sure you knew how long a road I was going down, but you never failed to be there for me. And lastly, to my wife, Amanda. I love you and appreciate beyond words the sacrifices you have made to see me to this day. I have been in school for our entire marriage. I promise I will stop for at least a little while. This is for the both of us.

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Introduction

In the United States, the percentage of the population over the age of 65 has risen sharply in recent years. In 1900, individuals over the age 65 comprised only 4.1 percent of the total population (Werner, 2011). By 2010, there were 40.3 million individuals over the age of 65, comprising 13 percent of the population (Werner, 2011). This trend is consistent worldwide. Individuals over the age of 80 will increase in number from 88 million in 2005 to 402 million in 2050 (United Nations, 2007). With an increasing proportion of the populace entering older adulthood, there is an imperative to address research topics associated with aging.

From a mental health perspective, a primary target for research within this population is cognitive aging. In a Harris Interactive survey, 61 percent of American adults stated they were somewhat or very concerned about age-related memory loss (Cutler, Whitelaw, & Beattie, 2002). Though fears of cognitive decline can be exaggerated, severe cognitive impairment is one of the top three most common mental health conditions faced by this population (American Association of Geriatric Psychiatry, 2004). These subjective concerns are congruent with objective data on cognition and aging. Data collected from the Seattle Longitudinal Study (Schaie, 2005) demonstrate linear decline in perceptual speed, attentional capacity, and working memory as we age. The increasing aged population and the prospect of cognitive decline can loom ominously when the cost of health care for lost independent functioning is considered. This creates an area of great need and opportunity.

Research into interventions for cognitive skills and cognitive decline has increased rapidly in recent years. These interventions can be broadly grouped into four general approaches. Three of these forms target objective cognitive improvement. These are cognitive rehabilitation, cognitive training, and cognitive stimulation (Bahar-Fuchs, Clare, & Woods, 2013). Cognitive rehabilitation, sometimes known as memory training, targets areas of specific weakness and strategies are used to improve functioning in that specific skill. Interventions of this variety include mnemonic strategies to improve memory, spaced retrieval, and the use of external aids and environmental support (Glisky & Glisky, 2008). Cognitive training more broadly targets mental fitness through practice on a variety of cognitive skills, such as memory or problem solving (Belleville, 2008). This training can be direct training in strategies to improve performance, or it can take the form of cognitive exercises (Mowzowski, Batchelor, & Naismith, 2010). Cognitive exercises are a multimodal form of training that use tasks such as serial subtraction, learning about new topics, reading aloud, or puzzles with the explicit goal of improving the resiliency of the aging brain (Lustig, Shah, Seidler, & Reuter-Lorenz, 2009). Cognitive stimulation research focuses on the effects of non-specific cognitive engagement on overall cognition (Hertzog, Kramer, Wilson, & Lindenberger, 2009). These activities may include playing chess, reading, completing crossword puzzles, or taking a class. Finally, there are interventions that target the subjective memory experience. Subjective interventions, such as expectancy modification, take a psychoeducational approach that deals with false beliefs about the nature of cognitive aging and to set realistic expectations of cognitive performance (Floyd & Scogin, 1997).

There have been large-scale, complex studies that demonstrate the effectiveness of the intervention methods mentioned above. The ACTIVE study (Ball et al., 2002; Willis et al., 2006)

was a large, multi-site study that examined the effects of three different intervention strategies, both on specific cognitive skills and on broader daily living activities. Results suggested that the effect of training on specific skills was significant and durable, but that little transfer occurred to non-trained abilities. Another large study, the IMPACT study (Smith et al., 2009), compared the use of computer-delivered cognitive training in auditory processing to an active control and found significant improvement in memory and attention, skills specifically trained by the exercises. Owen et al. (2010) performed a large online study ($n = 11,430$) of brain training and found no significant effect on general cognitive skills, though it did find large effects for directly trained skills. Research in cognitive interventions generally supports the efficacy of the training methods at improving the specific targets of training, but there is a paucity of research to support the transfer of these interventions to broader cognitive skills or daily living activities.

An area of research into cognitive intervention that is especially pertinent to this study is the use of video games as training. Basak and colleagues (2008) used training in a real-time strategy video game as an intervention for improving cognitive performance in older adults. Participants in this study played Rise of Nations, a game that combines real-time gaming with turn-based strategies. Participants improved significantly more than the control group in executive control functioning, as indicated by improvement in measures of working memory and reasoning. Another video game study with older adults found that a complex game video game called Space Fortress produced modest changes in performance on a letter-number sequencing task when special emphasis was given in the instructions (Stern et al., 2011). Though games such as these may blend some cognitive stimulation with some subtle cognitive training, recent trends show the development of games and technology to specifically target cognitive training.

