ABSTRACT

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We compare the effects of adaptive working memory training to a non-adaptive arithmetic and reading comprehension training paradigm on a variety of cognitive measures. Participants included 112 members of the University of Maryland community, 46 of whom successfully completed all of the training requirements. Participants completed a battery of cognitive tests prior to and following 20 hours of training over six weeks. Our research provides further evidence for the efficacy of adaptive working memory training for targeted working memory improvement. This study also offers support for the ability of non-adaptive arithmetic and reading comprehension training to improve general math ability and interference resolution.

COGNITIVE TRAINING: THE EFFECTS OF WORKING MEMORY TRAINING

By

Team Cognitive Training

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Chapter 1: Introduction

"Brain training" has become a hot topic in recent years. With the arrival of video games such as "Brain Age" by Nintendo and related spin-offs comes the question: does it actually work? While consumers debate the efficacy of these games, cognitive psychologists continue to strive for an answer. Owen et al. contend that the real question is not whether performance on cognitive tests can be improved through training, but rather whether these improvements lead to any real changes in cognitive functioning (Owen et al., 2010). In the Owens et al. study, 11,430 viewers of the popular British television show "Bang Goes the Theory" performed six weeks of online "brain training" on cognitive tasks designed to improve reasoning, memory, planning, visuo-spatial skills, and attention (Owen, et al., 2010). Although improvements were seen in every one of the trained tasks, no benefits were found to have transferred to untrained tasks (Owen, et al., 2010). This study, however, was largely designed to attract viewers to the show. It is merely one of dozens of studies in the field, many with conflicting methodologies and results.

A number of studies have investigated the possible remediating effects of cognitive training on individuals with cognitive ailments. Working memory training has been shown to enhance cognitive performance in children with Attention Deficit Hyperactive Disorder (ADHD), which suggests it could potentially be used to treat symptoms of ADHD (Klingberg, Forssberg, & Westerberg, 2002). Research has found cognitive deficits in individuals with schizophrenia, suggesting that successful cognitive training may be a valid way of remediating these deficits and allowing schizophrenics to lead more normal lives (Barch, 2005; Lesh, Niendam, Minzenberg,

& Carter, 2011; Nestor, Niznikiewicz, & McCarley, 2010; Ranganath, Minzenberg, & Ragland, 2008). Training may also be used to maintain cognitive abilities into old age and ward off dementia (Greenwood, 2007).

Brain training carries with it enormous potential: potential to aid the impaired, to assist educators, and even to expand intelligence. Our study compared two types of cognitive training. Adaptive training that targeted working memory capacity, a construct closely related to intelligence, was targeted as a means to improve related cognitive abilities. A second non-adaptive training was used to target math and reading comprehension as a means to improve the underlying cognitive mechanisms recruited for math and reading comprehension.

Chapter 2: Literature Review

Working memory is a cognitive system dedicated to maintaining, storing, and manipulating information simultaneously (Baddeley, 2003). The structure of working memory is currently debated. There are several proposed models for the structure of this system. Baddeley and Hitch's (2003) model of working memory consists of three parts: the visuo-spatial sketchpad, the phonological loop, and the central executive. The visuo-spatial sketchpad is a dedicated storage component specifically for visual and spatial stimuli (Baddeley, 2003). The phonological loop is a second dedicated storage component for verbal and auditory stimuli (Baddeley, 2003). The central executive component governs the maintenance and manipulation of information stored in both the visuo-spatial sketchpad and the phonological loop, as well as focusing attention and inhibiting interfering information (Baddeley, 2003).

Miyake & Shah (1999) offer a different definition of working memory as a process embedded in long-term memory. He conceptualizes working memory as cognitive processes that retain information in an unusually accessible state, allowing the information to be used in tasks requiring a mental component (i.e. problem solving, decision making, etc.). As Miyake et al. envision working memory as a process rather than a set of components, any processing mechanisms that help make information in the brain accessible are considered to be a part of the working memory system. The information involved in the working memory process is subdivided in to three hierarchically arranged faculties: long-term memory, the part of long-term memory currently activated, and the subset of activated memory that is the focus of

attention. Miyake et al.'s model sees working memory as a process inextricably linked to processes governing both attention and long-term memory.

Working memory is separate from short-term memory and fluid intelligence. A latent variable analysis of working memory, short-term memory, and fluid intelligence demonstrated that although short-term memory and working memory are closely related, they are, in fact separate constructs (Engle, Tuholski, Laughlin, & Conway, 1999). Working memory was shown to be strongly linked with fluid intelligence, while short-term memory was not (Engle, et al., 1999). Another latent variable analysis of these abilities that included processing speed and the aforementioned factors showed the same general results: working memory was a good predictor of fluid intelligence, while short-term memory and processing speed were not when they stressed memory and attention only minimally (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002). Working memory and fluid intelligence have been shown to be nearly isomorphic constructs when the storage and processing components of the working memory factor are considered (Colom, Abad, Rebollo, & Shih, 2008). When the storage component of working memory is not taken into account, the isomorphism between the two constructs is less stable; however, when the storage component is partialed out and short-term memory is taken into account, working memory and short-term memory together predict fluid intelligence (Colom et al., 2008).

Working memory has also been shown to predict academic performance. Alloway & Alloway (2010) demonstrated that working memory in children at age five was a better predictor than IQ of literacy and numeracy in the same children six

years later. Working memory early in a child's education is a good predictor of future academic success (Alloway & Alloway, 2010). Research has also shown that working memory is important for mathematical reasoning ability (Meyer, Salimpoor, Wu, Geary, & Menon, 2010). Meyer et al. demonstrated that the components of working memory used for mathematical reasoning actually shift during the course of childhood development (Meyer et al., 2010). In second graders the phonological loop and central executive components of working memory could be used to predict mathematical reasoning ability (Meyer et al., 2010). In third graders, however, visuo-spatial working memory was a better predictor (Meyer et al., 2010). These changes represent "a shift from prefrontal to parietal cortical functions" during mathematical skill development (Meyer et al., 2010). Yuan, Steedle, Shavelson, Alonzo, & Oppezzo (2006) also demonstrated a strong relationship between working memory ability and science achievement.

Working memory tasks consistently activate the same few regions of the brain: the prefrontal cortex, anterior cingulate, and parietal lobes. This suggests working memory is a neurophysiologic construct. Rypma & D'Esposito (2003) demonstrated that increased activity in the dorsolateral prefrontal cortex during the encoding phase of a working memory task was related to successful retrieval of the stimulus items when prompted. Both verbal and visual working memory, though treated as distinct constructs, share cognitive resources and may overlap more than originally suspected (Chein, Moore, & Conway, 2011). Chein et al. showed that both verbal and visuo-spatial working memory tasks caused increased activity in the prefrontal cortex and prefrontal anterior cingulate, and during both verbal and spatial

working memory recall, activity overlapped in anterior prefrontal and medial temporal lobes (Chein, et al., 2011). This suggests that verbal and visuo-spatial working memory, even though they may be distinct constructs, certainly share cognitive resources (Chein, et al., 2011). In a study using fMRI to monitor the brain activity of mathematically gifted male adolescents during mental rotation tasks, O'Boyle, Cunnington, Silk, Vaughan, Jackson, & Syngeniotis (2005) found that unique brain regions were activated. These "students bilaterally activate the parietal lobes and frontal cortex as well as the anterior cingulate" (O'Boyle et al., 2005). These are much of the same regions activated during working memory tasks in the previously mentioned studies, and are believed to house spatial attention, working memory, and executive processes central to intelligence (O'Boyle, et al., 2005). This suggests a close neurological relationship between working memory, mathematical reasoning, and intelligence.

Previous studies have demonstrated the ability of the human brain to adapt to rigorous cognitive training. Humans "can adapt their behavior on the basis of experience" (Mercado, 2008). Humans also have the ability to learn new cognitive skills, defined as " abilities that an organism can improve through practice or observational learning and that involve judgments or processing beyond what is involved in learning or performing a perceptual-motor skill", which simply "requires adjusting motor responses on the basis of sensory feedback" (Mercado, 2008). Cognitive plasticity is the capacity to acquire cognitive skills (Mercado, 2008). Cognitive plasticity is "conceptually equivalent to intelligence", as intelligence is

generally considered to be "the faculty of adapting one's self to circumstances" (Mercado, 2008).

Humans' capacity for cognitive plasticity is rooted in the brain's ability to change physically when presented with cognitively demanding tasks. Neural interconnectedness "changes in response to fluctuations in neural or glial activity" in a mechanism called neural plasticity (Mercado, 2008). Neural plasticity involves not only "changes in synaptic connections between individual neurons" but also "the addition of new neurons (neurogenesis), increased myleniation of axons, or changes in the size or shape of a neuron" (Mercado, 2008). Cortical networks are especially critical in accounting for intellectual capacity (Mercado, 2008). The building blocks of cortical networks are cortical modules, which are "anatomical and electrophysiological regularities in cortical circuits" (Mercado, 2008). The structure of these cortical modules is highly plastic. The brain can adjust the number of cortical modules available for a particular task, flexibly develop new configurations of cortical modules and rapidly switch between them as a function of task demands, and "dynamically adjust the selectivity of cortical modules based on experience" (Mercado, 2008).

Although evidence suggests that aging places constraints on plasticity, plasticity persist throughout the human lifespan. Chein & Morrison (2010) found that undergraduate students demonstrated significant improvement on measures of temporary memory after four weeks of working memory training, suggesting that neuroplasticity can persist into young adulthood. Faille (2006), in a study investigating the effects of cognitive training on the elderly, found that participants

with possible mild cognitive impairment outperformed those who were cognitively intact after training. She also found that individuals with no impairment or mild impairment respond similarly to training, and that men and women respond similarly as well. Thus, not only does neuroplasticity persist into old age, but it persists regardless of cognitive impairments or gender as well. This strongly suggests the wide generalizability of the possible benefits of cognitive training.

Despite the existence of age-related brain atrophy in adults due to synapse loss, dendritic regression, and white matter degeneration, studies suggest that neuroplasticity can facilitate physical recovery in elderly adults (Greenwood 2007). Greenwood (2007) demonstrated that despite the existence of brain shrinkage and atrophy in participants, neuroimaging showed that strategy-induced plasticity training caused increased activity in regions adjacent to the atrophied areas of the prefrontal cortex. The author suggests that these findings have implications for potentially ameliorating cognitive deficits in the elderly (Greenwood, 2007).

Recent neuroimaging research has documented significant physical changes in the prefrontal cortex, parietal lobes, and anterior gyrus as a result of training on working memory tasks. fMRI was used to measure brain activity before, during, and after training on a complex working memory task (Olesen, Westerberg, & Klingberg, 2004). Changes were observed in the middle frontal gyrus and superior and inferior parietal cortices (Olesen et al., 2004). Similarly, McNab et al. found that working memory training increases dopamine receptor D1 density in both the parietal and prefrontal cortices (McNab et al., 2009). This was observed in conjunction with an increase in working memory capacity (McNab et al., 2009). Westerberg & Klingberg

(2007) discovered that changes in brain activity only occurred in regions activated during an initial fMRI screening while completing a visuo-spatial working memory task and backwards digit-span task. These regions included the middle and inferior frontal gyrus (Westerberg et al., 2007). Changes were not observed in areas not activated in the initial screening (Westerberg et al., 2007). This data suggests that working memory training is able to cause targeted growth in specific regions of the brain correlated with working memory capacity (Westerberg et al., 2007).

Persson & Reuter-Lorenz (2008) provided further evidence for the efficacy of working memory training. Using fMRI, Persson et al. were able to identify tasks that activate overlapping regions of the prefrontal cortex, suggesting the tasks share cognitive resources (Persson et al., 2008). The participants were then trained using a high-interference working memory task (Persson et al., 2008). Participants improved their ability to resolve interference, and this improvement transferred to semantic memory, episodic memory, and other working memory tasks (Persson et al., 2008). Low interference versions of the working memory training tasks did not lead to transfer effects, suggesting that interference resolution is "plastic, adaptive, and can be improved through training" (Persson et al., 2008). This finding contradicted an earlier finding by Klingberg et al. (2005) that inhibition was not plastic. This study used working memory training to treat cognitive deficits in children with ADHD (Klingberg et al., 2005). The training resulted in improvements in response inhibition, reasoning, and reduced observable symptoms (identified by the children's parents) of ADHD (Klingberg et al., 2005).

Training general information processing abilities such as working memory may improve performance on broader measures of cognitive skill. Alloway et al. (2010) have shown working memory is a stronger predictor of future academic performance than IQ. In 2010, they showed that the working memory skills of five year old children were the best predictor of literacy and numerical reasoning in the form of reading, spelling, and math ability six years later. Similarly, Meyer et al. (2010) showed that working memory could predict mathematical reasoning ability in second and third graders. Improved working memory measures have also led to improved reading comprehension (Chein & Morrison, 2010).

Working memory has also been shown to predict performance on tasks requiring attentional control and inhibition, which suggests that these skills are not entirely separate (Kane & Engle 2003). Attentional control is the ability to focus and maintain attention on information relevant to the goal at hand. A corollary of attentional control is inhibition, which governs the ability to block information that competes with or distracts from the task at hand. Persson et al. (2008) demonstrated training that requires one to inhibit competing information transferred to other interference resolution tasks. Training that did not target the ability to inhibit this competing information did not yield the same far-reaching improvements in cognitive performance. Similarly, Chein et al. (2010) demonstrated that the extent of transfer to different processes is dependent on the extent to which training targets each general ability. Thus, training that targets general cognitive abilities may have far reaching benefits that extend beyond the tasks performed.

Cognitive training must follow several criteria to successfully enhance an individual's abilities and transfer to multiple measures of cognitive skill. The training must engage general information processing abilities, such as working memory and attentional control, used in nearly every cognitively demanding task. For training benefits to transfer to a particular task, the training and the transfer tasks must utilize common cognitive domains. Also, training benefits may be enhanced if training adapts to keep the mind performing at its capacity limit and maximize the activity of each cognitive process involved.

For training to transfer to non-practiced tasks, the transfer tasks must draw from the cognitive domains targeted by the training. Chein et al. (2010) found that verbal and visuo-spatial working memory training transferred to measures of inhibition and reading comprehension, but did not lead to measures of abstract reasoning believed to heavily rely on working memory. Chein suggests that the extent to which training transfers to different cognitive domains depends on the extent to which they are targeted by the training. The improved inhibition was believed to reflect improved attentional control as a result of the training. Similarly, reading comprehension was likely improved due to improved visual and verbal working memory stores, although Chein confirms the need for a more conclusive method for predicting training transfer.

Training that adapts to challenge participants may result in greater improvement than non-adaptive training. Tasks that adapt require the trainee to perform at a higher capacity may ensure the involvement of multiple cognitive processes. Training that does not adapt may challenge participants to improve in other

ways, such as response time, but may not continue to challenge the participant. Without sufficient challenge, the participants' processes may become automated. Neuroimaging analysis has revealed that through practice, activity in parts of the brain decreases, corresponding to a decrease in the demand placed on attentional control (Olesen et al., 2004). However, this decrease in activity may be a result in increased efficiency of neural processing. Adapting the difficulty of the task to performance maintains the engagement of executive control processes such as attentional control and minimizes task-specific strategies (Jaeggi, Buschkuehl, Jonides, Perrig, 2008). Adaptive training tasks that target working memory may result in improved performance on working memory measures and in improved performance on non-trained measures of inhibition and abstract reasoning (Klingberg et al., 2005). Adaptive difficulty may show itself to be a useful part of a successful cognitive training paradigm, especially one that seeks training transfer.

Pessoa, Gutierrez, Bandettini, & Ungerleider (2002) suggest that fMRI signal amplitude in the frontoparietal regions of the brain successfully predicts performance on individual trials in a visual working memory task. Similarly, Olesen et al. (2004) used fMRI to analyze changes in brain activity with training on a visuo-spatial working memory task. Olesen showed that training with the "Spanboard" task resulted in increased activity in the prefrontal and parietal cortices after working memory training. These regions are believed to house much of the executive control processes essential to working memory and higher-level cognition (Kane & Engle 2002). Contrary to Chein et al. (2010), Olesen et al. (2004) showed improvement on measures of inhibition, working memory, and abstract reasoning due to training

improvements. Persson et al., (2008) also used neuroimaging as a method to identify cognitive domains common to both training and transfer tasks. Persson et al. demonstrated improvement in different memory measures using training that targeted the ability to resolve interference. The improvement across these domains was attributed to training that successfully targeted and improved an executive control process utilized by each of these different memory measures. Neuroimaging was used to identify an interference-resolution process common to several different tasks. Persson proposes that more research should be performed to investigate the likelihood that overlapping neural networks can predict transfer between tasks. Klingberg et al. (2005) used fMRI imaging to identify cortical regions that were affected in children with ADHD. The tasks detailed in Olesen (2004) were used to train the children. The children improved on trained and non-trained measures of working memory as well as non-trained measures of abstract reasoning and inhibition. Parent-ranked symptoms of ADHD also declined as a result of the training. Thus, cortical structures identified with fMRI were improved with working memory training that targets these same neuroanatomical regions.

Recent reviews by Klingberg, Jaeggi, Conway, and Engle have come to the conclusion that more work is needed to determine whether working memory training will definitively generalize to improvements in overall intelligence (Buschkuehl & Jaeggi, 2010; Conway & Getz, 2010; Klingberg, 2010; Shipstead, Redick, & Engle, 2010). Buschkuehl and Shipstead developed specific criteria that a study must meet to claim that working memory training has indeed improved cognitive ability. Buschkuehl claimed that an ideal study would include:

1. A significant number of participants
2. Randomized assignment of participants to experimental/control conditions
3. An active control group that engages in activities that are as similar as possible to the training group (except for the factor that increases intelligence)
4. Carefully selected tests that assess different aspects of intelligence in multiple ways and are reliable for more than one testing administration (practice on a task reduces the intelligence demand)
5. Assessment of long-term effects to determine whether any potential improvements are maintained

Shipstead insists that a valid experiment would consist of a pre/post-test design including the following:

1. Random assignment to control/condition
2. Pretest to measure initial abilities of interest
3. Intervention based on group assignment
4. Posttest of abilities of interest

Shipstead also stated that a valid study must eliminate the following internal confounds:

1. History – events in the participants lives that occur between pre and post-tests, such as going to school (condition group contains all students, control group contains no students).
2. Maturation – changes in participants due to time. Aging may cause the observed changes.
3. Testing – the testing effect. Taking the pretest will improve your performance on the post test.
4. Instrumentation – the cognitive construct that a transfer task measures may change with repeated administrations.
5. Regression to the mean: participants who score low or high are likely to score high/low at post-test. Randomization incorporates this into both groups.
6. Interaction of selection: intervention may affect ADHD children differently than college students. Randomization cancels this out if it is not an interest of the study.
7. Control group must be as similar to the training group as possible. No-contact-control groups are not controlled for history.
8. Hawthorne effect – people's performance changes with the amount of attention they are given.
9. The effect that participants tend to behave as the experimenter expects.

Based on the criteria established in the literature, we designed our own cognitive training paradigm in order to investigate training transfer to multiple

cognitive domains in a general population. We utilized a training task similar to the Spanboard task (Olesson, 2004; Klingberg, 2005) in order to target working memory, attentional control and inhibition response; however, our version of the task was made adaptive in order to maximize cognitive engagement and keep participants performing at their cognitive capacity. A battery of pre- and post-tests was selected to assess both baseline performance of participants and gauge changes in performance after training. All confounds listed by Shipstead were considered when designing our methodology, and were controlled for as best as possible.