An emerging industry of commercially available products are being marketed as brain training. These products, such as Posit Science's Brain HQ or Lumosity, are advertised to address age-related changes in cognition, and consequently the fears of many adults have about those changes (George & Whitehouse, 2011). Research into the efficacy of these games is still emerging, but the current, independent data has not supported broader claims of improvement in skills outside of a directly trained tasks. This topic is timely, as the "brain fitness" industry was estimated to have annual revenues of \$300 million in 2010 and is expected to approach annual figures in the billions of dollars by 2015 (Fernandez, 2012). One such product is the *Brain Age* series of games by Nintendo that are based upon the work of Japanese neuroscientist Ryuta Kawashima.

Kawashima et al. (2005) designed a protocol to activate the prefrontal cortex when working with a group of dementia patients, as this was the region implicated by the cognitive problems experienced by these patients. They identified mental arithmetic and reading aloud as two tasks which activated dorsolateral prefrontal cortex and these tasks were used as a cognitive intervention. Participants would engage in these activities most days during a given week and complete two to five sheets of problems at a time. The tasks took approximately 20 minutes a day to complete and this procedure was carried out over the course of six months. This group of tasks was termed "learning therapy" by the researchers (Kawashima et al., 2005). The intervention group was compared to a group of matched control participants, with measurement completed at baseline and after six months of training (Kawashima et al., 2005). There was significant decline in the control group on MMSE scores during the six months and there was no change in the score for the training group. Also, the difference between the six month scores for the two groups was significant, such that the training group scored significantly higher on the

MMSE. Also assessed were scores on a variety of measures that the researchers used as a Frontal Battery Assessment (FAB), a group of tests that would measure frontal lobe abilities. There was a significant improvement in the combined scores of the battery from baseline to the six month follow-up within the training group, and there was a significant difference between the scores of the two groups (Kawashima et al., 2005).

This research was used to develop a series of games under the title *Brain Age* by Nintendo. The *Brain Age* series of games propose the use the cognitive exercises as a way to train the brain (“What is Brain Age?,” 2007). The game is marketed as a mental workout and is part of the growing contingent of commercial products with this purpose. The purpose of this study is to examine the effects of this product on cognition in older adults.

Current Study

The primary aim is to assess the effects of using the commercially available products of the *Nintendo DS* and the *Brain Age* game on speed-of-processing in a group of community-dwelling older adults. Based upon the results of previous speed of processing interventions and the content of the *Brain Age* video game, the primary hypothesis was that game play would significantly improve performance on measures of processing speed over the performance of a weekly contact control group on those measures. A second primary hypothesis was that the game would significantly improve scores on measures of executive function that are directly trained in the game tasks (i.e., trail making and Stroop task) was also assessed. To further address research questions, the effect of *Brain Age* on working memory and reasoning, other abilities sensitive to age-related decline were examined. However, since the *Brain Age* game most directly appears to train processing speed and literature fails to support transfer effects in cognitive training, significant differences between groups were not expected. The effect of the *Brain Age* game on

subjective memory scores was also be examined, due to the interactive feedback of the game.

Finally, individual regression analyses were conducted to explore the relationship between both frequency and length of time playing the *Brain Age* game and level of improvement in the outcome measures.

Methods

Participants

Participants for this study were recruited from the local community through a variety of methods. Presentations were made at a variety of sites, including older adult housing communities and senior centers. Participants for the study were also identified using a subject database created through a memory screening outreach done by the psychology department's geropsychology practicum clinic. Additionally, flyers were handed out and/or displayed at several older adult events. Recruitment focused on identifying individuals concerned about their memory and thinking skills.

Inclusion criteria for the participants were: (1) 55 years of age or older; (2) subjective concern over changes in cognition and memory as evidenced by self-report; (3) an ability to read as self-reported by the participant; and (4) adequate vision for viewing and performing the intervention as indicated by successfully reading the screen.

Exclusion criteria included: (1) significant cognitive impairment as indicated by a score below 20 (de Jager, Budge, & Clarke, 2003) on the modified Telephone Interview for Cognitive Status (TICS-M; Breitner et al., 1990); (2) depression as indicated by a score of more than 5 on the Geriatric Depression Scale-15 (GDS-15; Sheikh & Yesavage, 1986); (3) self-report of current substance abuse; or (4) self-report of any current suicidal or homicidal ideations.

Forty individuals assented to the consent and screening process and all forty were found eligible and randomized into the study. Twenty were randomly assigned to each group.

Seventeen experimental group participants and 15 control group participants completed all study requirements, for an attrition rate of 20%.

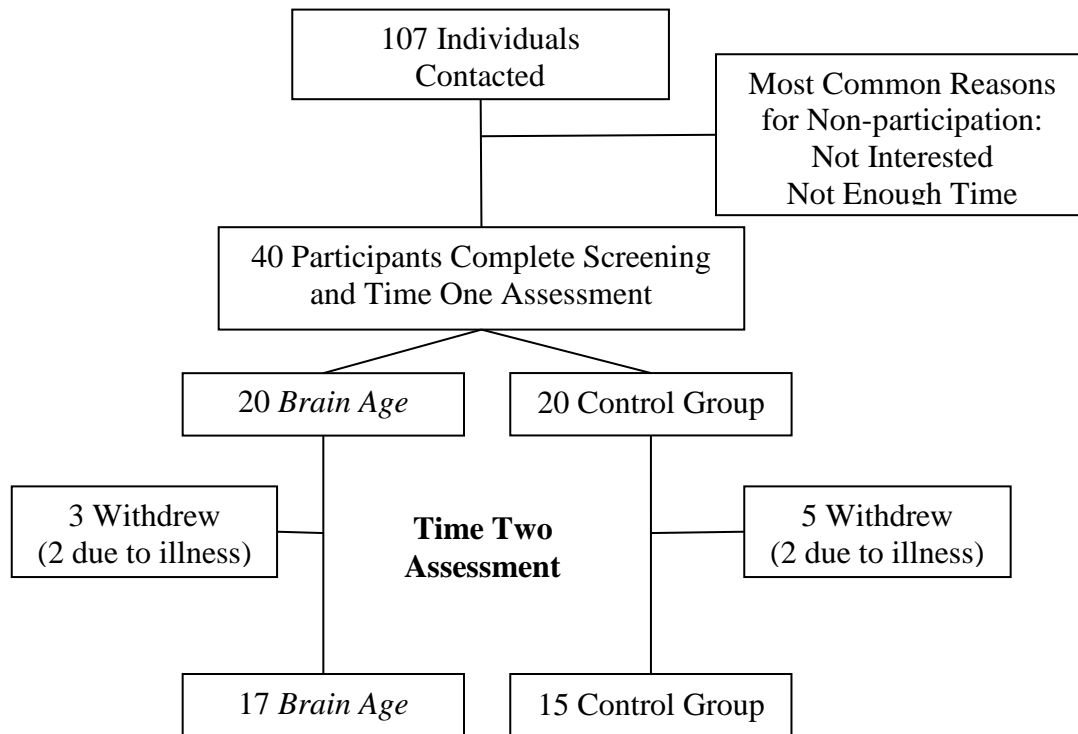


Figure 1. Flow of participants through study.

Sample characteristics are presented in Table 1. The sample was largely Caucasian (95%) and female (78%). The group had a mean age of 71. Participants in this study were also well educated, with 85% completing at least some college coursework and 60% holding a college degree. Mean scores on the TICS-M ($M = 37.7$) were considerably higher than that of reported mean norms for this test. The distribution of demographic variables, screening measures, and T1 scores were evaluated for significant differences between groups. There were no significant findings.

Table 1
Participant Demographics for Overall Sample and By Group

Variable	Overall, (n = 40)	Brain Age, (n = 20)	Control, (n = 20)
Age (<i>M</i> ± <i>SD</i>)	71.0 ± 11.0	73.9 ± 10.3	68.1 ± 11.1
Sex			
Male	9 (22.5%)	3 (15.0%)	6 (30.0%)
Female	31 (77.5%)	17 (85.0%)	14 (70.0%)
Race			
Caucasian	38 (95.0%)	19 (95.0%)	19 (95.0%)
African-American	2 (5.0%)	1 (5.0%)	1 (5.0%)
Marital Status			
Never Married	3 (7.5%)	3 (15.0%)	0 (0%)
Married	16 (40.0%)	7 (35.0%)	9 (45.0%)
Divorced	7 (17.5%)	2 (10.0%)	5 (25.0%)
Widowed	14 (35.0%)	8 (40.0%)	6 (30.0%)
Years of Education (<i>M</i> ± <i>SD</i>)	15.9 ± 2.9	16.1 ± 3.2	15.7 ± 2.5
Adequacy of Monthly Income to Meet Needs			
Somewhat	6 (15.0%)	1 (5.0%)	5 (25.0%)
Mostly	5 (12.5%)	2 (10.0%)	3 (15.0%)
Yes	29 (72.5%)	17 (85.0%)	12 (60.0%)
Self-Reported Health			
Poor	3 (7.5%)	1 (5.0%)	2 (10.0%)
Fair	10 (25.0%)	3 (15.0%)	7 (35.0%)
Good	14 (35.0%)	9 (45.0%)	5 (25.0%)
Very Good	12 (30.0%)	6 (30.0%)	6 (30.0%)
Excellent	1 (2.5%)	1 (5.0%)	0 (0%)
GDS-15 Score (<i>M</i> ± <i>SD</i>)	1.5 ± 1.5	1.0 ± 1.1	1.9 ± 1.8
TICS-M Score (<i>M</i> ± <i>SD</i>)	37.7 ± 4.2	38.0 ± 3.7	37.4 ± 4.8

Note. GDS-15 = Geriatric Depression Scale – 15; TICS-M = Modified Telephone Interview for Cognitive Status.