Chapter 3: Methodology

Experimental Questions and Design

With this experiment, we wished to address the following questions:

1. Can working memory capacity be increased through training?
2. Can quantitative reasoning ability/reading comprehension be improved through training?
3. Will training to increase working memory capacity improve performance on tasks that use working memory, such as quantitative reasoning?
4. Will training to improve quantitative reasoning ability improve performance on abilities related to it, such as working memory capacity?

To test these questions, we designed an experiment that required eligible participants to complete a pre-test to measure baseline cognitive abilities, to complete 18-20 hours of training on one of our interventions, and to complete a post-test following the training that measured the same abilities as the pre-test. Participants completed either a working memory intervention or a quantitative reasoning/reading comprehension training intervention.

Participant Demographics

We recruited a total of 112 people within the University of Maryland campus and the College Park community who wished to participate in this experiment. Participants were recruited via flyers posted on campus and class announcement emails. The participants' ages ranged from 18 to 31 years (M= 19.53, SD=2.05).

Every person who wished to participate in our study was screened for eligibility using a survey distributed by email. All eligible participants must:

- be at least eighteen years of age
- have normal or corrected vision and not be colorblind
- be right-handed
- have not previously participated in a cognitive training study
- have never had head trauma or a concussion
- never have been diagnosed with mental disabilities
- must not regularly play videogames, either online or on a gaming console.

All qualified participants completed a two and a half hour pre-test administered in a computer laboratory. Prior to the pre-test, participants were randomly assigned to one of the two training interventions. The working memory training group trained using the Block Span and Shape Builder tasks, which are explained in the Tasks section below. The math and reading comprehension training group trained with the Sentencical and Number Piles task. Participants in both groups were asked to complete the same pre-test and associated post-test, in addition to 18 to 20 hours of training. The training was divided into 15 minute sessions, for a total of 60 to 80 sessions to be completed over approximately six weeks.

Of the original 112 participants who enrolled in this experiment, 46 completed the training and returned for the post-test. Each training condition retained 23 participants. The remaining 66 participants voluntarily ended their participation or could not complete the specified amount of training within the 6 week time frame. Participants who completed fewer than ten training sessions were invited to take the

post-test and were placed in a Low Contact condition. This group consisted of participants who completed little to no training, but took a pre-test and post-test. A total of 62 participants completed the post-test according to the following breakdown:

Completed Training: 46 (23 Block Span, 23 Sentencical)

Low Contact: 16 (9 Block Span, 7 Sentencical)

Participants were compensated with cash payment. Those who completed training and came in for the post test were entered into a raffle for cash prizes.

Materials and Procedure

Recruitment for participants began at the beginning of the Fall 2010 semester. Scheduling and communication occurred via e-mail. Qualified participants completed the pre-test in the Biology -Psychology building (BPS) in Lab 0140 during a scheduled time and date. A Gemstone team member was assigned to administer each experimental session and was required to follow a specific scripted protocol, listed in the Appendix, to provide consistency in the experiment.

During the pre-test session, participants were required to fill out a qualification survey and sign informed consent forms for their participation in the study. The first set of tasks was completed on paper with pen and took 90 seconds each. These tasks were Letter Comparison, Summing to 10, and Canceling Symbols. Participants completed the remaining tasks on the computer. These tasks were G-math Arithmetic, Reading Span (Rspan), Modular Arithmetic, Verbal Learning, Raven's Progressive Matrices, and Stroop. Participants were then assigned a unique testing login to www.thehygeneproject.org, a website for training and testing run by

Dr. Michael Dougherty. Participants completed four tasks online measuring working memory and numerical abilities: Letter Number Sequencing task, Number Piles task, Block Span task, and Shape Builder task. These tasks are described in more detail below. The tasks were all administered and monitored by a member of the experimental team, and were administered in the order listed above.

After participants completed the pre-tests, they were assigned a unique login to the training website. The working memory training group trained using two tasks designed to train working memory: the adaptive Block Span task and the adaptive Shape Builder task (described in more detail below).The math and reading comprehension training group trained using two tasks designed to train math and reading comprehension: the Sentencical task and the Number Piles task (described in more detail below). Each participant was instructed to login to the training website and to complete one training session on each task in the lab with us so that we could answer any questions about the training and ensure that they completed the tasks successfully.

When training was completed, participants were advised to complete three training sessions per day. Each training session consists of 7.5 minutes of each of their assigned tasks, for a total of 15 minutes. This required 45 minutes of training per day and would pace participants to complete the 80 training sessions in six weeks. E-mail reminders were sent to participants at least twice a week to encourage training and to notify them how many sessions they have completed thus far. To ensure that participants were keeping up with their training, we asked them to do their training in the 0140 lab with us once every week. At the end of each of these meetings, we

would tell each person how many new high scores they had earned. Each new training high score for participants awarded them one more entry into a bonus lottery if they completed the full amount of training (at least 60 but no more than 80 training sessions) for the study.

The second lab session for the post-test consisted of the administration of complementary versions of the same battery of tests as the pre-test. Participants were compensated with cash for completing this session and debriefed following their completion.

Tasks

Specific tasks were developed and/or programmed for the purposes of this study. All of the tasks, with the exception of G-Math and the paper tasks were coded in Microsoft Excel or DirectRT. The tasks were designed to measure the cognitive abilities of interest before training. These cognitive abilities include working memory (visuo-spatial and verbal), interference, attention, and quantitative reasoning (mathematical ability). We programmed tasks to measure these abilities based on what is established in the literature and we created several new tasks specific for this experiment.

Perceptual Speed Tasks

Letter Comparison Task. This task was used to measure participants' perceptual speed. Participants circled as many identical pairs of letter sequences as they could in 90 seconds. Sequences of letters were typed on paper in discrete pairs in three columns. The task was included in a packet of paper tasks. The participants

were instructed when to begin circling letter pairs and notified when to stop. Participants were instructed when to begin the task then told when to stop circling letter sequence pairs after 90 seconds. A participant's score was the number of correctly circled pairs.

Summing to Ten. This task was used to measure participants' perceptual speed. Participants circled as many pairs of adjacent numbers that summed to ten as possible in 90 seconds. The task consisted of a page of continuous numbers typed without spaced. Using a pen and the paper task, participants were instructed when to begin and when to end circling. A participant's score was the number of correctly circled number pairs.

Cancelling Symbols. This task was used to measure participants' perceptual speed. Participants circled as many C and D letters as they could within 90 seconds. The task consisted of a typed page of random letters without spaces. Participants were instructed when to begin and when to stop. A participant's score was the number of correctly circled letters the participant got within 90 seconds.

Quantitative Reasoning Tasks

G-Math. Participants completed simple arithmetic problems and input their single digit responses using the keyboard number pad. This task was used as a measure of mathematical ability. A series or simple arithmetic steps were displayed successively on the computer screen and participants had to use order of operations and solve the whole arithmetic problem. The only functions involved were addition, subtraction, multiplication, and division. The participants first completed a practice round to familiarize themselves with the program, and then they completed the task.

The practice round consisted of five questions. This task was programmed using Java. The G-Math program generated an excel spreadsheet with a list of the participants' questions, the participants' responses, the correct responses, and the reaction time for each question. The raw data was coded as follows: percent correct overall, percent easy correct, percent easy incorrect, percent hard correct, percent hard incorrect. The reaction time for each of these categories was calculated as well as the natural log of each of the reaction times.

Modular Arithmetic: The object of modular arithmetic is to judge the truth value of a problem statement such as $51 \equiv 19 \pmod 4$. It was used as a measure of mathematical ability of participants. To do this, the problem's middle number is subtracted from the first number (i.e. 51 – 19 = 32) and this difference is divided by the mod number (i.e. 32/4 = 8). If the dividend is equal to a whole number (as here, 8), then the problem is true. If it does not equal a whole number, the problem is false. Because of formatting difficulties we used the symbol "~" instead of the normally used symbol "≡." We presented 10 practice problems, followed by two sets of 6 easy problems, 6 hard problems, then 6 medium problems with their right hand recording true answers and their left hand recording false answers. We then repeated that with their left hand reporting true answers and their right hand reporting false answers. Every true problem had a conjugate false problem within the same problem set where the mod number was either 1 more or 1 less than the true answer (ex. true problem: $9 \sim 6 \pmod 3$, conjugate false problem: $9 \sim 6 \pmod 4$). For the practice and easy problems, the first two numbers were single digit and the mod number was the exact difference between those numbers (ex. $9 \sim 6 \pmod 3$). For the medium problems, the

first two numbers were double digit and the mod number was a single digit number that was the exact difference between those numbers (ex. 23 ~ 19 (mod 4)). For the hard problems, the first two numbers were double digits and the mod number was a single digit number that divided into the first difference (ex. 28 ~ 13 (mod 3)). We recorded the participants' responses to each trial and whether they were correct or incorrect as well as their response times. We coded the data by selecting only the correct answers and taking the average of the participant's response times to (a) the hard problems, (b) the medium problems, and (c) the easy problems. These are the values that we used for data analysis.

Working Memory/ Interference Tasks

Reading Span. The task was used as a measure of working memory within the study. Participants were shown a series of sentences and asked to evaluate if they were grammatically correct or not. If a sentence was grammatically correct participants would select the "M" key for true. If the sentence was not grammatically correct then the participant was instructed to select the "Z" key. "T" and "F" stickers were placed on each respective key for "true" and "false." Between each sentence a word was displayed on the computer screen. After the participants were shown a sequence of sentence, word, sentence, word, they were asked to recall and type in all the words. Participants completed two practice rounds prior to beginning the actual task. This task was utilized to gauge participants' working memory capacity (Engle, Kane, et al., 1999). The task was programmed using DirectRT, and data was coded as follows; the number of words a participant is able to correctly recall in order is called their reading span. In analyzing the data, a total span score is given, with a

total of 60 points possible. One point is given for each word that is correctly recalled in the sequence and if the sentence displayed before is correctly identified as correct or incorrect. However, no point is given if the sentence is incorrectly identified, even if the word is correctly recalled. This ensures that the participant is not only focused on recalling the sequence of words correctly, but focused on the sentences as well.

Verbal Learning. The Verbal Learning task is a proactive interference task. It assesses paarticipants' ability to learn new information in the face of interference from competing information. Participants are presented a list of eight words followed by a list of ten integers. Participants are then prompted to enter the sum of the digits, followed by as many words from the previous list as they can remember. Participants were presented the instructions followed by one practice round, then prompted to complete the task. The task was programmed in Microsoft Excel for Direct RT. The task was coded according to the following scheme; for each of the ten vocabulary lists we summed the items correctly recalled, the items recalled from prior lists, and any items recalled that were never presented to the participants.

Stroop. The Stroop task was developed to measure a participant's inhibition and attention skills. The names of colors were flashed on a computer screen in various colored text. The participant was supposed to respond by quickly pressing a key that corresponded with the color font that was displayed. The participant had to inhibit responding to the name of the color word displayed. There were three types of trials. A congruent trial occurred if the color named was displayed in that color font. For example, if the word RED is displayed, it is considered a congruent trial. An incongruent trial occurred if the color name was displayed in a different colored font.

For example, if the word BLUE is displayed in red font, it is considered a incongruent trial. A baseline trial occurred when number of characters were displayed in a colored font. For the baseline trial, only the character X was used and the number of the characters corresponded to the number of letters in the color name. For example, if XXX is displayed, it is considered a baseline trial. We used a total of four color names and font colors – red, blue, green, and yellow. The test consisted of 75% congruent, 12.5% incongruent and 12.5% baseline trials. This test took approximately ten minutes for the participants to complete. We recorded whether or not the participant correctly answered each trial and how long their response time was. We coded the data by calculating a value referred to as the Stroop Effect by subtracting the number of their correct answers to the baseline trials from the number of their correct answers to the incongruent trials. We calculated a second value referred to as the Stroop Cost by subtracting the number of correct answers to the congruent trials from the number of their correct answers to the incongruent trials. These are the two values we used in our analysis.

Fluid Intelligence

Raven's Progressive Matrices. This task was adapted from Raven's Standard Progressive Matrices and was used as a non-verbal measure of fluid intelligence. Participants were shown an image required to examine the image, determine the overall pattern, then select the missing segment of the image from eight possible choices. The participant chooses the correct answer by selecting the appropriate number of the answer on the number pad of his or her keyboard. The task took about ten minutes to complete. As the participant progresses, the geometric matrices (the

overall images) become more intricate, and the general theme of the image becomes more complicated. Therefore the images, or problems, presented to the participants, get increasingly more difficult to solve. The task is not timed and participants have as much time as needed to complete the task. The 48 images were separated into 2 groups by odd and even number to be split into separate tasks for the pre and post-test. For this study the task was programmed using DirectRT. It was coded based on the number of correct and incorrect responses, average response time for correct responses, average response time for incorrect responses, and the natural log of these average response time. The raw data for each participant was used for data analysis.

Online Assessment and Training Tasks

Block Span. The Block Span task was used in our study as a measure of visuo-spatial working memory. Participants were shown a series of squares flash in various spatial positions in a 4 x 4 grid and were asked to remember the order that each square flashes. After the final square flashed, the participant prompted their response by clicking the squares in the same order that they appeared. The more squares the participant remembered correctly without making a mistake, the higher the score. The task increased in difficulty with multiple sequences of flashing blocks. The start of each new sequence is indicated by a flash of the grid. This task was coded by taking the high score from the pre-test and the high score (final score) from the post-test. The difference of the scores from post-test score minus pre-test was used to determine the participant's improvement. The scoring of the assessment is dependent upon the degree of accuracy with which participants recall the sequences.

This task was also used as a training task for the Working Memory training group. Participants were instructed to train on this task for at least 60 sessions and no more than 80 sessions over the course of six weeks. This task is adaptive and increases in level of difficulty as participants improve over the course of the six weeks of training. Each time a participant signs in to complete a training session the session begins at the level of difficulty that the participant finished at in the last session. Each time a participant logged into his or her training account, the participant's score was recorded for each individual session he or she completed of this task. These scores were used to track participants' performance in the training task over the six weeks of training.

Letter-Number Sequencing. This task was utilized as a measure of verbal working memory. The participant was presented with a series of between N and N of numbers and letters, one at a time, and intermixed. The task is to remember the numbers and letters and report them in ascending order. However, the participant must first report all of the numbers before the letters. The responses were entered in with the keyboard or by clicking on the onscreen buttons. The task varied in difficulty, and the participant is occasionally presented with multiple sequences of letters and numbers, which must be remembered separately. The task was scored using the final score from the pre-test session and the final score from the posttest session. The difference from post-test minus pre-test determined the participant's improvement. The scores themselves were functions of the accuracy with which participants entered the letter and number sequences.

Number Piles. Number Piles task was used in the study to gauge participants' mathematical ability. The participant must complete as many simple arithmetic problems as possible. A target sum is provided to participants and the participant must find a given amount of integers that sum to the target amount. The number of integers needed is indicated to the right of the game screen. The participant only needs to find two integers at first, but eventually needs to find three integers. The task was coded by finding the difference between the final post-test score and the final pre-test score. The difference between the scores denotes participants' improvement. The scores themselves are indicative of the amount of levels and amount of sums the participant complete.

This task was also used as a training task for the Math and Reading Comprehension training group. Participants were instructed to train on this task for at least 60 sessions and no more than 80 sessions over the course of six weeks. This task is not adaptive and does not increase in level of difficulty that the game starts with each new log-in. Within a discreet training session the game progressively gets harder, but the game does not start at a higher level of difficulty as a participant improves over the course of the training. Scores from each individual training session participants completed in this task were recorded and used to track participants' progress throughout the six weeks of training.

Shape Builder. This task was used as a measure of visuo-spatial working memory (and verbal working memory, to some degree). Shape Builder tests participants' ability to remember the order and spatial position in which a series of colored geometric shapes are presented. The participant was asked to remember the

order, spatial position, and color of each shape. After the final shape is presented, the participant had to recreate the sequence by clicking on the correct colored shape and dragging it to the appropriate spatial position. To code the task the difference between the post-test score and the pre-test score was found to determine participants' improvement.

This task was also used as a training task for the Working Memory training group. Participants were instructed to train on this task for at least 60 sessions and no more than 80 sessions over the course of six weeks. This task is adaptive and increases in level of difficulty as participants improve over the course of the six weeks of training. Each time a participant signs in to complete a training session the session begins at the level of difficulty that the participant finished at in the last session. Scores from each individual training session participants completed in this task were recorded and used to track participants' progress throughout the six weeks of training.

Sentencical. This task was used to gauge participants' reading comprehension ability. A sentence was displayed to the participant, and the participant was required to read the sentence and answer a question about that specific sentence. The majority of the sentences require participants to maintain information or recall information from the previous sentence to answer the question.

Some sentences require interference resolution, and others require participants recall information from previous sentences or from previous knowledge (trivia type questions.

Participants responded by clicking the correct choice of two answers on the screen. This task was used exclusively for participant training. It is a non-adaptive

task, and the starting difficulty level of the game does not increase as participants train throughout the six weeks.

This task was coded in the following manner; every time a question was answered correctly, the participant was awarded 10 points. The participants' scores from all of their trials were summed to form an overall score. The combined score of all of the trials completed in the seven-minute training session was the session score. Training data for each participant was averaged to yield the training curve for the Math and Reading Comprehension experimental group. The scores for each training session number were averaged to provide an overall training curve for the group. The raw score data itself was used in our analysis to gauge task improvement.

Chapter 4: Results and Discussion

Pretest Results

Assessment task variables and descriptions.

To perform an analysis of the data, the relevant variables from each task were chosen to compare both the participants' pretest scores and the effects of the training on their improvement from pretest to post-test. A thorough description of how each variable was calculated can be found in the appendix. The variables that were used in the analysis as well as the relevant descriptions are displayed in Table 1.

Table 1: Relevant variables used for each task in the study and their descriptions.

Assessment Tasks (Abbreviated Term)	Relevant Variables	Description
Summing to Ten (ST)	precorrect_ST	The number of times a participant correctly circled adjacent numbers that summed to ten.
	STDiff	
Verbal Learning (Verbal)	premeanL1recall	The average number of correctly recalled List 1 words from the different word groups.
	RecallL1diff	
	premeanL2recall	The average number of correctly recalled List 2 words from the different word groups.
	RecallL2diff	
	premeanL3recall	The average number of correctly recalled List 3 words from the different word groups.
	RecallL3diff	
Reading Span (Rspan)	Pre_Rspan_recall	The total number of words correctly recalled during the session.
	RspanRecallDiff	
	Pre_Rspan_grammar	The total number of sentences correctly identified as grammatically correct.
	RspanGrammarDiff	
Letter Comparison (LC)	precorrect_LC	The number of times a participant correctly circled matching sequences of letters.
	LCDiff	
Cancelling Symbols (CS)	precorrect_CS	The number of times a participant correctly circled the letters "c" or "d."
	CSDiff	
Ravens Progressive Matrixes (Ravens)	Rav_pre_C	The total score achieved by completing the figure.
	RavensDiff	

Shape Builder (Shapes)	Pre_shapes	The total score achieved by selecting the correct color, shape, and location of the stimuli in the presented sequences.
	ShapesDiff	
Block Span (Blocks)	Pre_blocks	The total score achieved by selecting the correct location of the stimuli in the presented sequences.
	BlocksDiff	
Letter Number Sequencing (LNS)	Pre_lns	The total score achieved by correctly recalling and reordering the presented sequences of letters and numbers.
	LNSDiff	
Stroop	PreStroopEffect	The average difference in response time between the incongruent trials and the baseline trials.
	StroopEffectDiff	
Number Piles (Mathpiles)	Pre_mathpiles	The total score achieved by quickly summing multiple blocks to a target value.
	MathpilesDiff	
Modular Arithmetic (Mod)	PreModMeanRT_hard	The average response time for correctly answering the easy difficulty trials.
	ModRTEasydiff	
	PreModMeanRT_medium	The average response time for correctly answering the medium difficulty trials.
	ModRTMeddiff	
	PreModMeanRT_easy	The average response time for correctly answering the hard difficulty trials.
	ModRTHarddiff	
G-Math	G_pre_rt_easy_c	The average response time for correctly answering the easy difficulty trials.
	GmathRTEasydiff	
	G_pre_rt_hard_c	The average response time for correctly answering the hard difficulty trials.
	GmathRTHarddiff	
Note: All of the variables that begin with "pre" are the scores from the participants' pretests. All of the variables that end in "diff" are the difference between the participants' post-test and pretests computed as post-test score minus pretest score.		