Measures

Sociodemographic Questionnaire. A sociodemographic questionnaire was completed at the screening assessment. Information was obtained on age, sex, ethnicity, marital status, educational attainment, subjective memory complaints, perceived income adequacy, general overall health, reading ability, vision, current substance abuse, and current suicidal and

homicidal ideations. This information was used to assess eligibility for participation and to assess the equivalence of the two randomly assigned groups.

Modified Telephone Interview for Cognitive Status (TICS-M). The TICS-M is a cognitive screening measure (Breitner et al., 1990). It has a maximum score 50 and mean of 32.4 ($SD = 3.2$) in a normative sample (Welsh, Breitner, & Magruder-Habib, 1993). Using scores below 20 as a cutoff has proven effective in identifying individuals with cognitive decline (de Jager, Budge, & Clarke, 2003).

Geriatric Depression Scale – 15 (GDS-15). The GDS-15 is a self-report measure of depression for use in older adults (Sheikh & Yesavage, 1986). The 15 items that make up the GDS-15 were selected due to a high correlation with depression in validation studies with a longer 30-item measure. The questions look for symptoms within the past week and are answered with a dichotomous yes/no answer choice. The 30-item version was found to have a sensitivity of 84% and a specificity of 95% for detecting depression in community-dwelling older adults (Brink et al., 1982). In a validation study, Sheikh and Yesavage (1986) reported that the GDS-15 and the 30-item version were equally effective at identifying depressed individuals and were highly correlated ($r = .84$).

Trail Making Test (TMT). The TMT is a frequently used neuropsychological test of executive function and working memory (Reitan, 1979). The test is comprised of two parts. TMT A is a timed task that requires a participant to connect randomly spread numbers, 1 to 25, in ascending numerical order. TMT B is another timed tasks that requires the participant to connect randomly spread numbers, 1 to 13, and letters, A to L, in an alternating and ascending pattern (1-A-2-B...L-13). A difference score between the trials (TMT B- TMT A) is used as the primary score to control for the effect of motor speed (Corrigan & Hinkeldey, 1987).

The Stroop Color and Word Test. The Stroop Color and Word Test (Golden & Freshwater, 2002) is test of executive function that requires the suppression of a habitual response. It is a standardized paper version of this popular test. It has three parts. In part one (Word), the participant reads the names of colors printed from a page for forty-five seconds. In part two (Color), the participant names the color of ink used of non-word (XXX) stimuli for forty-five seconds. The final part (Color-Word) requires the participant to name the color of ink used, ignoring the names of colors that are printed with the ink, again over a forty-five second period. Raw scores are calculated as the number of correct responses during the time period. For this study, the raw Color-Word subtest scores will be used to examine the training effect of the game, as this task is part of *Brain Age*.

Symbol Search. Symbol Search is a subtest of the Wechsler Adult Intelligence Scale – Fourth Edition (WAIS-IV) and is a measure of processing speed (Wechsler, 2008). Within a specified time limit participants must indicate the presence or absence of symbols based upon given target symbols. The subtest has good reliability ($r = .81$) and had a test-retest correlation of $r = .81$ after a mean delay of 22 days.

Coding. Coding is a subtest of the WAIS-IV that measures processing speed (Wechsler, 2008). The participant must copy symbols from a key into boxes that correspond to a paired number. This task has a time limit of 120 seconds. The subtest has good reliability ($r = .86$) and had a test-retest correlation of $r = .86$ after a mean delay of 22 days.

Digit Span. Digit Span is a subtest of the WAIS-IV that measures working memory (Wechsler, 2008). The subtest has three parts: Digit Span Forward, Digit Span Backward, and Digit Span Sequencing. Each part has eight items of two trials each. Digit Span Forward requires the participant to recall a sequence of numbers in the order read to them. In Digit Span

Backward, the participant must recall the sequence in reverse order. Digit Span Sequencing is completed by recalling the given number string in order from lowest to highest. The subtest has good reliability ($r = .93$) and had a test-retest correlation of $r = .83$ after a mean delay of 22 days.

Arithmetic. Arithmetic is a subtest of the WAIS-IV and is a measure of working memory (Wechsler, 2008). Participants must solve arithmetic word problems mentally within a given time limit. The subtest has good reliability ($r = .88$) and had a test-retest correlation of $r = .83$ after a mean delay of 22 days.

Matrix Reasoning. Matrix Reasoning is a subtest of the WAIS-IV that measures perceptual reasoning (Wechsler, 2008). The subtest has 26 items that are comprised of 2x2 matrices and series completion tasks that require the individual to select the missing piece from 5 choices. The subtest has good reliability ($r = .90$) and had a test-retest correlation of $r = .74$ after a mean delay of 22 days.