Correlations.

The correlations between all of the tasks were calculated using pretest scores. This correlation analysis was used to validate the newly developed tasks and to determine the relationships among the tasks. Table 2 shows the validation of the non-quantitative reasoning tasks. A majority of these tasks have been published, reviewed, and validated. Consistent with previous research, the Block Span task (Blocks), which is considered a measure of visuo-spatial working memory capacity (sWM), correlated with measures of working memory capacity (WMC) (T. Klingberg, et al., 2005;

Olesen, et al., 2004). LNS, a complex verbal working memory task, correlated with other measures of verbal working memory capacity (vWM), as expected. One of the new tasks, the Shape Builder task (Shapes), correlated with measures of WMC.

Table 2: Descriptive correlations and statistics for non-quantitative reasoning tasks.

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1	precorrect_ST	-												
2	premeanL1recall	0.30**	-											
3	premeanL2recall	0.32***	0.69***	-										
4	premeanL3recall	0.27**	0.64***	0.75***	-									
5	Pre_Rspan_recall	0.25**	0.41***	0.31***	0.24**	-								
6	Pre_Rspan_grammar	0.13	0.18	0.12	0.05	0.26**	-							
7	precorrect_LC	0.25	0.12	0.20*	0.20*	0.1	0.06	-						
8	precorrect_CS	0.27**	0.09	0.01	0.06	-0.1	0.16	0.26**	-					
9	Rav_pre_C	0.29**	0.25**	0.29**	0.28**	0.24**	0.06	0.09	-0.17	-				
10	Pre_shapes	0.30*	0.42***	0.31***	0.29**	0.47	0.3**	0.07	0.15	0.37***	-			
11	Pre_blocks	0.37***	0.21*	0.21*	0.25**	0.33***	0.16	0.08	0.02	0.29**	0.62***	-		
12	Pre_lns	0.13	0.26**	0.06	0.01	0.39***	0.14	0.09	0.07	0.24*	0.33***	0.29**	-	
13	PreStroopEffect	-0.12	-0.16	-0.08	-0.1	0.05	-0.12	-0.07	0.07	-0.06	-0.17	-0.02	0.11	-
	Mean	22.62	5.68	4.82	4.39	42.73	57.83	28.81	22.62	13.46	1581.74	1467.5	526.22	165.36
	SD	5.58	1.03	1.32	1.29	10.94	2.08	6.58	5.58	4.46	471.56	493.52	261.8	227.21
	Skew	-0.2	-0.58	-0.21	0.02	-0.61	-1.67	0.81	-0.2	-0.31	0.16	0.33	0.1	1.3
	Kurtosis	-0.15	0.49	-0.16	-0.42	0.08	4.14	2.01	-0.15	-0.32	-0.5	-0.39	-0.79	11.23

Note. Correlations marked "*" are significant at the $p<0.05$ level. Correlations marked "**" are significant at the $p<0.01$ level. Correlations marked "***" are significant at the $p<0.001$ level. PreStroopEffect correlations are negative because the variable is time-dependent, not score-dependent like the other measures (i.e. faster times (smaller values) equate to better performance on time-dependent tasks, whereas larger values equate to better performance on score-dependent tasks).

In order to validate the new quantitative reasoning tasks, G-Math and Mathpiles, the correlations were calculated between these tasks and a previously validated quantitative reasoning task, the Modular Arithmetic Task (here forth called Mod, see Table 3). Both G-Math and Mathpiles also correlated strongly with Mod (all ps<0.001).

Table 3: Descriptive correlations and statistics for quantitative reasoning tasks.

Variable		1	2	3	4	5	6
1	Pre_mathpiles	-					
2	PreModMeanRT_hard	-0.47***	-				
3	PreModMeanRT_medium	-.056***	0.80***	-			
4	PreModMeanRT_easy	-0.56***	0.81***	0.82***	-		
5	G_pre_rt_easy_c	-0.51***	0.61***	0.61***	0.66***	-	
6	G_pre_rt_hard_c	-0.55***	0.55***	0.57***	0.58***	0.76***	-
Mean		1650.80	5229.06	2904.79	1870.72	2011.66	5048.89
SD		387.24	1964.82	1441.06	626.04	526.24	1695.84
Skew		0.10	1.77	2.48	1.56	1.38	1.68
Kurtosis		-0.39	5.45	9.57	4.23	2.08	4.29

Note. Correlations marked "*" are significant at the p<0.05 level. Correlations marked "**" are significant at the p<0.01 level. Correlations marked "***" are significant at the p<0.001 level. The Mod and G-math correlations are sometimes negative because the variables are time-dependent, not score-dependent like the other measures (i.e. faster times (smaller values) equate to better performance on time-dependent tasks, whereas larger values equate to better performance on score-dependent tasks).

The correlations between the quantitative reasoning tasks and the other tasks were determined (see Table 4). It is important to note the correlations between the assessment versions of the training tasks and the other assessment tasks because we expect these related tasks to show improvement after extensive training. As noted previously, Table 3 shows that Mathpiles (one of the tasks used to train the math and reading comprehension group), is strongly correlated with the other quantitative reasoning tasks (p<0.001), and Table 4 shows that Mathpiles also correlates well with the other measures of WMC (p<0.01). Also, Table 1 shows that both the assessment

version of Shapes and the assessment version of Blocks, the two tasks used in the working memory training group, correlate with the WMC tasks (p<0.01) and Table 4 shows that both tasks are correlated with the measures of quantitative reasoning (p<0.01).

Table 4: Descriptive correlations between non-quantitative reasoning tasks and the quantitative reasoning tasks.

Variable	Pre_ mathpiles	PreMod MeanRT_ hard	PreMod MeanRT_ medium	PreMod MeanRT_ easy	G_ pre_rt_ easy_c	G_ pre_rt_ hard_c
precorrect_ST	0.45***	-0.34***	-0.29**	-0.40***	-0.30***	-0.29**
premeanL1recall	0.30**	-0.34***	-0.21*	-0.38***	-0.27**	-0.20
premeanL2recall	0.19*	-0.28**	-0.15	-0.27**	-0.10	-0.06
premeanL3recall	0.16	-0.28**	-0.18	-0.28**	-0.12	-0.14
Pre_Rspan_recall	0.25**	-0.41***	-0.28**	-0.36***	-0.26**	-0.17
Pre_Rspan_grammar	0.12	-0.12	-0.15	-0.23*	-0.07	-0.09
precorrect_LC	0.27**	-0.40***	-0.34***	-0.38***	-0.26**	-0.21*
precorrect_CS	0.13	-0.09	-0.08	-0.10	-0.08	-0.03
Rav_pre_C	0.3**	-0.21*	-0.24*	-0.36***	-0.20*	-.023*
Pre_shapes	0.48***	-0.44***	-0.39***	-0.43***	-0.38***	-0.38***
Pre_blocks	0.36***	-0.30**	-0.30**	-0.33***	-0.31***	-.032***
Pre_lns	0.28**	-0.44***	-0.32***	-0.32***	-031**	-0.24
PreStroopEffect	-.12	0.13	0.05	0.15	0.03	0.00

Note. Correlations marked "*" are significant at the p<0.05 level. Correlations marked "**" are significant at the p<0.01 level. Correlations marked "***" are significant at the p<0.001 level. The Stroop, Mod, and G-math correlations are sometimes negative because the variables are time-dependent, not score-dependent like the other measures (i.e. faster times (smaller values) equate to better performance on time-dependent tasks, whereas larger values equate to better performance on score-dependent tasks).

Exploratory factor analysis.

An exploratory factor analysis was performed to investigate the structure of the variables we tested. With six factors, the original factor analysis explained 70% of the variance within the data (see Tables 5 and 6). The factor pattern was further analyzed by rotating it, which explained 95% of the variance within our data (see

Table 5 and 7). Rotating the factor pattern allowed us to more easily inerpret the factor structure. By looking at which variables loaded on each factor, the factors can be defined as follows: Factor 1 is a quantitative reasoning factor; Factor 2 is a verbal task factor; Factor 3 is a spatial working memory capacity/ general fluid intelligence (sWM/gF) factor; Factor 4 is a visuo-spatial working memory capacity (vWM) factor; Factor 5 is a perceptual speed factor; and Factor 6 is a Stroop-like interference factor (see Table 8). All of the quantitative reasoning tasks loaded onto Factor 1 (as well as some part of LC, but the significant loading of LC was on Factor 5). The Verbal task probably loaded onto its own factor due to the number of variables and amount of data specifically submitted to the exploratory factor analysis from this task. Ravens, Blocks, and Shapes loaded strongly onto Factor 3, and both Mathpiles and ST had partial loadings on this factor. Rspan and LNS both loaded significantly on Factor 4. Shapes also partly loaded on Factor 4, possibly indicating a vWM component in Shapes due to the necessity of remembering the color and shape of the stimuli. As one completes the Shapes task, a common strategy is mentally say "blue triangle" and to spatially remember where the blue triangle is. Saying "blue triangle" involves one's verbal working memory. All of the recognized perceptual speed tasks (LC, CS, and ST) significantly loaded on Factor 5. Stroop significantly loaded on Factor 6, though considering the combination of Stroop and the partial loading of LNS, this factor probably includes some interference measure. The inter-factor correlations also provide some interesting results (see Table 9). Defining significant canonical correlation as >0.3, the quantitative reasoning factor is significantly correlated with both the sWM/gF factor (correlation=0.438) and the vWM factor (correlation=0.344)

and slightly correlated with the Verbal Task factor (correlation=0.292). The sWM/gF factor is slightly correlated with vWM factor (correlation=0.282) and the Verbal Task factor (correlation=0.263). The Math and Reading Comprehension group trained on Mathpiles, which significantly loaded on the quantitative reasoning factor and partially loaded on the sWM/gF factor. The Working Memory Training group trained on the adaptive version of Blocks that significantly loaded on the sWM/gF factor. They also trained on the adaptive version of Shapes that significantly loaded on the sWM/gF factor and partially loaded on the vWM factor.

Table 5: Total variance explained for the exploratory factor analysis.

Factor	Initial Eigenvalues			Extraction Sums of Squared Eigenvalues			Rotation Sums of Squared Eigenvalues		
	Total	% of Variance	Total %	Total	% of Variance	Total %	Total	% of Variance	Total %
1	6.34	33.4	33.4	6.34	33.4	33.4	5.42	28.5	28.5
2	2.20	11.6	44.9	2.20	11.6	44.9	3.32	17.5	46.0
3	1.39	7.3	52.3	1.39	7.3	52.3	3.46	18.2	64.2
4	1.32	6.9	59.2	1.32	6.9	59.2	2.83	14.9	79.1
5	1.12	5.9	65.1	1.12	5.9	65.1	1.86	9.8	88.9
6	1.06	5.6	70.6	1.06	5.6	70.6	1.26	6.6	95.5
7	0.88	4.7	75.3						
8	0.77	4.0	79.3						
9	0.68	3.6	82.9						
10	0.60	3.2	86.0						
11	0.53	2.8	88.8						
12	0.46	2.4	91.2						
13	0.41	2.1	93.4						
14	0.32	1.7	95.1						
15	0.28	1.5	96.5						
16	0.23	1.2	97.7						
17	0.19	1.0	98.7						
18	0.14	0.8	99.4						
19	0.11	100.0	100.0						

Selection Criteria: Factors with an eigenvalue less than 1 were discarded.

Table 6: Original factor pattern.

Variable	Factor					
	1	2	3	4	5	6
PreModMeanRT_hard	-0.810	0.220	0.190	0.156	-0.191	0.190
PreModMeanRT_medium	-0.772	0.343	0.193	0.177	-0.069	0.142
PreModMeanRT_easy	-0.843	0.181	0.153	0.132	-0.011	0.218
G_pre_rt_easy_c	-0.715	0.402	0.196	-0.001	0.001	0.016
G_pre_rt_hard_c	-0.672	0.385	0.115	0.114	0.063	-0.103
Pre_mathpiles	0.701	-0.223	0.008	0.076	-0.296	0.036
premeanL1recall	0.553	0.587	0.022	-0.130	0.270	-0.079
premeanL2recall	0.480	0.723	-0.086	-0.250	0.127	0.109
premeanL3recall	0.474	0.654	-0.158	-0.315	0.079	0.193
Rav_pre_C	0.413	0.081	0.376	-0.242	-0.456	0.104
Pre_blocks	0.568	-0.045	0.423	0.061	-0.139	0.427
Pre_shapes	0.688	0.055	0.411	0.100	-0.082	0.035
Pre_Rspan_recall	0.576	0.141	0.327	0.242	0.297	-0.153
Pre_rspan_grammar	0.315	0.189	0.302	0.502	0.097	-0.352
Pre_lns	0.452	-0.250	0.305	0.145	0.449	0.078
precorrect_LC	0.478	0.133	-0.521	0.225	-0.067	0.116
precorrect_CS	0.161	0.256	-0.379	0.708	-0.063	0.066
precorrect_ST	0.535	0.169	-0.095	0.297	-0.336	0.286
PreStroopEffect	-0.151	-0.320	-0.054	0.065	0.484	0.661

Note: Some of the correlations are negative because faster times (smaller values) equate to better performance on time-dependent tasks (Stroop, Mod, and G-math), whereas larger values equate to better performance on score-dependent tasks (all other tasks).

Table 7: Rotated factor pattern (standardized regression coefficients).

Variable	Factor					
	1	2	3	4	5	6
PreModMeanRT_hard	0.893	-0.141	0.155	-0.103	0.060	0.013
PreModMeanRT_medium	0.933	-0.006	0.055	0.013	0.063	0.026
PreModMeanRT_easy	0.854	-0.090	0.012	-0.074	0.016	0.153
G_pre_rt_easy_c	0.831	0.140	-0.044	0.013	-0.105	-0.058
G_pre_rt_hard_c	0.738	0.091	-0.199	0.123	-0.013	-0.102
Pre_mathpiles	-0.520	-0.164	0.409	0.004	0.165	-0.112
premeanL1recall	-0.030	0.758	-0.065	0.279	-0.018	-0.038
premeanL2recall	0.088	0.921	0.058	-0.005	0.042	-0.009
premeanL3recall	0.018	0.906	0.093	-0.155	0.046	0.039
Rav_pre_C	0.001	0.072	0.732	-0.100	-0.203	-0.242
Pre_blocks	0.032	0.036	0.757	0.146	0.007	0.252
Pre_shapes	-0.114	0.063	0.517	0.392	-0.030	-0.044
Pre_Rspan_recall	-0.085	0.152	0.060	0.680	0.000	0.035
Pre_rspan_grammar	0.127	-0.109	-0.002	0.764	0.194	-0.230
Pre_lns	-0.246	-0.043	0.036	0.515	-0.132	0.384
precorrect_LC	-0.376	0.199	-0.101	-0.142	0.579	0.041
precorrect_CS	0.122	-0.041	-0.132	0.209	0.854	0.019
precorrect_ST	-0.046	0.074	0.471	-0.035	0.519	0.003
PreStroopEffect	0.063	0.002	-0.042	-0.102	0.050	0.892

Rotation Method: Promax (power = 3).

Note: Some of the correlations are negative because faster times (smaller values) equate to better performance on time-dependent tasks (Stroop, Mod, and G-math), whereas larger values equate to better performance on score-dependent tasks (all other tasks).

Table 8: Rotated factor pattern (standardized regression coefficients) displaying only significant values.

Variable	Factor						Task
	Quantitative Reasoning	Verbal Task	sWM / gF	vWM	Perceptual Speed	Stroop / Interference	
PreModMeanRT_hard	0.893						Mod
PreModMeanRT_medium	0.933						
PreModMeanRT_easy	0.854						
G_pre_rt_easy_c	0.831						G-math
G_pre_rt_hard_c	0.738						
Pre_mathpiles	-0.520		0.409				Mathpiles
premeanL1recall		0.758					Verbal
premeanL2recall		0.921					
premeanL3recall		0.906					
Rav_pre_C			0.732				Ravens
Pre_blocks			0.757				Blocks
Pre_shapes			0.517	0.392			Shapes
Pre_Rspan_recall				0.680			Rspan
Pre_rspan_grammar				0.764			
Pre_lns				0.515		0.384	LNS
precorrect_LC	-0.376				0.579		LC
precorrect_CS					0.854		CS
precorrect_ST			0.471		0.519		ST
PreStroopEffect						0.892	Stroop

Rotation Method: Promax (power = 3).
Note: Loadings > 0.3 considered significant. Some of the correlations are negative because faster times (smaller values) equate to better performance on time-dependent tasks (Stroop, Mod, and G-math), whereas larger values equate to better performance on score-dependent tasks (all other tasks).

Table 9: Inter-factor correlations

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Factor 1	-					
Factor 2	-0.292	-				
Factor 3	-0.438	0.263	-			
Factor 4	-0.344	0.244	0.282	-		
Factor 5	-0.166	0.185	0.124	0.091	-	
Factor 6	-0.054	-0.161	-0.009	0.011	-0.089	-

Note: Some of the correlations are negative because faster times (smaller values) equate to better performance on time-dependent tasks (Stroop, Mod, and G-math, which make up significant portions of Factors 1 and 6), whereas larger values equate to better performance on score-dependent tasks (all other tasks that make up Factors 2, 3, 4, and 5).

The correlation tables and the factor analysis enable us to draw the conclusion that training on the adaptive versions of Shapes and Blocks may lead to direct improvement on the other sWM/gF tasks and possibly improvement on the quantitative reasoning, vWM, and Verbal tasks (Chein & Morrison, 2010). Training on Mathpiles may lead to direct improvement on the other quantitative reasoning tasks and possibly improvement on the sWM/gF, vWM, and Verbal tasks (Chein & Morrison, 2010).

T-test results.

We performed multiple t-test analyses on the pretest scores for the different groups and established that there were no significant differences in performance between the three groups. These analyses only evaluated the pretest scores of the participants that completed the post-test, so that the differences between each group on each task from pretest to post-test could be accurately analyzed. According to the t-test analyses, there were no significant differences in pretest performance between the Working Memory group and the Math and Reading Comprehension group (see Table 10), between the Working Memory group and the Low Contact group (see Table 11), or between the Math and Reading Comprehension group and the Low Contact group (see Table 12). Therefore, the random assignment of the participants into the Working Memory group and the Math and Reading Comprehension group at the beginning of the study was sufficient, and any differences found between the groups can be considered valid.