Visual Puzzles. Visual Puzzles is a subtest of the WAIS-IV and is a measure of perceptual reasoning (Wechsler, 2008). There are 26 items that require an individual to choose 3 pieces from 6 choices to form a target puzzle. This must be completed within a time limit. The subtest has good reliability ($r = .89$) and had a test-retest correlation of $r = .74$ after a mean delay of 22 days.

Multifactorial Memory Questionnaire (MMQ). The MMQ is a self-report measure that assesses three dimensions of memory (Troyer & Rich, 2002). The subscales include a twenty item measure of self-rated ability (MMQ-Ability), an 18 item scale of one's contentment with one's ability (MMQ-Contentment), and a 19 item measure of strategy use in memory tasks (MMQ-Strategy). The items are rated on a 5-point Likert scale. The scale has demonstrated

validity and reliability as a measure of subjective memory and is brief, taking approximately 10 minutes to complete.

Intervention

The training puzzles contained in the *Brain Age* game place a premium not only on the accuracy of completing the tasks, but also on the speed with which one can complete the tasks. There are nine training puzzles. Four of these puzzles include hard modes that increase the difficulty of the task. Five of the training puzzles involve mathematical calculations, again with a premium placed on completing the problems quickly. Two tasks require the participant to count quickly, either syllables in a phrase or moving stimuli. The other two tasks require the participant to read aloud, with the score based on speed, and to memorize numbered stimuli that appear briefly from low to high. As a participant progresses through the game, these puzzles unlock and offer the increased difficulty levels, offering continued novelty in the training puzzles. Scores are presented as speeds of performance, such as car speed or jet speed. Faster speeds indicate better performance on the task. Scores are tracked across game play to plot progress in the overall performance of users and presented to users in chart form. Ultimately, improvement of one's *Brain Age* is the primary goal of the game. The "brain age" is calculated based on performance of tasks similar to a Stroop test (Stroop, 1935), speed counting, word memory, or timed simple calculations. One's "brain age" in the game is calculated based on the speed and accuracy of completing the test, ultimately being scored as a function of hypothetical functioning of the brain at certain ages. The best score one can receive is a brain age of 20. The game interactively encourages participants to continue to work and improve both specific task scores as well as their overall brain age.

Procedure

Participants who indicated interest in the study completed a review of the consent form with an IRB approved researcher. They were then screened for the eligibility requirements using the sociodemographic questionnaire, TICS-M, and GDS-15 to assess for inclusion and exclusion criteria as outlined above in the participants section. Eligibility screening and subsequent study requirements occurred at a site of convenience for the participant, with the majority choosing to meet in her/his home.

Individuals who met eligibility requirements completed a Time One (T1) assessment following the screening, in the majority of cases on the same day as the consent and screening process. At the T1 assessment, participants completed the objective cognition measures, which included the subtests Symbol Search, Coding, Digit Span, Arithmetic, Matrix Reasoning, and Visual Puzzle from the WAIS-IV, the TMT, and the Stroop Color and Word Test. They also completed a subjective memory measure, the MMQ. All measures were administered in a random order. Following the T1 assessment, the participant was randomly assigned to either the intervention group or a weekly contact control group. Random assignment was performed using an online random number generator called Research Randomizer (Urbaniak & Plous, 2011).

Participants who were assigned to the intervention group completed training for the use of the *Nintendo DS* and *Brain Age* game following the assessment, with the majority completing training on the same day. The training protocol was established in a pilot study. Participants were provided a *Nintendo DS* video game system, the *Brain Age* video game, and a notebook that included an illustrated guide to using the *Nintendo DS*, a list of common problems, and a journal section for noting their use of the system. The participant and researcher walked through the initial set-up for the game and created an account for the participant within the system. The

participants completed one game under direct observation during this walk-through. Following this guided walk-through, the participant needed to demonstrate mastery by completing the process of turning on the system and playing a game within her/his account. If the participant failed to do this, guided walk-throughs continued until the participant could complete the process without assistance.

The intervention group was asked to play the game three times a week for at least 30 minutes at a time for a period of four weeks. The games to be completed were from the core “Training” games or the “*Brain Age Check*” section within *Brain Age* video game. After each game use, the participants were asked to note the date and beginning and end times for the game play session in the provided journal section within the notebook. Participants were provided with the principal investigator’s telephone number so that any problems with the system or game could be quickly addressed. The researcher only received calls from five participants concerning issues with the game, and three of those individuals called multiple times. The researcher contacted the participant weekly to check in on game use and to ensure that information was being noted in the journal within the notebook.

The control group did not receive any training or materials following the completion of the T1 assessment. These control group participants received weekly phone calls to control for the weekly contact that occurred with the intervention group. These phone calls occurred over a four week period.

Following the four week period for both the intervention and control groups, a Time Two (T2) assessment was completed. This assessment again included the objective cognitive measures and the subjective memory measure. Following the completion of the T2 assessment, all participants received remuneration in the form of \$10 and *Brain Games #1: Lower Your*

Brain Age in Minutes a Day (Editors of Publications International (Eds.), 2007), a book of cognitive exercises similar to those completed within the *Brain Age* video game.

Analyses

Data were analyzed for this study using IBM SPSS Statistics Version 22 for Windows. For all analyses, a significance level of $p < .05$ was used. Before any analyses were completed, descriptive statistics were examined to assess the random distribution of individual variables between groups. There were no significant differences between groups. Missing data were addressed with a carry-forward design. For each broad cognitive domain (processing speed, working memory, and reasoning), WAIS-IV scale scores were combined to create composite scores. Each participant has a T1 and T2 composite. The T2 composite scores had the T1 composite scores subtracted from it to create difference scores. Difference scores were also calculated for the TMT, Stroop Color-Word, and the contentment, ability, and strategy subtests of the MMQ. Individual one-way analyses of covariance (ANCOVAs) were used to test for the effect of the Brain Age game on each of the areas of interest: processing speed, working memory, reasoning, TMT, Stroop, and the contentment, ability, and strategy subtests of the MMQ. Time One scores for each of the measures were used as covariates. Finally, to examine the effect of the amount of game play time has on outcome measures, individual linear regressions were utilized for experimental group completers.

Power Analysis

An initial sample size for this study was based on a power analysis performed using the G*power program (Faul, Erdfelder, Lang, & Buchner, 2007). The power analysis was conducted using conventional alpha (.05) and power (.80) levels. The effect size used is based upon results reported in a meta-analysis by Papp, Walsh, and Snyder (2009). Four studies reported in the

analysis trained directly processing speed and measured improvement on speed-of-processing tasks (Ball et al., 2002; Edwards et al., 2002; Mahncke et al., 2006; Smith et al., 2009). An average of the four studies' effect sizes was $d = 1.03$. To complete a power analysis for an ANCOVA, the d statistic had to be transformed to an f . The relation in this instance was $f = \frac{1}{2} d$ (Cohen, 1988), therefore an $f = .50$ was used in the analysis. A minimum sample size for this study with an effect size of $f = .50$ requires a total sample 34 participants. An ANCOVA analysis with an alpha of $p = .05$ and the current sample of 40 would be powered to find an $f = .45$.

Results

Effect on Speed-of-Processing

An ANCOVA was conducted using group assignment as the independent variable, the processing speed difference score for the dependent variable, and the T1 processing speed composite score as a covariate. The ANCOVA was not significant, $F(1, 37) = 2.49; p = .12$. Training with the game *Brain Age* had no significant effect on the change from T1 to T2 in comparison to the control group on speed of processing. Means are presented in Table 2.

Effects on the TMT and the Stroop Color-Word Test

An identical ANCOVA structure was used to examine the effects of direct training on the TMT and the Stroop Color-Word Test, with difference scores for the dependent variable and T1 performance on each test entered as a covariate. These analyses targeted directly trained skills from the game, as there are both a Trails and Stroop task that are part of the game. Group assignment did not significantly affect scores on the TMT, $F(1, 36) = 1.31; p = .26$. However, a significant effect was found for scores on the Stroop Color-Word Test, $F(1, 37) = 8.61; p < .01; \eta_p^2 = .19$. A significant difference in change scores on the Stroop Color-Word test was seen between groups, with the *Brain Age* group improving performance from T1 to T2. A paired samples *t*-test found that the improvement from T1 to T2 in the *Brain Age* group was significant $t(19) = -3.04; p < .01$. The group had a $M = 32.50$ at T1 and a $M = 37.45$ at T2. The Stroop task was the most repetitively trained outcome measure as it was part of the brain age calculation. Again, means for the ANCOVA analyses can be found in Table 2.

Effects on Working Memory and Reasoning

ANCOVAs were also used in these analyses to examine the difference scores of the Working Memory and Reasoning composite scores with T1 composite scores used as covariates. These analyses were secondary to the primary hypotheses of this project, as little evidence in the literature suggests transfer effects from cognitive training. Working memory was not significantly affected by the training, $F(1, 37) = .01; p = .94$. This was expected given the lack of training tasks that specifically targeted working memory. An analysis on the effect of training on reasoning was similarly non-significant, $F(1, 37) = 2.60; p = .12$. This finding was also expected based upon prior research. Refer to Table 2 for means.