Table 10: Equal variance t-tests on pretest performance between the Working Memory group and the Math and Reading Comprehension group.

Variables	Df	t-value	p-value
PreModMeanRT_hard	43	1.65	0.1072
PreModMeanRT_medium	43	0.83	0.4110
PreModMeanRT_easy	43	0.19	0.8504
G_pre_rt_easy_c	43	0.23	0.8229
G_pre_rt_hard_c	43	0.54	0.5903
pre_mathpiles	43	0.75	0.4589
premeanL1recall	43	1.56	0.1266
premeanL2recall	43	1.31	0.1982
premeanL3recall	43	1.24	0.2213
Rav_pre_C	43	0.21	0.8364
pre_blocks	43	0.13	0.8941
pre_shapes	43	0.32	0.7510
pre_rspan_recall	43	0.42	0.6783
pre_rspan_grammar	43	1.15	0.2581
pre_lns	43	1.31	0.1967
precorrect_LC	43	0.19	0.8537
precorrect_CS	43	0.19	0.8524
precorrect_ST	43	1.41	0.1652
prestroopEffect	43	1.49	0.1436

Note: $p<0.05$ is significant.

Table 11: Equal variance t-tests on pretest performance between the Working Memory group and the Low Contact group.

Variables	Df	t-value	p-value
PreModMeanRT_hard	36	1.73	0.0920
PreModMeanRT_medium	36	1.05	0.3025
PreModMeanRT_easy	36	0.52	0.6032
G_pre_rt_easy_c	36	0.10	0.9172
G_pre_rt_hard_c	36	0.54	0.5896
pre_mathpiles	36	0.70	0.4869
premeanL1recall	36	0.07	0.9424
premeanL2recall	36	0.74	0.4611
premeanL3recall	36	0.60	0.5493
Rav_pre_C	36	0.48	0.6376
pre_blocks	36	0.41	0.6813
pre_shapes	36	0.48	0.6316
pre_rspan_recall	36	0.76	0.4543
pre_rspan_grammar	36	0.46	0.6507
pre_lns	36	0.06	0.9548
precorrect_LC	36	0.33	0.7412
precorrect_CS	36	0.36	0.7211
precorrect_ST	36	0.42	0.6798
prestroopEffect	36	0.70	0.4869

Note: $p<0.05$ is significant.

Table 12: Equal variance t-tests on pretest performance between the Math and Reading Comprehension group and the Low Contact group.

Variables	Df	t-value	p-value
PreModMeanRT_hard	37	0.61	0.5429
PreModMeanRT_medium	37	0.65	0.5212
PreModMeanRT_easy	37	0.68	0.5020
G_pre_rt_easy_c	37	0.06	0.9542
G_pre_rt_hard_c	37	0.21	0.8383
pre_mathpiles	37	0.15	0.8854
premeanL1recall	37	1.13	0.2645
premeanL2recall	37	1.92	0.0628
premeanL3recall	37	1.62	0.1131
Rav_pre_C	37	0.30	0.7655
pre_blocks	37	0.38	0.7054
pre_shapes	37	0.75	0.4593
pre_rspan_recall	37	0.98	0.3347
pre_rspan_grammar	37	0.38	0.7093
pre_lns	37	0.79	0.4373
precorrect_LC	37	0.15	0.8805
precorrect_CS	37	0.40	0.6941
precorrect_ST	37	0.57	0.5693
prestroopEffect	37	0.25	0.8053

Note: $p<0.05$ is significant.

Training Results

The training tasks and how they were scored are described in Table 13.

Table 13: Training task names and descriptions.

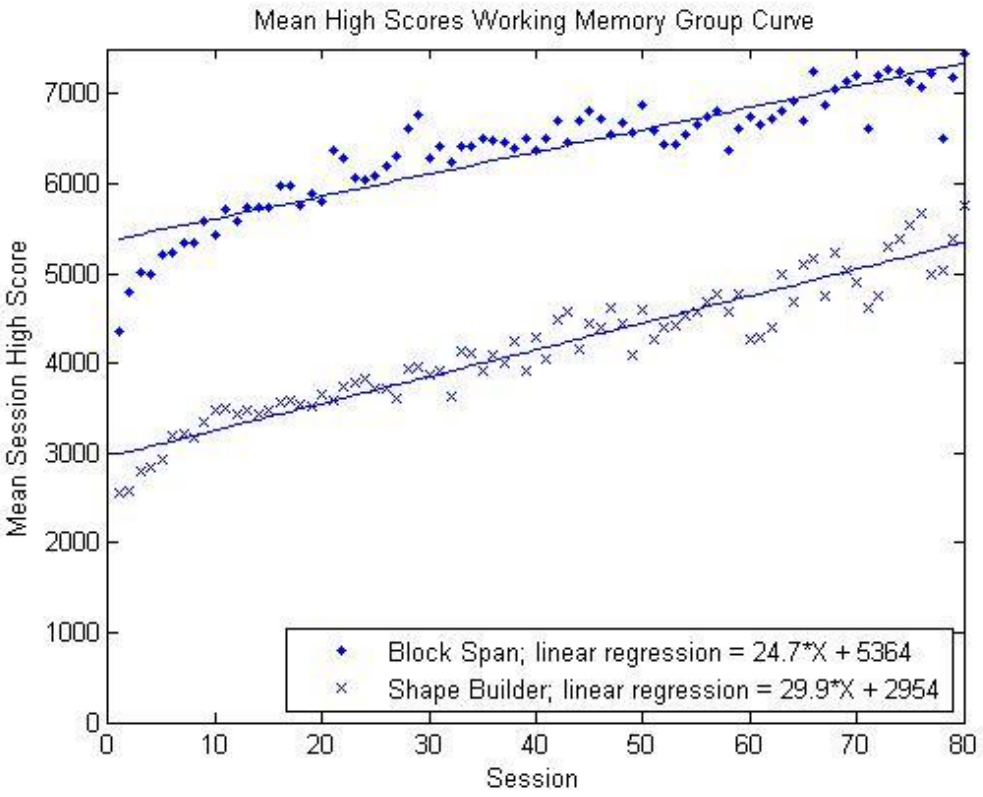
Training Group	Training Tasks (Abbreviated Term)	Description
Working Memory group	Shape Builder (Shapes)	The total score achieved by selecting the correct color, shape, and location of the presented sequences.
	Block Span (Blocks)	The total score achieved by selecting the correct location of the presented sequences.
Math and Reading Comprehension	Number Piles	The total score achieved by quickly summing multiple blocks to a target value.
	Sentencical	The total score achieved by reading sentences and answering simple sentences.

Note: The training versions of Shape Builder and Block Span are adaptive versions of the assessment tasks. The training version of Number Piles is the same as the assessment version of Number Piles.

In order to draw conclusions about the effectiveness of the training programs, it was first necessary to demonstrate that the participants improved on the task upon which they trained. The high scores of all of the participants for each training session were averaged and then plotted. There were two training groups, the Working Memory group trained on the adaptive versions Blocks and Shapes and the Math and Reading Comprehension group trained on Mathpiles and Sentencical. The Low Contact group (N=16) consisted of people who dropped out of the study before completing significant training (a maximum of 10 sessions and an average of 3.8 +/- 2.9).

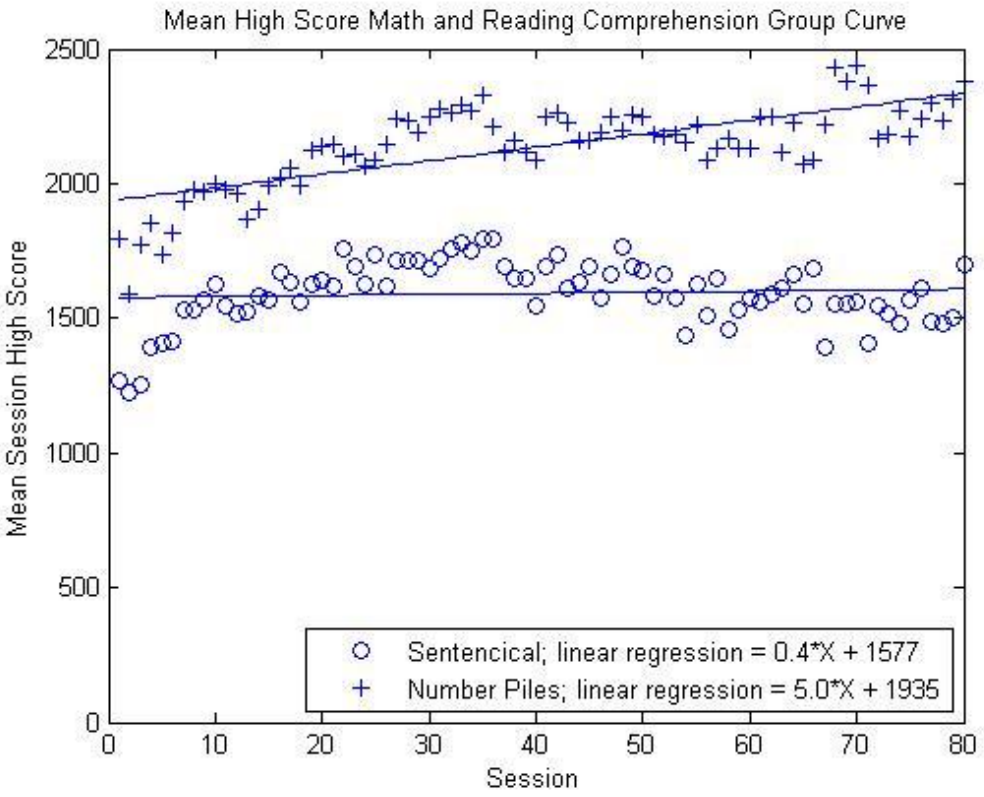
Figure 1 below shows the trends for the participants who were in the Working Memory group and completed the post-test. For the Working Memory group (N=23), completion ranged from a minimum of 59 sessions to the maximum of 80 sessions. Participants in the Working Memory group completed an average of 74.1 +/- 8.3 sessions. It is clear that as participants completed more training sessions, their scores consistently increased. The participants showed a 63% average improvement from their initial session to their final session on the Blocks adaptive training task and a 107% improvement on the Shapes adaptive training task.

Figure 1: Blocks and Shapes training curve (average high score for all participants on each session) with calculated linear regression lines.



Similarly, Figure 2 below shows the trends for the participants who were in the Math and Reading Comprehension group and completed the post-test. The participants showed a 28% average improvement from their initial session to their final session on the Mathpiles non-adaptive training task and a 22% improvement on the Sentencical non-adaptive training task. For the Math and Reading Comprehension group (N=23), completion ranged from a minimum of 56 sessions to the maximum of 80 sessions. The participants in the Math and Reading Comprehension group completed an average of 72.1 +/- 9.1 sessions.

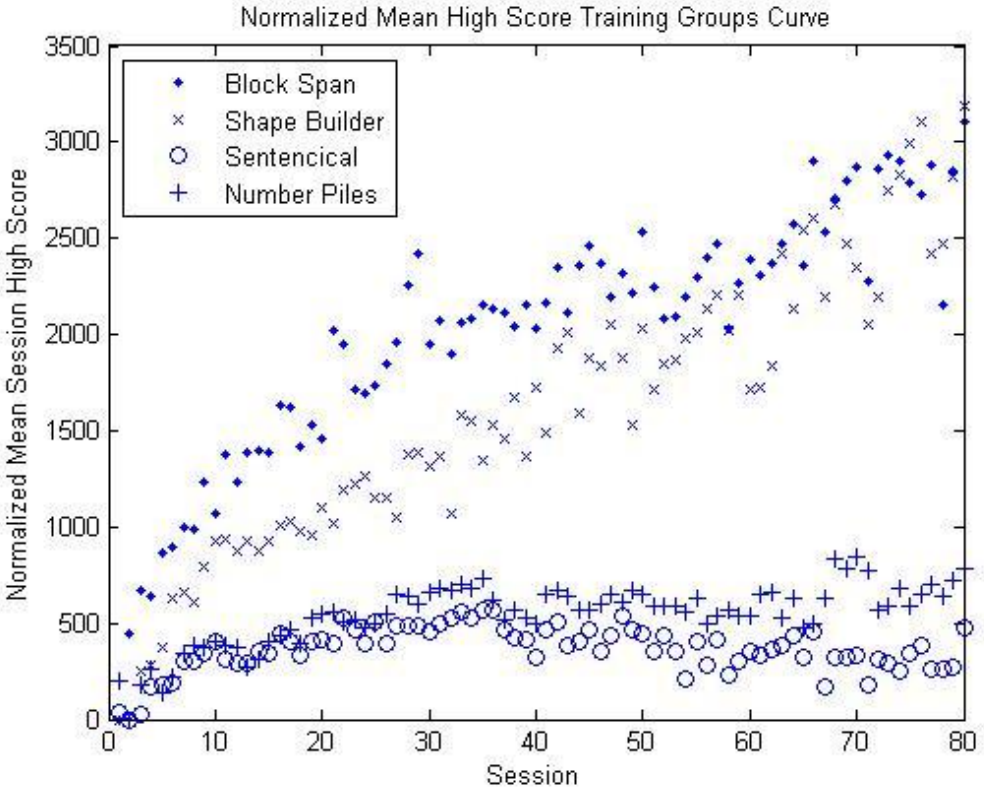
Figure 2: Number Piles and Sentencical training curve (average high score for all participants on each session) with calculated linear regression lines.



To better compare the training results between the groups, the mean session scores were normalized by the minimum mean session scores (session 1 for the Working Memory group and session 2 for the Math and Reading Comprehension group) (see Figure 3). The normalized scores clearly show a separation between the two groups, with the scores for the adaptive training tasks (Blocks and Shapes) grouping together separate from the grouped scores for the non-adaptive training tasks (Sentencical and Mathpiles). This difference in adaptivity means that Blocks and Shapes both become more difficult as participants completed more training sessions. This allows participants to improve their performance and scores. Meanwhile, the only way a participant could achieve a higher score in Mathpiles and Sentencical was by having a faster response time, which allowed the participant to

answer more questions per session. When comparing the improvement in performance during training using normalized scores, participants training on Blocks and Shapes improved more than participants training on Sentencical and Mathpiles. This was confirmed when comparing the percent improvement on each task. As stated above, improvement on Blocks was 63%, on Shapes was 107%, on Sentencical was 22%, and on Mathpiles was 28%, showing increased improvement for adaptive training.

Figure 3: Normalized mean high score training groups curve.

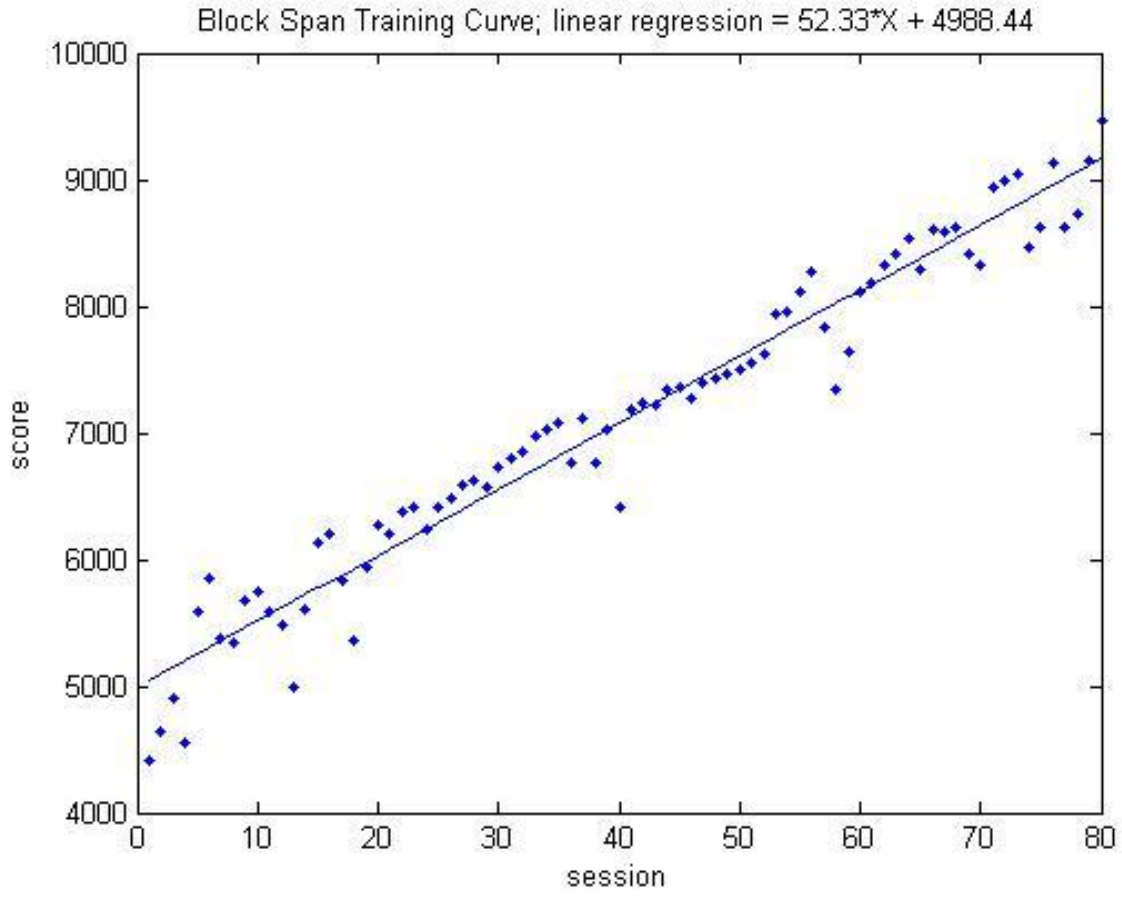


It is also important to note the difference in the slope of the regression curves between the four different training tasks. Comparing the regression curves for Blocks and Shapes in Figure 1 shows that Shapes (slope = 29.9) has a steeper slope than Blocks (slope = 24.7). Slope is an indication of the rate of change of improvement

indicating participants improved on Shapes faster than they improved on Blocks. This occurred because Blocks only required participants to remember one feature (location) for each series of stimuli displayed whereas Shapes required the participant to remember three features (color, shape, and location) for each series. Comparing the regression curves for Mathpiles and Sentencical in Figure 2 shows that Mathpiles (slope = 5.0) has steeper slope than Sentencical (slope = 0.4), indicating the participants improved more quickly on Mathpiles than Sentencical. The slopes of the adaptive training tasks, Blocks and Shapes, were much steeper than the slopes of the non-adaptive training tasks, Mathpiles and Sentencical, possibly indicating the superiority of adaptive training. As seen in Figures 2 and 3, the slopes of Mathpiles and Sentencical seem to level off after session 35, possibly indicating that the participants reached their maximum performance capacity at that point. The leveling and slight decrease in the scores on the Sentencical task may also be due to the addition of approximately 4,000 new sentences to the task partially through the training. This decrease in score on the Sentencical task may have either been due to a decreased response time or to answering more questions incorrectly. However, the difficulty of Shapes was increased at level 30, but no visible signs of that change were detected in the data.

An ideal training curve for the training is demonstrated by sequential improvement from one training session to the next. Figure 4 below shows a nearly ideal training curve achieved by a participant in the Working Memory group. Although the participant had several sessions where his score was lower than a previously achieved score, the overall curve demonstrates a model training pattern.