Effects on Subjective Memory

A final series of ANCOVAs were performed to examine the effect of the intervention on subjective memory assessments from the MMQ. All three subscales were used. Improvement in the contentment subscale would indicate more positive feelings about an individual's memory. With the difference score as the dependent variable and the T1 score as covariate, group assignment had no significant effect on contentment with one's memory, $F(1, 37) = 2.40; p = .13$. Improvement on the ability subtest would indicate fewer problems forgetting information in various real-life scenarios. Again, an ANCOVA controlling for T1 scores failed to find a significant effect, $F(1, 37) = .37; p = .55$. Lastly, improvements in the strategy subtest scores would demonstrate an increase in compensatory memory strategies. The result was similarly non-significant, $F(1, 37) = 1.47; p = .23$. As noted above with working memory and reasoning measures, research suggests that specific instruction is necessary to produce significant change in subjective memory. See Table 2 for means.

Effect of Game Play on Scores

Participants in the training condition were asked to play the game for a minimum of 12 sessions for a minimum total of 360 minutes (each session was to last at least 30 minutes) over the 4 week intervention. For individuals who returned data about their participation ($n = 18$), mean training sessions and time was calculated. An outlier who completed an extremely high number of training sessions (38) and consequently had a high number of minutes participated (1530) was excluded to minimize skew. Individuals in the *Brain Age* group completed an average of 15 sessions ($SD = 4$) for an average of 484 minutes ($SD = 148$). Three participants failed to meet the minimum requirement of 12 sessions and 5 failed to spend a total of 360 minutes or more on training. Individual linear regressions were used to examine the effect of frequency and time spent in training on the outcome measures. Neither the time spent on the training nor the frequency of sessions was found to significantly affect scores on any of the eight outcome measures.

Table 2

Mean Scores by Group and Time

	Time	<i>Brain Age, M ± SD</i>	<i>Control, M ± SD</i>
Processing Speed	1	23.25 ± 3.37	20.10 ± 5.36
	2	24.50 ± 3.36	20.30 ± 5.85
TMT	1	54.95 ± 36.74	99.50 ± 139.32
	2	53.53 ± 25.98	100.25 ± 119.15
Stroop Color-Word Test	1	32.50 ± 12.97	28.80 ± 13.03
	2	37.45 ± 10.81	27.95 ± 10.89
Working Memory	1	21.95 ± 3.65	20.65 ± 4.93
	2	22.65 ± 4.82	21.30 ± 5.16
Reasoning	1	21.25 ± 4.39	21.35 ± 5.24
	2	23.35 ± 5.85	21.70 ± 5.19
MMQ-Contentment	1	43.15 ± 9.92	38.90 ± 12.14
	2	41.60 ± 9.61	40.50 ± 11.79
MMQ-Ability	1	47.85 ± 6.06	47.50 ± 10.25
	2	47.80 ± 7.26	46.60 ± 10.56
MMQ-Strategy	1	36.80 ± 8.27	35.35 ± 10.71
	2	39.75 ± 9.55	36.00 ± 11.89

Note. TMT = Trail Making Test; MMQ-C = Multifactorial Memory Questionnaire - Contentment; MMQ-A = Multifactorial Memory Questionnaire - Ability; MMQ-S = Multifactorial Memory Questionnaire – Strategy.

Discussion

To date, there have been few randomized studies of the *Brain Age* game with older adults. This study found that one directly trained and practiced skill within the game did significantly improve as a result of the game's use. Of two specifically trained cognitive tasks (trail making and the Stroop effect), only improvement on the Stroop Color-Word test was found to be significant. Though measures of processing speed were not significantly affected, scores on the measure were trending in the expected direction. Furthermore, the tasks contained in the game had no significant effect on the broader cognitive skills and subjective evaluations measured in this study. Results did not support significant improvement on measures of working memory, reasoning, or self-rated memory contentment, memory ability, or the use of memory strategies. Though not significant, scores on the reasoning measure again showed positive change in the expected direction. The overall results of the current study are in line with broader trends in the field, which suggest that cognitive training fails to produce transfer effects (George & Whitehouse, 2011), but a larger study may have potential to examine the significance of the effects seen on scores of processing speed and reasoning.

As annotated in the introduction, a recent large online study of brain training failed to produce effects on any measures that were not directly part of the training protocol (Owen et al., 2010). Research specific to the use of Nintendo products have also found similar results. A study of middle-aged adults who used the game *Big Brain Academy*, a game played on the Nintendo Wii system, found that the game produced significant improvements on in-game scores, but had no effect on general measures of cognitive abilities (Ackerman, Kanfer, & Calderwood, 2010).

McDougall and House (2012) used a similar study design, randomizing 41 participants into an examination of the effect *Dr. Kawashima's Brain Training* (a UK version of the *Brain Age* game). Their findings were similarly limited. Despite these trends, another recent evaluation of the *Brain Age* game demonstrated more promising results. In a randomized control trial utilizing 32 younger adults, the game was found to significantly improve working memory, processing speed, and executive functions (Nouchi et al., 2012). The use of healthy younger adults and more prescriptive and regular use of the game tasks set this study apart from the current one, but do suggest that further research with this game may demonstrate value.