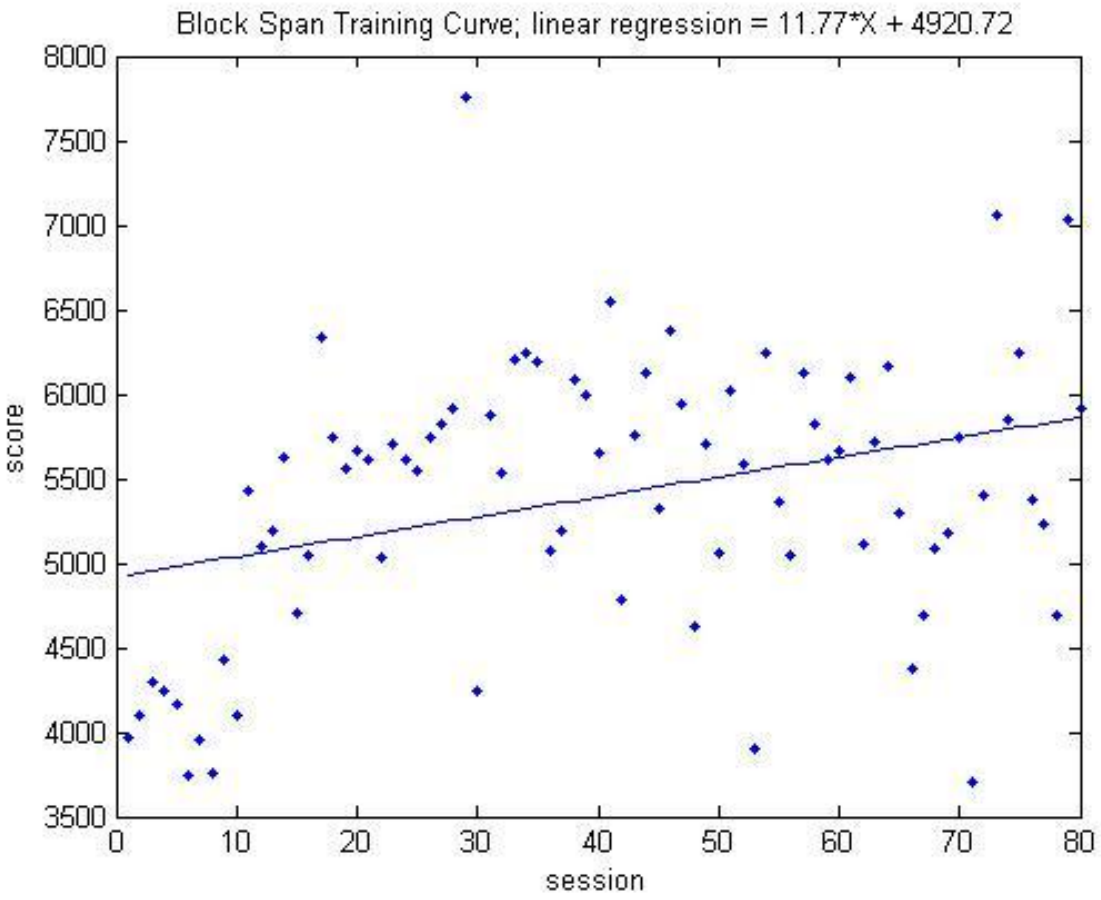
Figure 4: Block Span task training curve for one participant in the Working Memory group with a calculated linear regression line.



In contrast, Figure 5 below shows the training curve for a representative participant in the Working Memory group. Although the participants' scores per session are scattered and there are many sessions where the participant did not perform at the level of his previous sessions, the regression line shows that the overall score trend is increasing. This participant is typical of most participants peformance over the 80 trials. It is expected during training that a participants performance will plateau as they reach their maximum possible performance on a task (Vogel &

Machizawa, 2004). As seen in Figure 5, the participant's improvement was greater from trials 1-40 than it was from trials 41-80.

Figure 5: Block Span task training curve for one participant in the Working Memory group with a calculated linear regression line.



For the participants who completed the training, the general trend on each training task was positive indicating that training on each of these tasks does lead to improvement on the tasks (see Figures 4, 5, 6, 7, and 8). Those who trained on the adaptive working memory tasks (i.e. Blocks and Shapes) improved more quickly than those who trained on the math and reading comprehension tasks (i.e. Mathpiles and Sentencical).

Figure 6: Shape Builder task training curve for one participant in the Working Memory group with a calculated linear regression line.

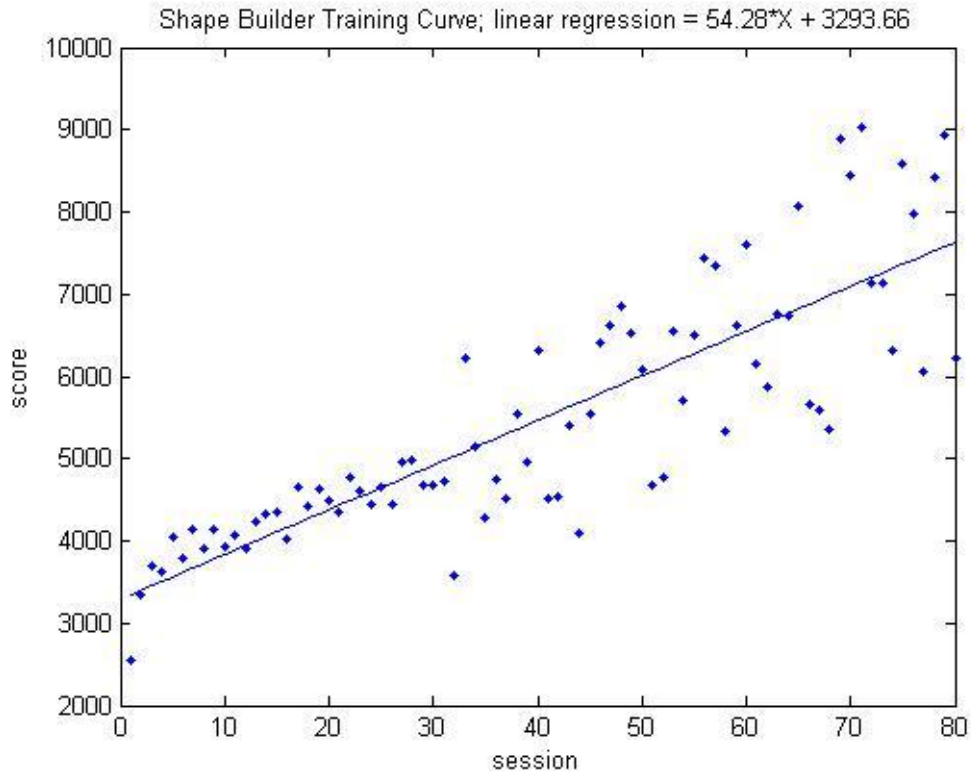


Figure 7: Number Piles task training curve for one participant in the Math and Reading Comprehension group with a calculated linear regression line.

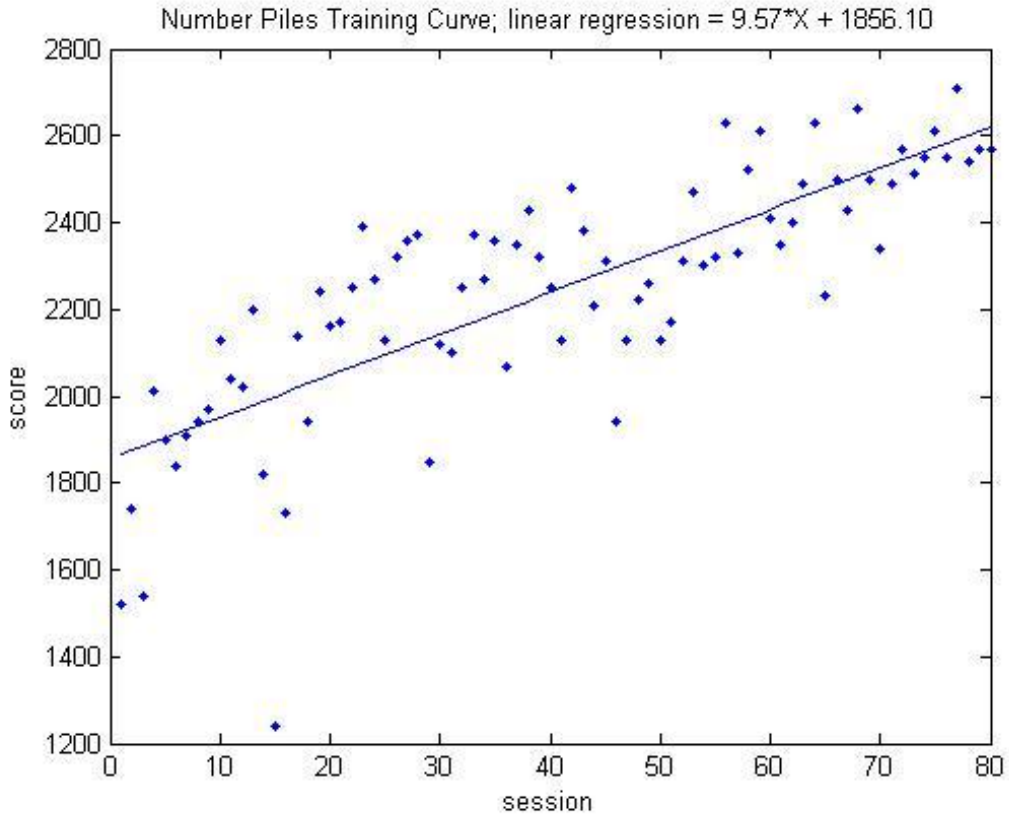
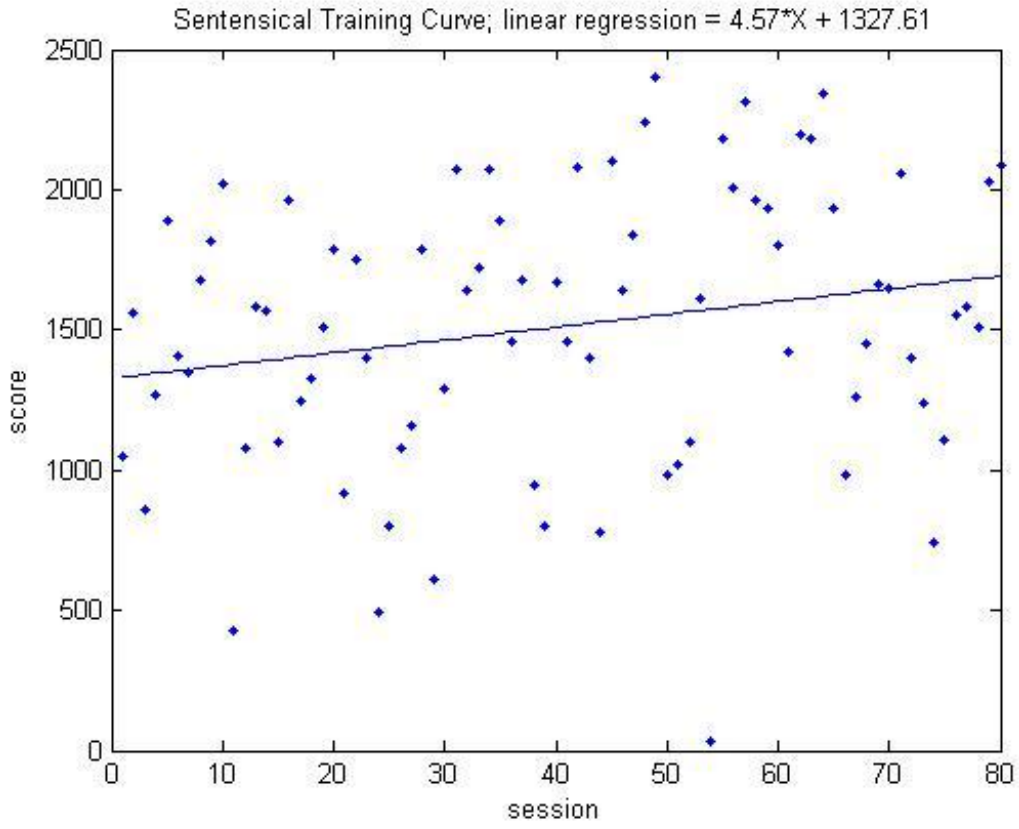


Figure 8: Sentencical task training curve for one participant in the Math and Reading Comprehension Group with a calculated linear regression line.



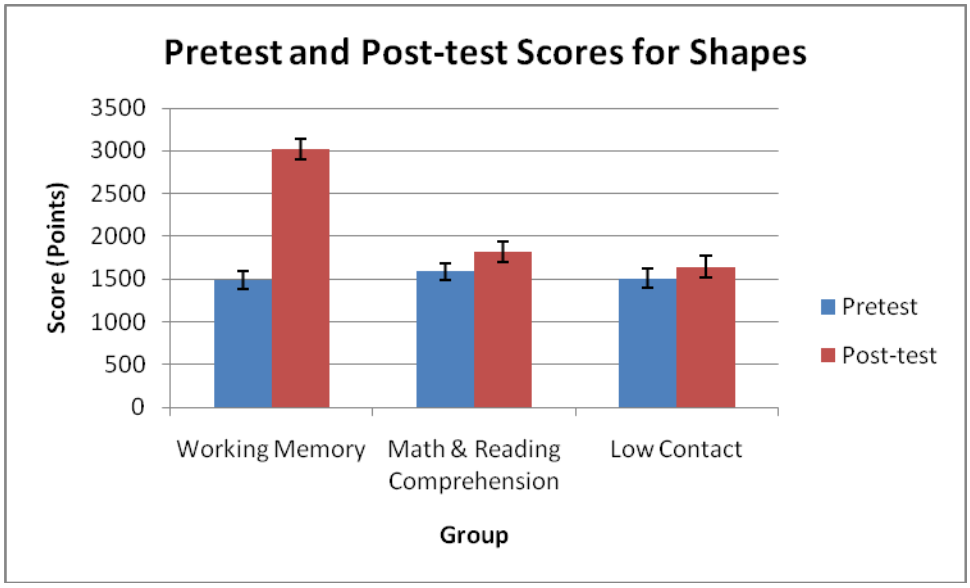
Pre to Post-test Results

Multiple t-tests were conducted analyzing both whether significant improvement occurred within a group from the pretest to post-test as well as whether significant improvement occurred between the different groups. The full results of these analyses are detailed in the appendix. Unless otherwise mentioned, there were no significant statistical differences within each group's data and between the different groups.

Shape builder.

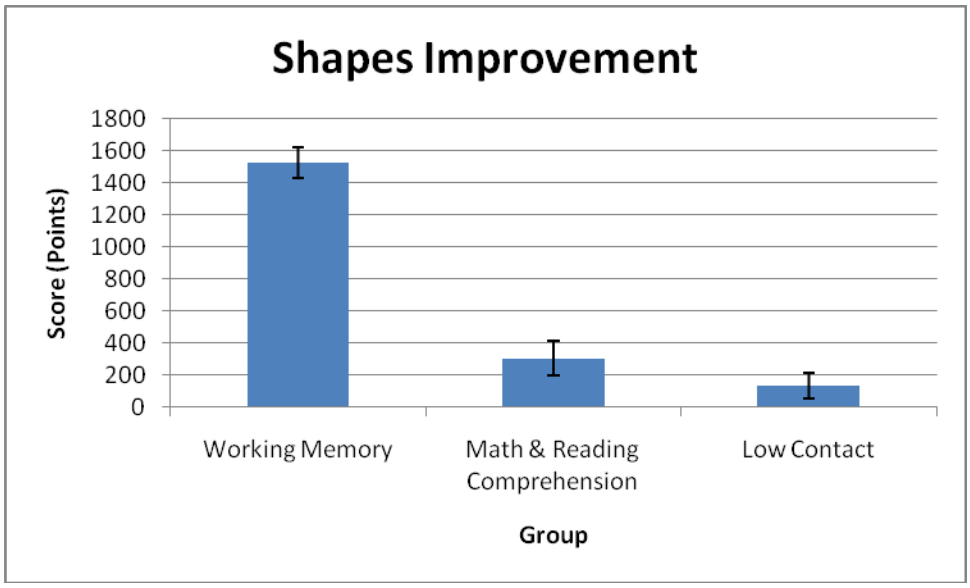
The Working Memory group was the only group that showed a significant statistical difference in its performance on Shapes from pretest to post-test $t(22) = 15.74$, $p<0.0001$. This effect can be seen in Figure 9. The participants achieved points on Shapes according to the following scoring scheme: 5 points for only the correct location, 10 points for the correct location and shape, 15 points for the correct location and shape and color.

Figure 9: **Each group's pretest and post**-test scores on the Shape Builder task.



In addition, as expected and seen in Figure 10, the Working Memory group improved on the Shapes assessment more than the Math and Reading Comprehension group $t(43) = 8.01$, $p<0.0001$ and the Low Contact group $t(36) = 10.42$, $p<0.0001$.

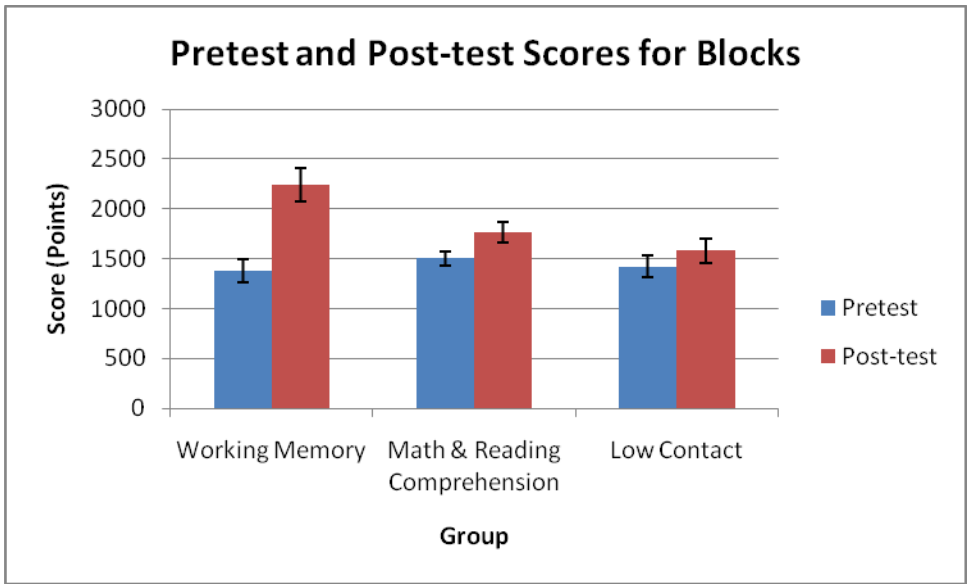
Figure 10: **Each group's improvement on** Shapes from the pretest to the post-test.



Block span.

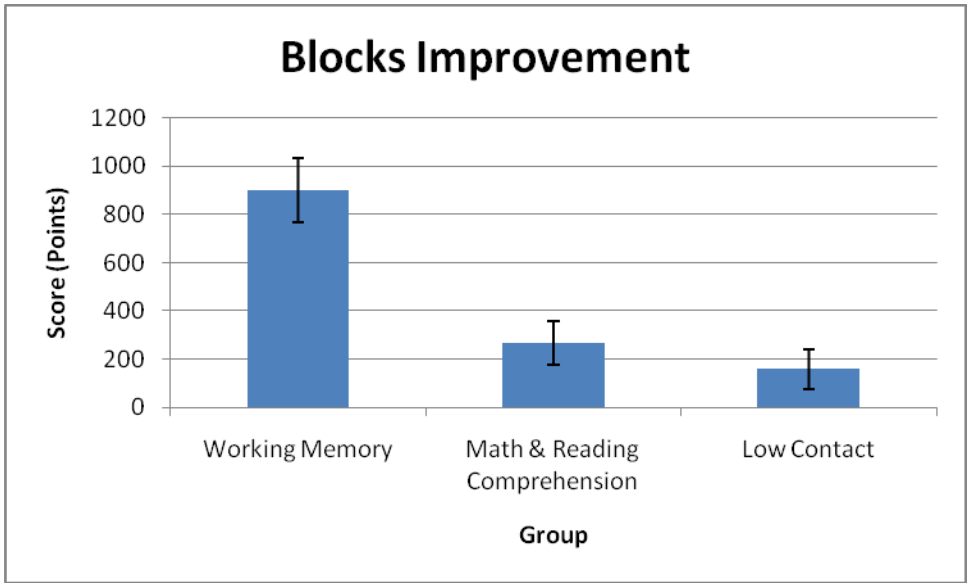
The Working Memory group trained on an adaptive version of Blocks and the participants improved from pretest to post-test $t(23) = 6.39$, $p<0.0001$ (see Figure 11). Mathpiles was correlated to Blocks (see Table 4) and the factor that Mathpiles loaded on correlated to the factor that blocks loaded on (see Tables 8 and 9), which may have led the Sentencical group to also improve on Blocks $t(22) = 2.98$, $p=0.0069$ (see Figure 11). The participants achieved points on Blocks according to the following scoring scheme: 10*X, where X is the number of sequential correct responses within a specific sequence.

Figure 11: **Each group's pretest and** post-test scores on the Blocks task.



As expected and seen in Figure 12, the Block Span group improved on the Blocks assessment more than the Sentencical group $t(43) = 3.95$, $p=0.0003$ and the Low Contact group $t(36) = 4.28$, $p<0.0001$.

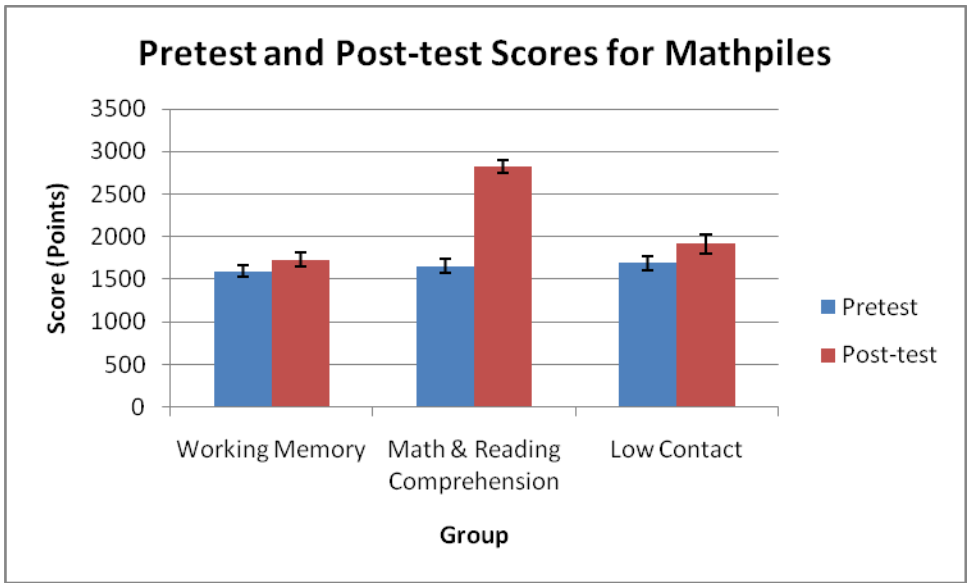
Figure 12: **Each group's improvement on the assessment version of Block Span from the pretest** to the post-test.



Number piles.

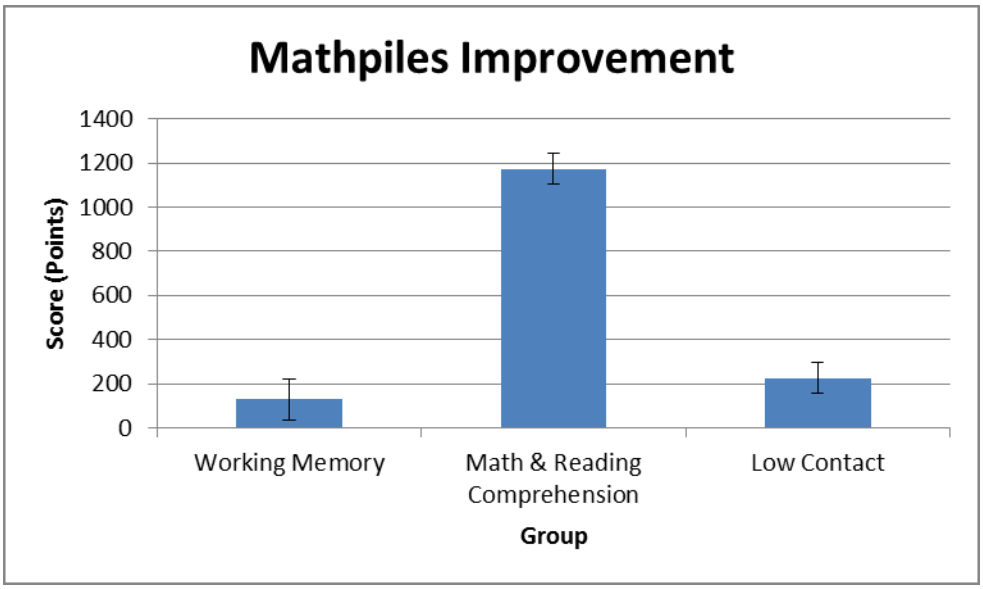
The Math and Reading Comprehension group showed improvement in their performance on Mathpiles from pretest to post-test $t(23) = 16.88$, $p<0.0001$ (see Figure 13). The Low Contact group also improved from pretest to post-test $t(16) = 3.18$, $p=0.0061$ but showed no improvement relative to the other groups (see Figures 13 and 14). Participants received points on Mathpiles according to the following scheme: 10*X, where X is the number of sequential correct responses.

Figure 13: **Each group's pretest and post**-test scores on the Mathpiles task.



Similar to the results from Blocks and Shapes, the Math and Reading Comprehension group improved on the Mathpiles assessment more than the Working Memory group $t(43) = 8.75$, $p<0.0001$ and the Low Contact group $t(37) = 9.28$, $p<0.0001$ (see Figure 14).

Figure 14: **Each group's improvement on** Mathpiles from the pretest to the post-test.



Modular arithmetic.

Figures 15 – 18 show the performance of the three groups on Mod from pretest to post-test. This task was evaluated based on reaction time; therefore, improved performance is the result of a faster reaction time, which equates to a smaller or negative value. Participants' response times reflect how long they took to correctly answer the easy, medium and hard problems respectfully. Results from the Mod task showed that participants in the Math and Reading Comprehension group improved on the easy problems $t(22) = 6.68$, $p<0.0001$ and on the medium problems $t(22) = 6.06$, $p<0.0001$ (see Figures 15 and 16), while participants in the Working Memory group improved only on the easy problems $t(20) = 2.41$, $p=0.0260$ (see Figure 15). There was no improvement within the Low Contact group. There was no difference in improvement between the groups on any of the different difficulty problems for Mod (see Figure 18).

Figure 15: **Each group's pretest and post**-test scores on the easy problems of Mod

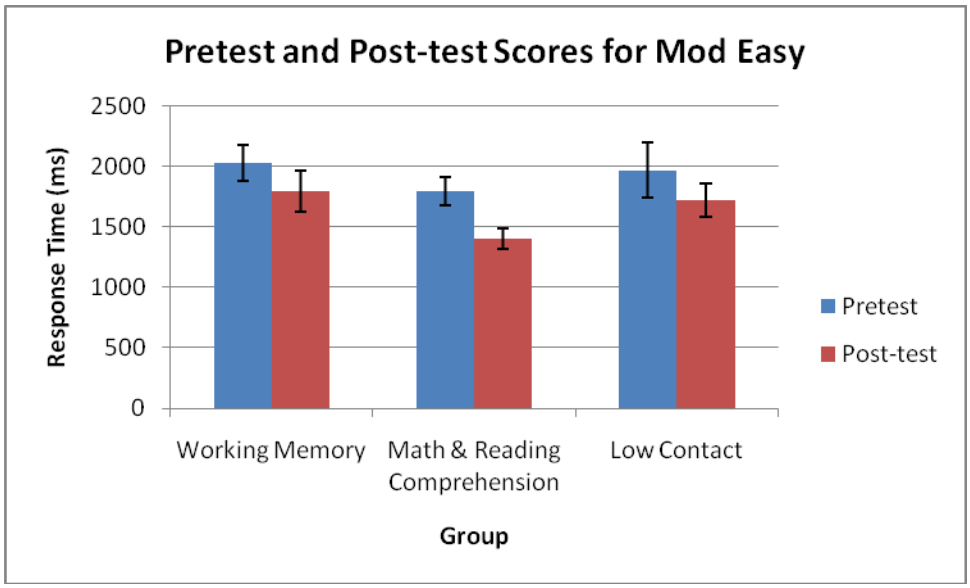


Figure 16: **Each group's pretest and post**-test scores on the medium problems of the Mod

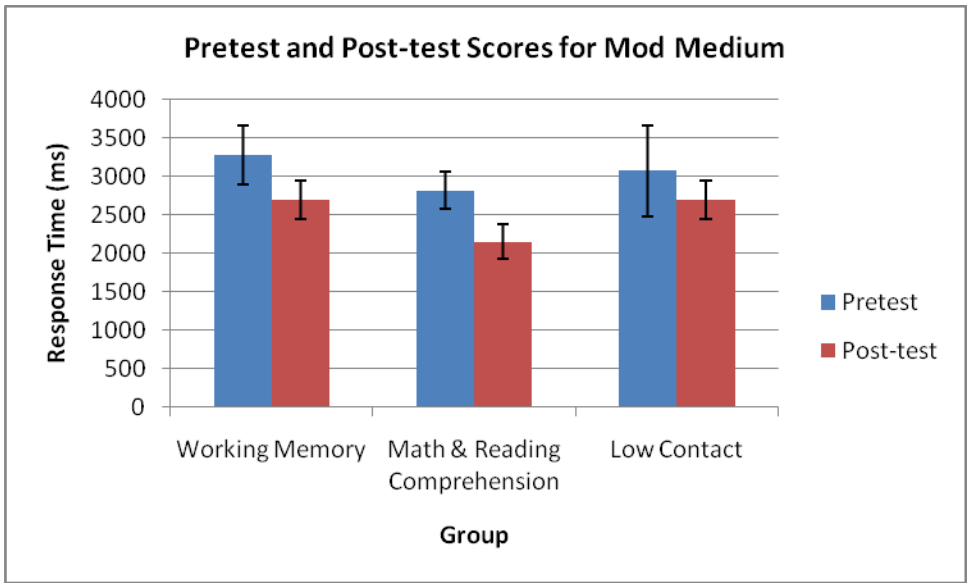


Figure 17: **Each group's pretest and post-test scores on the hard problems of the Mod**

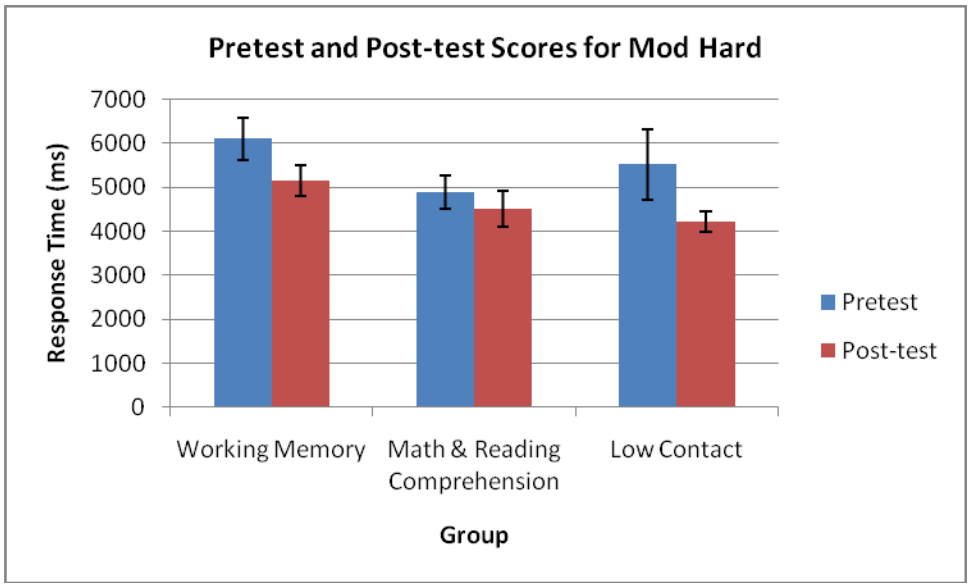
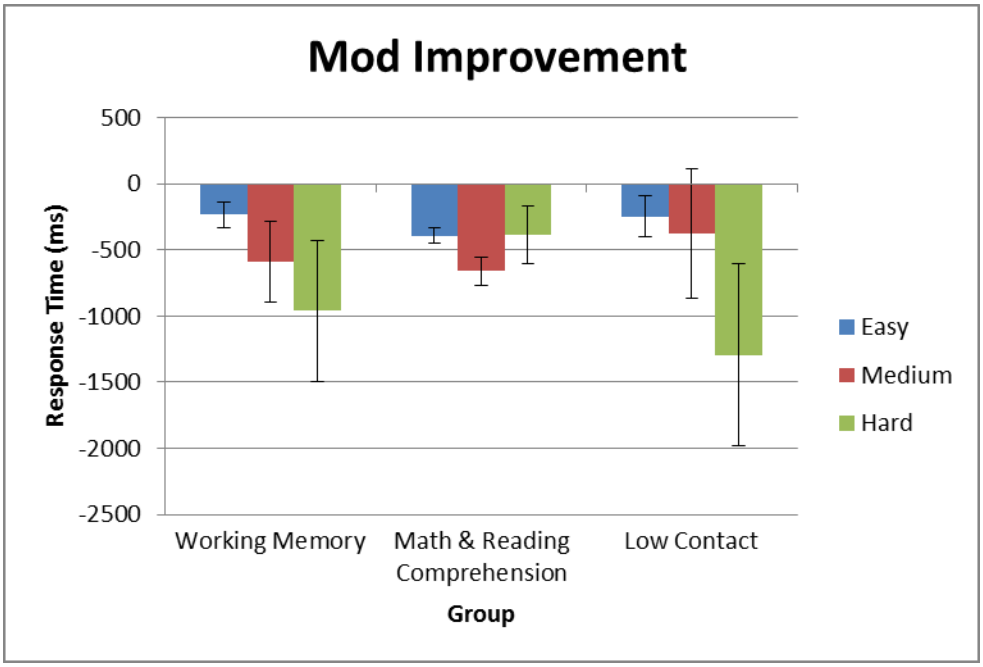


Figure 18: **Each group's improvement on the easy, medium, and hard Mod**



G-math.

G-math was also evaluated based on reaction time; therefore an improvement is represented by a faster reaction time, which equates to a smaller or negative value. Participants' response times reflect how long they took to correctly answer the easy and hard problems respectfully. None of the groups improved on the easy difficulty problems, possibly because the participants had already almost reached their maximum performance due to the questions not being challenging enough to allow a participant to improve significantly (see Figure 19). The Math and Reading Comprehension group improved on the hard problems $t(23) = 5.21$, $p<0.0001$ (see Figure 20). None of the groups improved relative to one another (see Figure 21).

Figure 19: Each group's pretest and post-test scores on the easy problems of the G-math task.

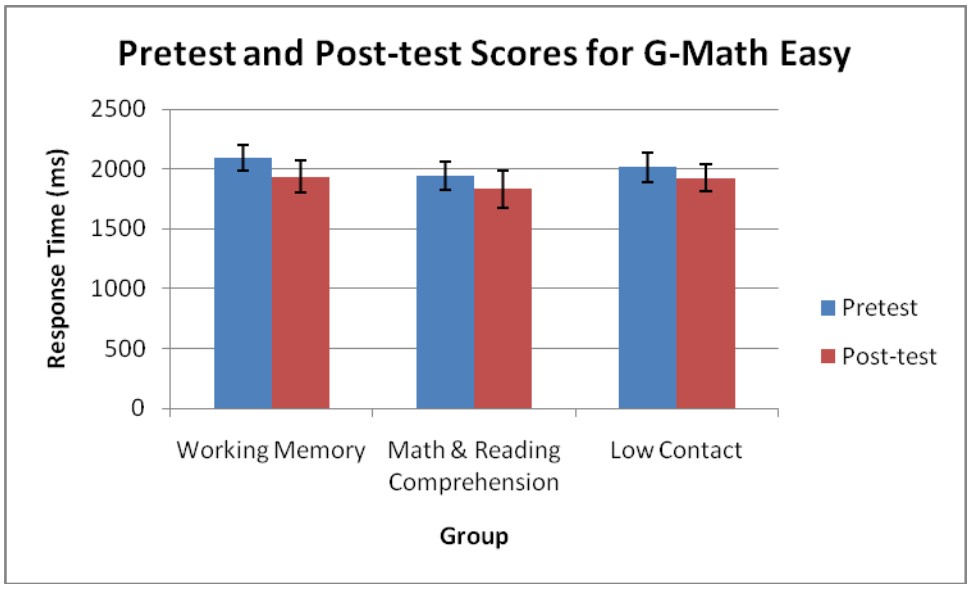


Figure 20: **Each group's pretest and post**-test scores on the hard problems of the G-math task.