Another perspective that may provide benefit is the consideration that games such as *Brain Age* may best be considered cognitive stimulation as opposed to cognitive training. Real world use of the game appears more similar to playing cards, completing puzzles, or playing board games than an approximation of specific cognitive skills training. Therefore, research expectations should be tempered in light of the findings on this method of intervention. Research does support benefits for engagement in these activities, but the ultimate value is generally presented as a life-long strategy for prevention of age-related cognitive decline, rather than immediate enhancement of cognitive skills (Hertzog et al., 2009).

Though many participants initially were apprehensive about playing a video game, the majority of the individuals in the current study had little difficulty learning to play the game. Participants also reported that they enjoyed playing the game. Results demonstrated that the game was effective at teaching them a specific skill. These facts demonstrate that there is a place for technology-based interventions with older adults. It also highlights a research imperative for evaluation of these games. Future expectations that the general population should have must be

better informed by this research. The emerging commercial market may oversell the benefits and therefore sound research must be advanced to balance these messages.

Study Limitations

This study had several limitations. First, the sample was well educated and started with a higher baseline of cognitive ability (high TICS-M score) than may be present in a more representative sample of the general population. These factors may have diminished the ability of this study to detect gains produced by the training and stimulation of the cognitive tasks because of higher current functioning. Another limitation may have been the intervention design, which maximized a “real world” evaluation of the game by allowing the individuals the freedom to play the games with no formal protocol. A more rigorous practice schedule may have produced better training. Another possible limitation is the focus on speed-of-processing. Skills in this game are shown to affect the prefrontal cortex, a primary site of cognitive aging. Though Stroop and Trails were included, inclusion of other measures of executive functioning, a prefrontal cortex skill, may have captured more near transfer. This study was also limited by the product itself. Due to some reliability issues, namely problems with writing and voice recognition, in-game scores were not thought to be sufficiently reliable for scientific evaluation. Lastly, the study had a small sample size, though it was similar to other studies with this game. Though a review of the results does not suggest the lack of findings were due to a lack of power, a larger sample would allow for a more robust examination of the intervention.

Future Directions

The literature supports that interventions for cognitive aging issues can be successful, but it has yet to demonstrate a strong base of support for the emerging commercial and video game-based interventions. While the development of more targeted, training-specific resources could

add to the utility of these resources, the long term effects of cognitive gaming should be explored. Research into cognitive stimulation suggests a protective effect for continued cognitive engagement (Hertzog et al., 2009). Playing games such as *Brain Age* or using other cognitive products may demonstrate more positive benefits for participants in a longitudinal research design. Longitudinal research could explore the rate of cognitive decline in participants, which could speak to utility of these products to address the progressive issues cognitive aging. Further studies of the short-term benefits should evaluate the delivered dose of the intervention, such as frequency of use, time spent during each session, or specific protocols for the games played, could provide further benefit, as there are to date no consistent, research-based recommendations for these factors.

Summary and Conclusions

Cognition intervention research will continue to be an important and highly visible topic as the aging of the world population continues. Concern about cognitive aging will continue to drive a proliferation of products available to meet those concerns on the commercial market. The present study addressed the utility of such a product in producing changes in cognitive skills with focused use. As with previous research in the field, benefits of the game were limited to directly trained tasks. Though broader effects on cognitive ability and subjective evaluations were not significantly demonstrated, trends in the data suggest further research with a larger sample may find other significant effects. Overall, the present study demonstrated that older adults can make use of new technologies and benefit from the training provided, but transfer to more generalized cognitive abilities and everyday functional skills continues to be a highly sought result and expectations about the benefits of these products should be modest.

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Appendix

Office for Research
Institutional Review Board for the
Protection of Human Subjects

THE UNIVERSITY OF
ALABAMA
R E S E A R C H

November 19, 2013

Andrew Presnell
Dept. of Psychology
College of Arts & Sciences
Box 870348

Re: IRB Protocol # 11-014-R2
"An Examination of the Effect of a Commercially Available Cognitive
Training Program on Speed-of-Processing"

Dear Mr. Presnell:

The University of Alabama Non-Medical IRB recently met to consider your renewal application. The IRB voted to approve your protocol for a one year period.

Your application will expire on 11/14/2014. You will receive a notice of the expiration 90 days in advance. If your research will continue beyond this date, complete the IRB Renewal Application. If you need to modify the study, please submit the Modification of An Approved Protocol form.

Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, please complete the Request for Study Closure.

Please use reproductions of the IRB approved stamped consent form or information sheet to obtain consent from your participants.

Should you need to submit any further correspondence regarding this application, please include the above application number.

Good luck with your research.

Sincerely,

Carpaneto T. Myles, MSM, CIM, CIP
Director & Research Compliance Officer



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