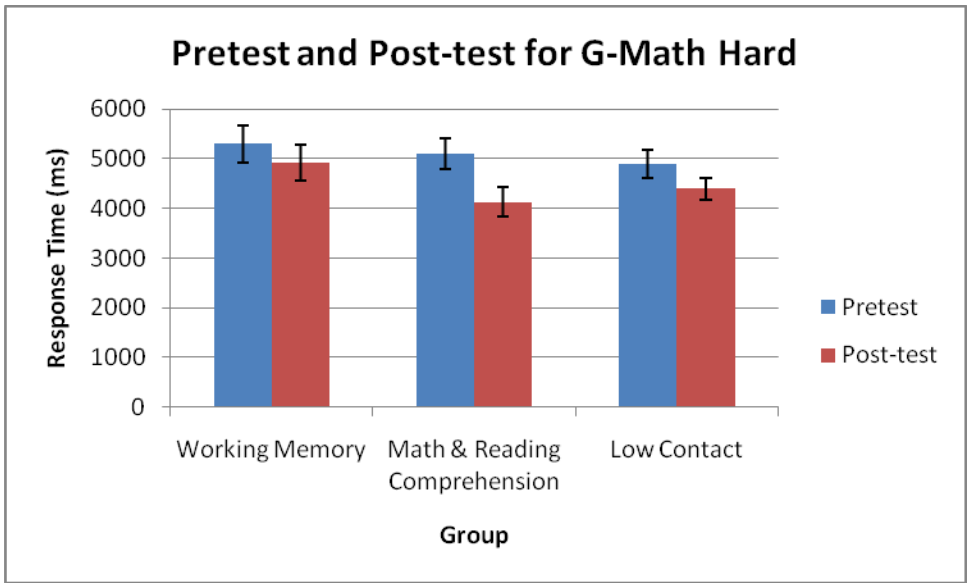
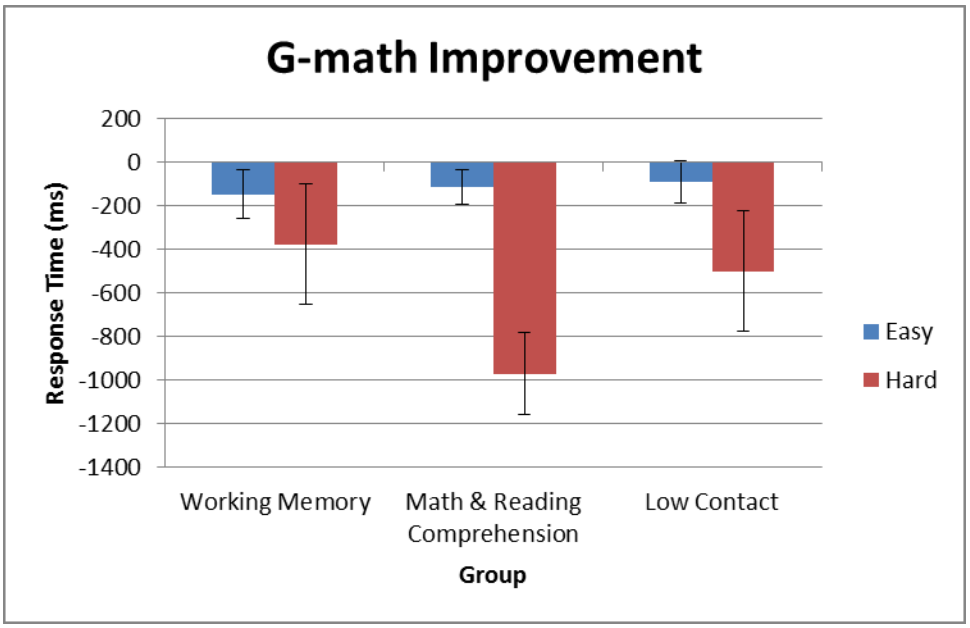


Figure 21: **Each group's improvemen**t on the easy and hard G-math problems from the pretest to the post-test.



Ravens progressive matrices.

Although Ravens correlated well with both the sWM tasks ($p<0.01$ for Blocks and $p<0.001$ for Shapes) and with Mathpiles ($p<0.01$) and it loaded heavily on the sWM/gF factor, Figure 23 illustrates that there was no significant difference in

improvement between the training groups. There was also no significant difference between pretest and post-test scores for any group (see Figure 22). The lack of improvement on Ravens and its reliance on other cognitive functions, such as Blocks and Shapes, suggests that there is another cognitive function utilized when completing the task. According to the literature, Ravens is a measure of fluid intelligence (gF) (Chein & Morrison, 2010; Westerberg & Klingberg, 2007). This may indicate that neither training one's sWM nor training one's quantitative ability leads to a transfer effect on gF. Participants received one point for every correctly solved matrix.

Figure 22: **Each group's pretest and post-test scores on the Raven's Progressive Matrices task**

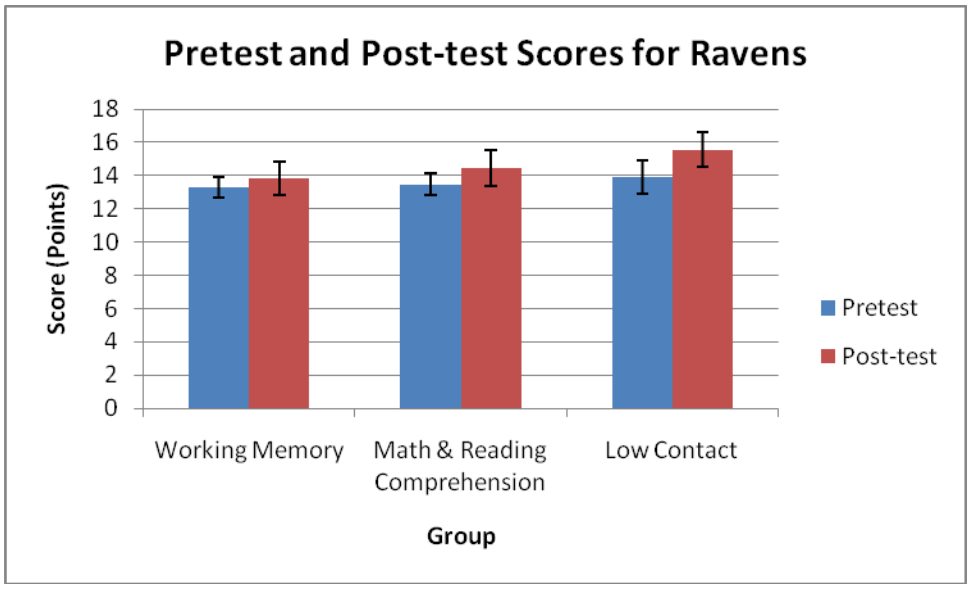
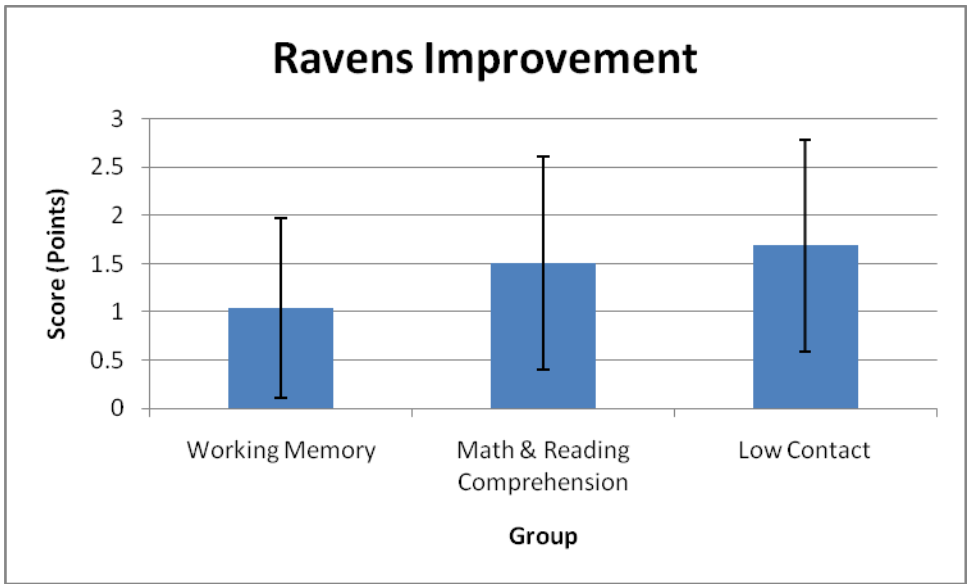


Figure 23: **Each group's improvement on Ravens Progressive Matrices from the pretest to the post-test.**



Letter number sequencing.

The Working Memory group was the only group that showed an improvement from pretest to post-test on its performance on LNS $t(22) = 2.10$, $p=0.0005$ (see Figure 24). This was expected because LNS is correlated with both Blocks ($p<0.001$) and Shapes ($p<0.01$) (see Table 2) and Shapes partially loaded on the vWM factor, the factor where LNS strongly loaded (see Table 8). As shown in Figure 25, there was no difference in improvement between groups. Participants received 10 points for every sequence the recalled correctly; the entire sequence had to be recalled correctly to receive points.

Figure 24: **Each group's pretest and post-test scores on the Letter Number Sequencing task.**

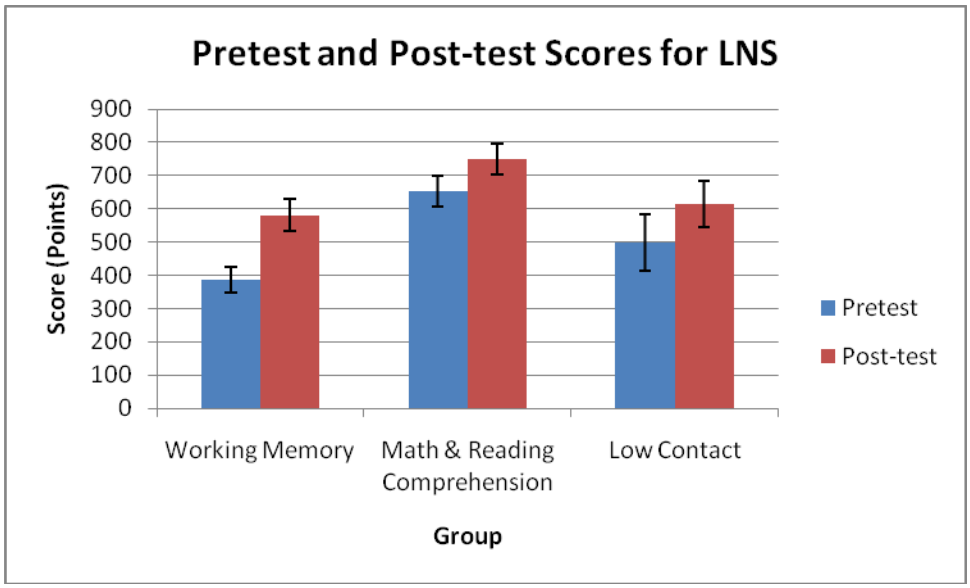
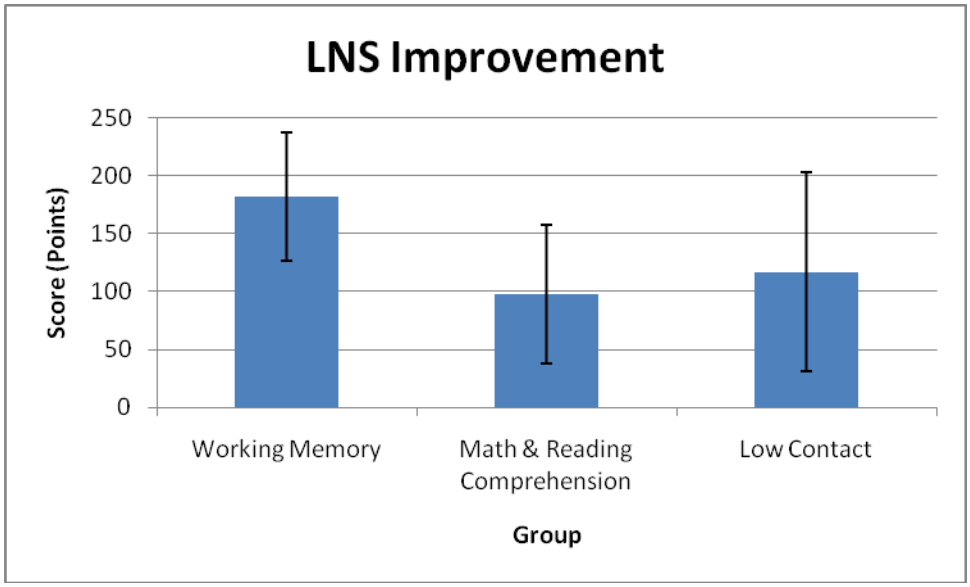


Figure 25: **Each group's improvement on Letter Number Sequencing from the pretest to the post-test.**

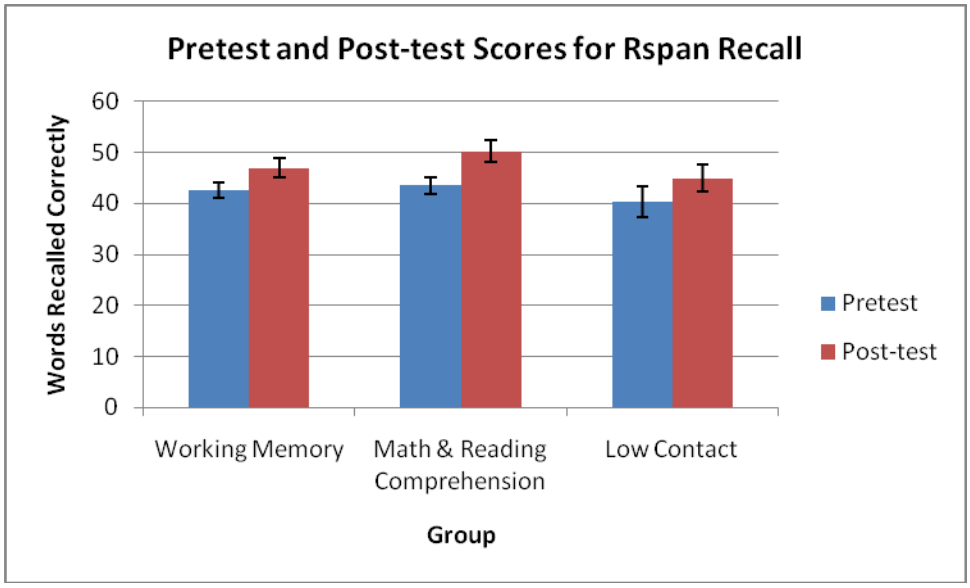


Reading span.

There was significant improvement within all of the groups on the recall portion of Rspan – for the Working Memory group $t(22) = 2.65$, $p=0.0149$; for the Math and Reading Comprehension group $t(23) = 2.98$, $p=0.007$); and for the Low

Contact group t(15) = 2.32, p= 0.0357 (see Figure 26). Participants received one point for each word they recalled correctly.

Figure 26: **Each group's pretest and post-test scores on the recall portion of the Reading Span task.**



The Working Memory group was the only group that showed improvement t(21) = 2.37, p=0.0272 on the grammar portion of Rspan as seen in Figure 27. Participants received one point for each sentence they correctly identified as grammatically correct or incorrect. Rspan Grammar loaded very heavily on the vWM factor, which Shapes also partially loaded on (Table 8). Shapes and Rspan Grammar also correlated with $p<0.01$ on the pre-test, which may explain these unexpected results. However, this improvement only equates to the Working Memory group correctly identifying one more sentence at the post-test than at the pretest. There was no difference in improvement on the recall or grammar portions of Rspan between the groups (see Figure 28).

Figure 27: **Each group's pretest and post-test scores on the grammar portion of the Reading Span task.**

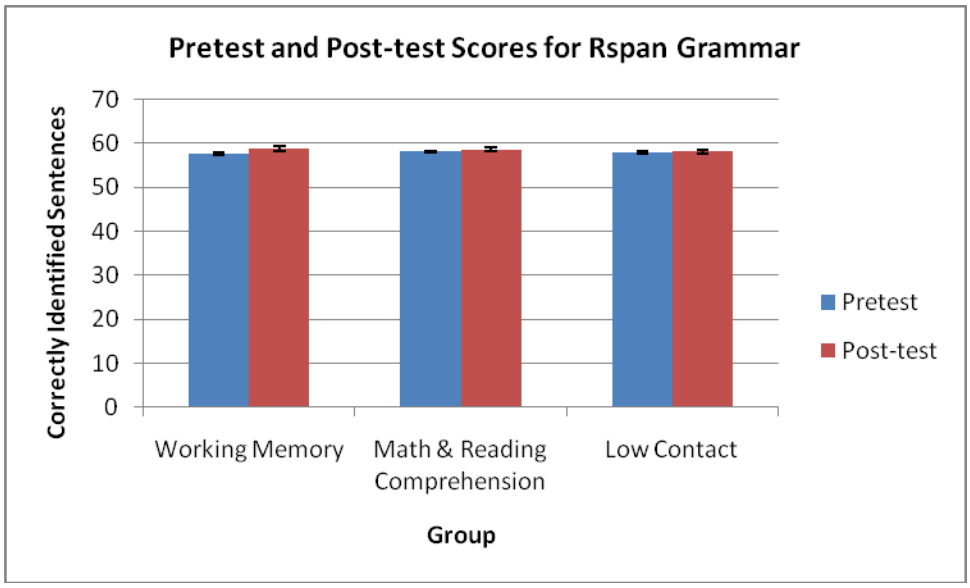
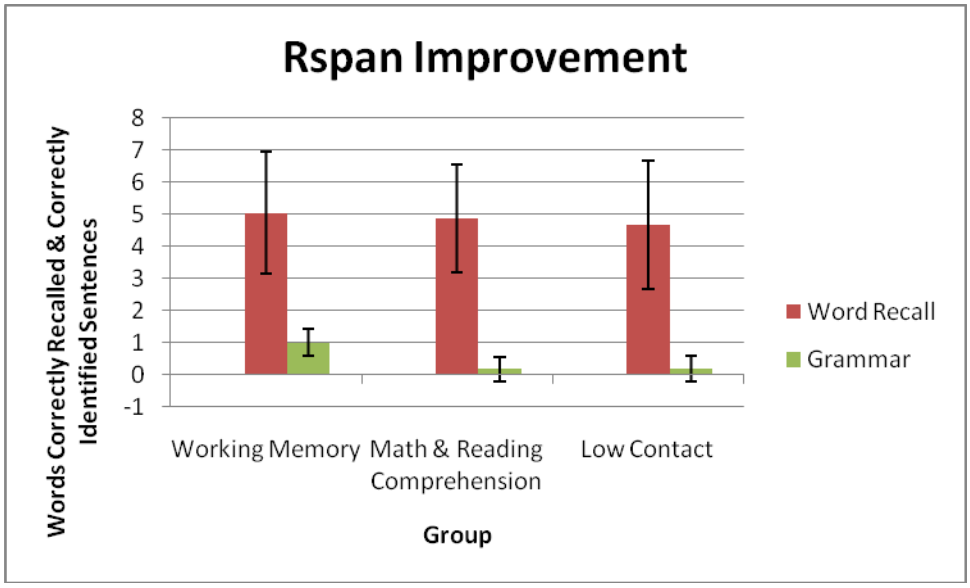


Figure 28: Each group's **improvement on the grammar and word recall portions of Reading Span from the pretest to the post-test.**



Summing to ten.

The results from ST were unexpected, especially because ST correlated with Shapes ($p<0.05$), Blocks ($p<0.001$), and Mathpiles ($p<0.001$). Improvement on ST is measured by the difference in the number of times a participant correctly circled

adjacent digits that summed to 10, so improvement should be positive. The Low Contact group decreased in performance on ST $t(16) = 2.49$, $p=0.0246$, but no group had a significant difference in performance compared to the other groups from pretest to post-test (see Figures 29 and 30). We suspect that the decrease in performance is related to differences in task construction between the pretest and the post-test. In the allotted ninety seconds, most participants were only able to analyze the first 250-350 digits. In the first 355 digits of the pretest, there were 36 adjacent pairs that summed to ten while there were only 25 in the first 355 digits of the post-test. Thus, participants did not have enough answers available in the ST post-test to improve their performance, regardless of changes in their cognitive abilities.

Figure 29: **Each group's pretest and post-test scores on the Summing to Ten task.**

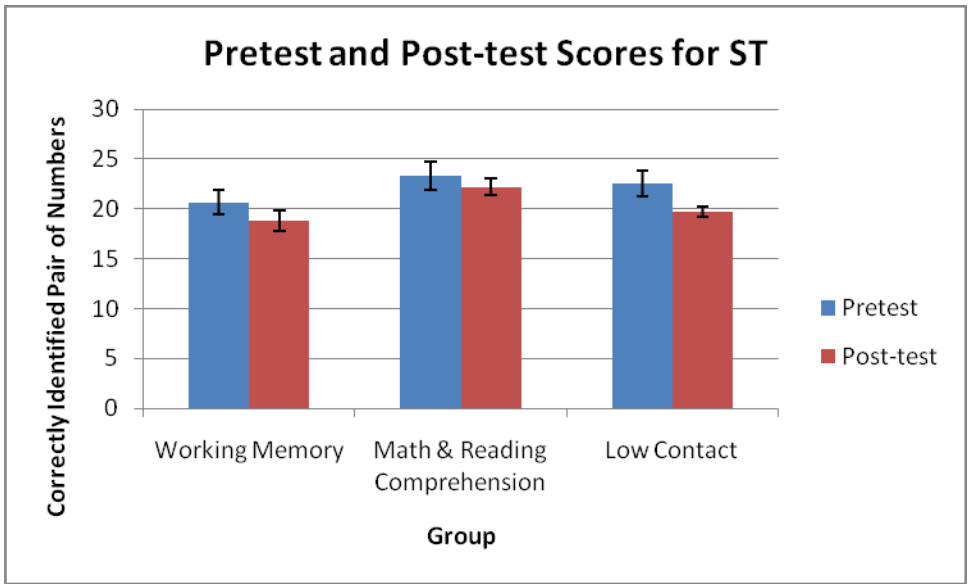
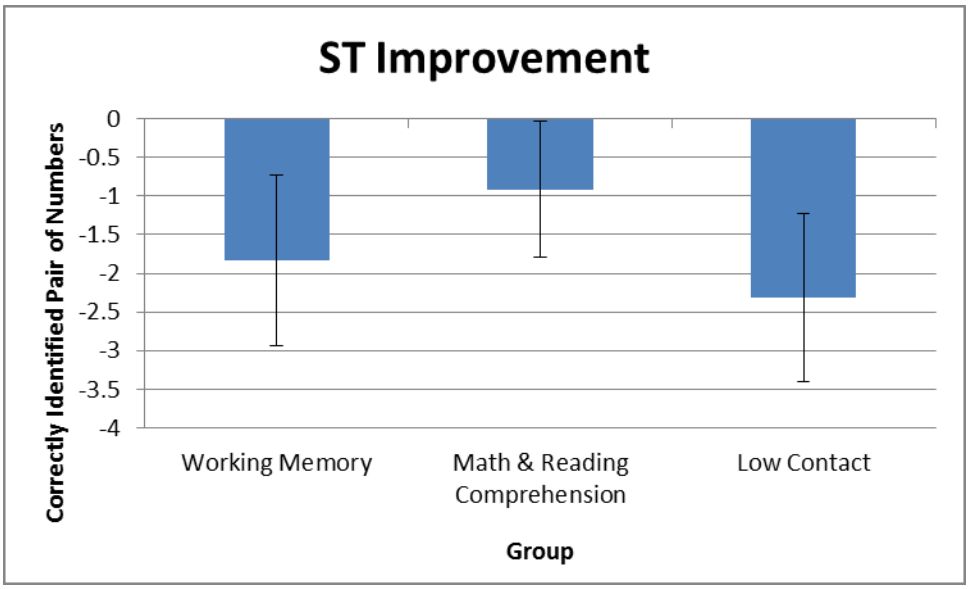


Figure 30: **Each group's improvement on Summing to Ten from the pretest to the post-test.**



Verbal learning.

As seen in Figures 31 and 33, within the Low Contact group the participants decreased their performance on Verbal from pretest to post-test for both the List 1 recall $t(15) = 3.93$, $p=0.0015$ and List 3 recall $t(15) = 4.00$, $p=0.0013$. As seen in Figures 32 and 33, within the Math and Reading Comprehension group, the participants improved on Verbal from pretest to post-test for both the List 2 recall $t(22) = 2.21$, $p=0.0381$ and List 3 recall $t(22) = 2.12$, $p=0.0455$. The Working Memory group did not improve within the group from pretest to post-test on Verbal (see Figures 31, 32, and 33). The number of words the participants correctly recalled from each respective list was recorded.

Figure 31: **Each group's pretest and post**-test scores on recalling List 1 of the Verbal Learning task.

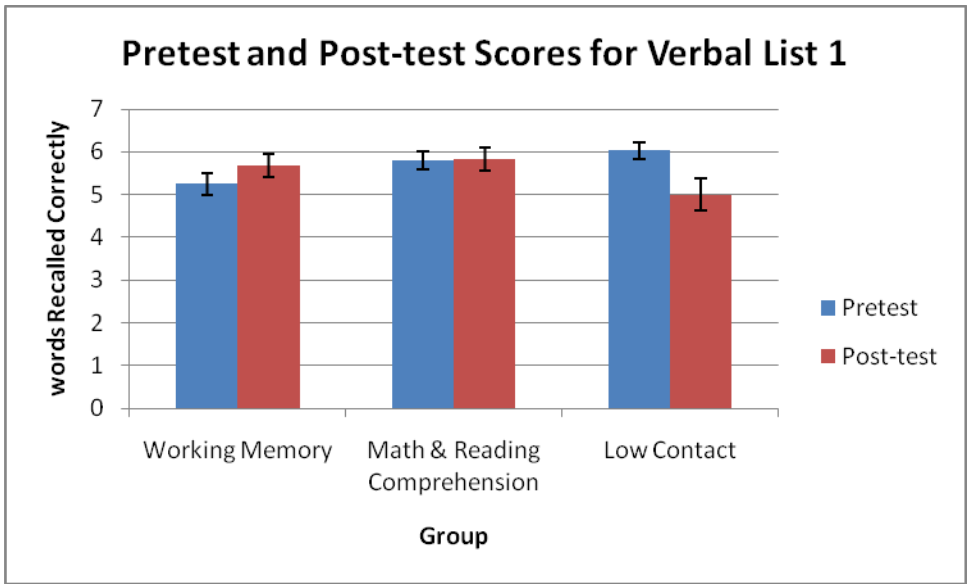


Figure 32: **Each group's pretest and post**-test scores on recalling List 2 of the Verbal Learning task.

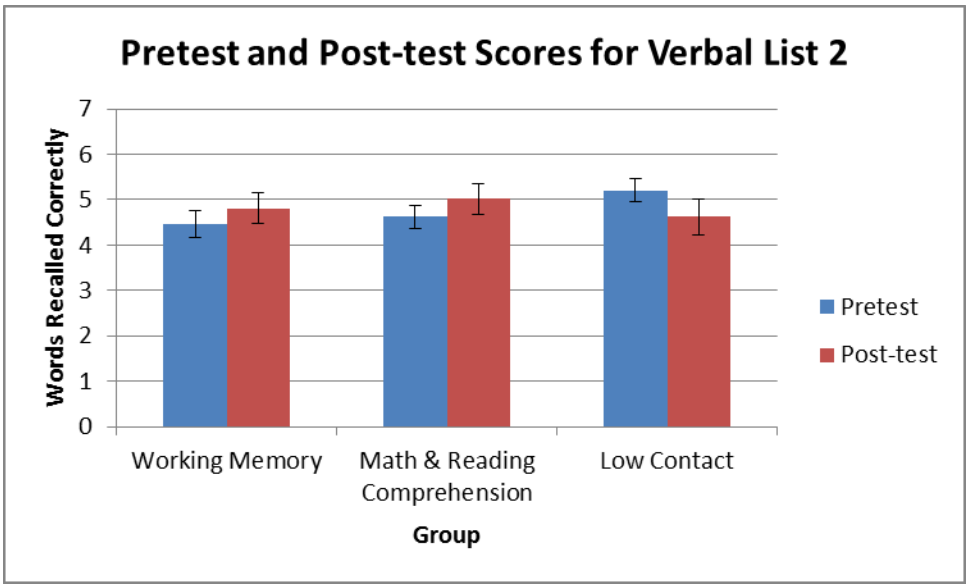
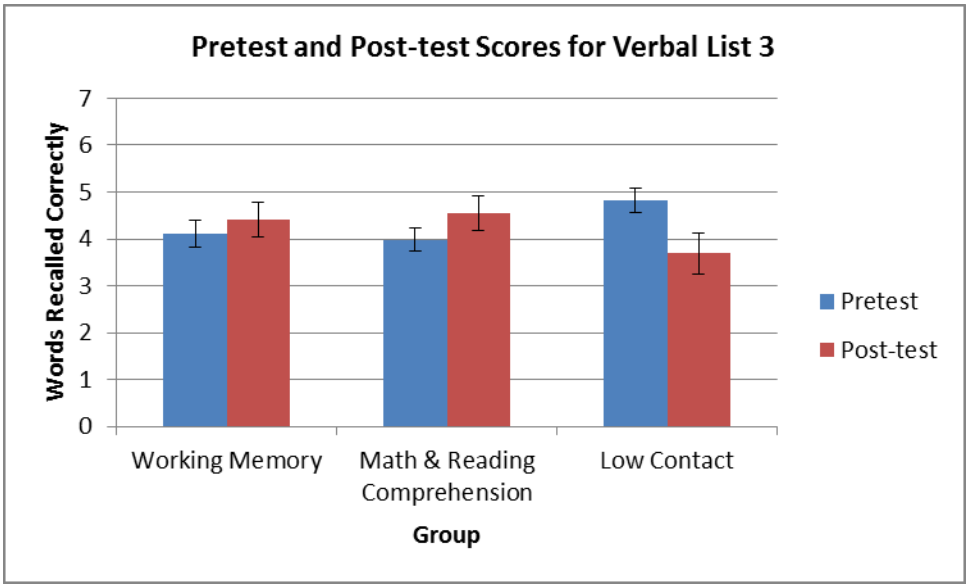
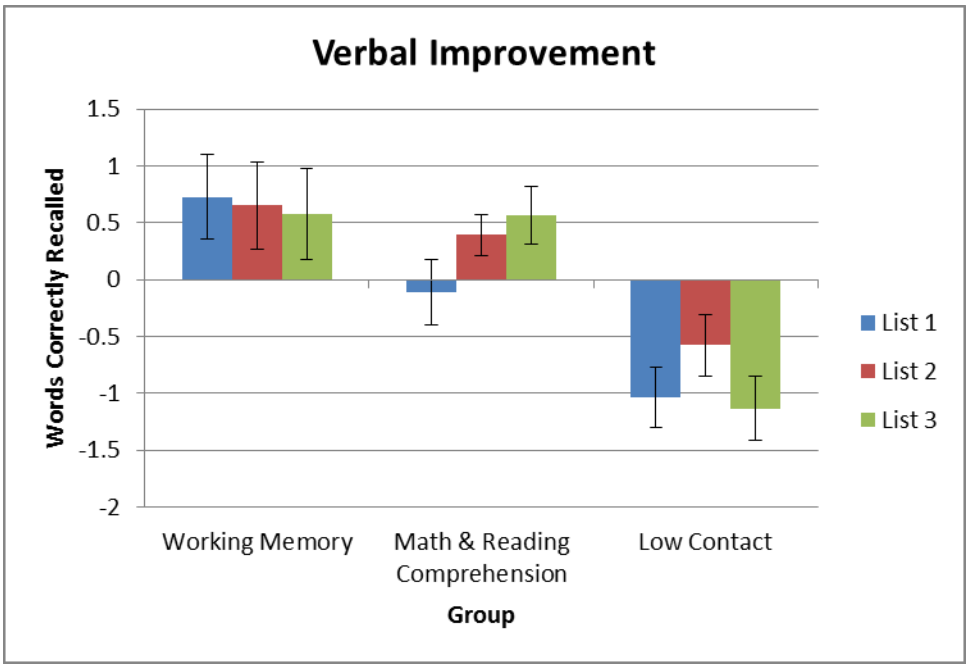


Figure 33: **Each group's pretest and post-test scores on recalling List 3 of the Verbal Learning task.**



Both Blocks and Shapes correlated with the Verbal List 1, 2, and 3 recall variables (at most $p<0.05$); and Mathpiles correlated with the Verbal List 1 and 2 recall variables ($p<0.01$ and $p<0.05$, respectively) (see Tables 2 and 4). Also, the factors that Blocks, Shapes, and Mathpiles loaded on correlated with the factor that Verbal loaded on (see Tables 8 and 9). The Working Memory group improved relative to the Low Contact group on List 1 recall $t(37) = 3.53$, $p=0.0012$, List 2 recall $t(37) = 2.37$, $p=0.0234$, and List 3 recall $t(37) = 3.20$, $p=0.0029$. The Math and Reading Comprehension group improved relative to the Low Contact group on List 1 recall $t(38) = 2.24$, $p=0.0314$, List 2 recall $t(38) = 3.12$, $p=0.0036$, and List 3 recall $t(38) = 4.26$, $p<0.0001$ (see Figure 34).

Figure 34: **Each group's improvement on Verbal Learning from the pretest to the post-test.**



Letter comparison.

As seen in Figure 35, all three groups improved on their performance on LC from pretest to post-test: the Working Memory group $t(24) = 8.08$, $p<0.0001$, the Math and Reading Comprehension group $t(23) = 7.33$, $p<0.0001$, and the Low Contact group $t(16)= 6.4$, $p<0.0001$. None of the groups improved relative to each other (see Figure 36). Participants received one point for every correctly identified letter sequence.

Figure 35: **Each group's pretest and post-test scores on the Letter Comparison task.**

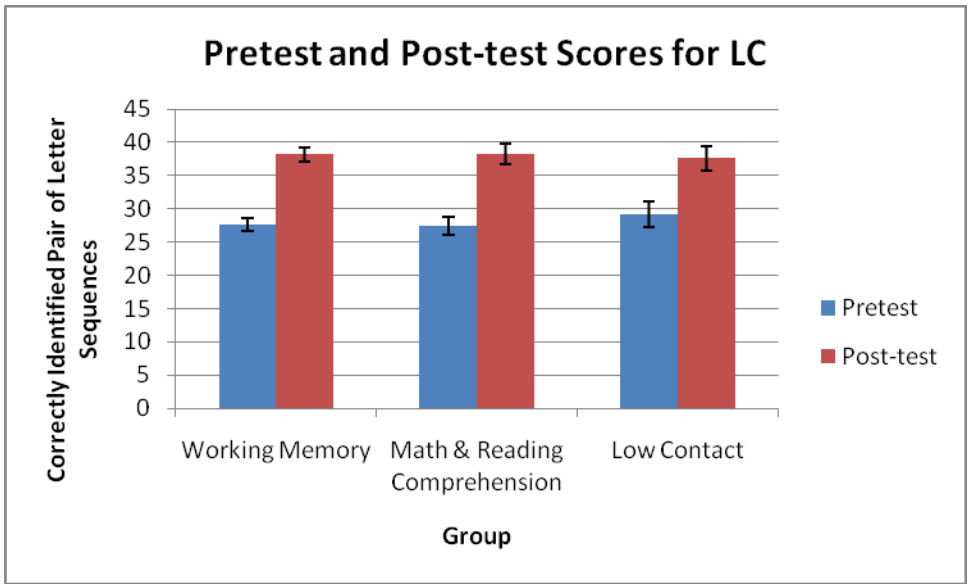
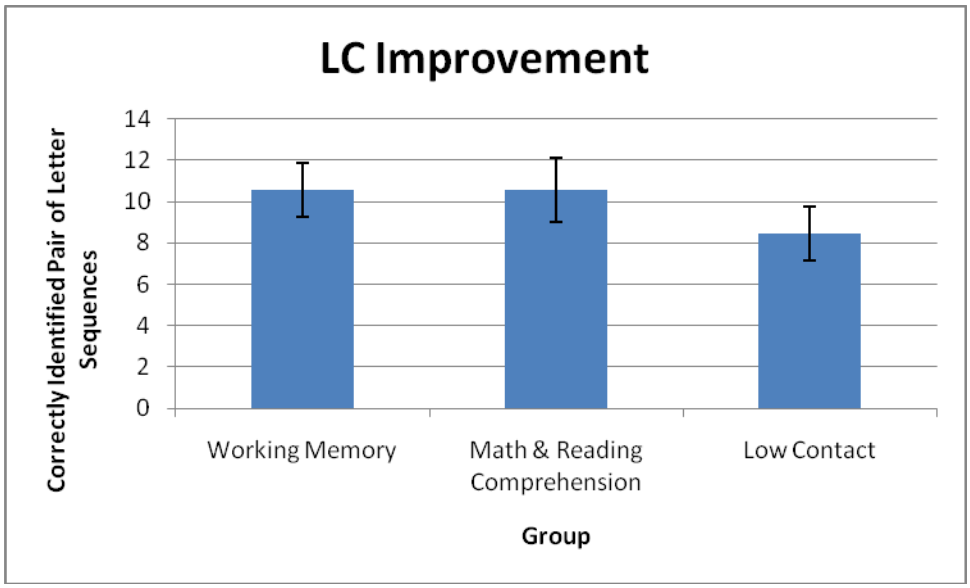


Figure 36: **Each group's improvement on Letter Comparison from the pretest to the post-test.**



Canceling symbols.

As seen in Figure 37, the Working Memory group and Math and Reading Comprehension group showed no changes within their groups from pretest to post-test on CS, while the Low Contact group showed a decrease in their performance $t(16) = 2.48$, $p=0.0255$. None of the groups showed a significant difference in

performance relative to the other groups (see Figure 38). Participants received one point for every correctly identified letter "C" or "D."

Figure 37: **Each group's pretest and post-test scores on the Canceling Symbols task.**

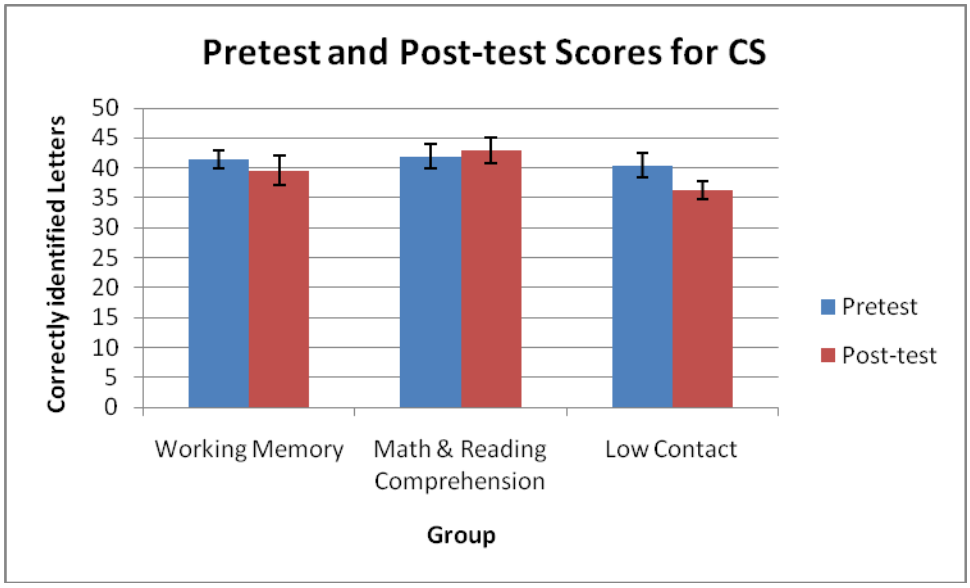
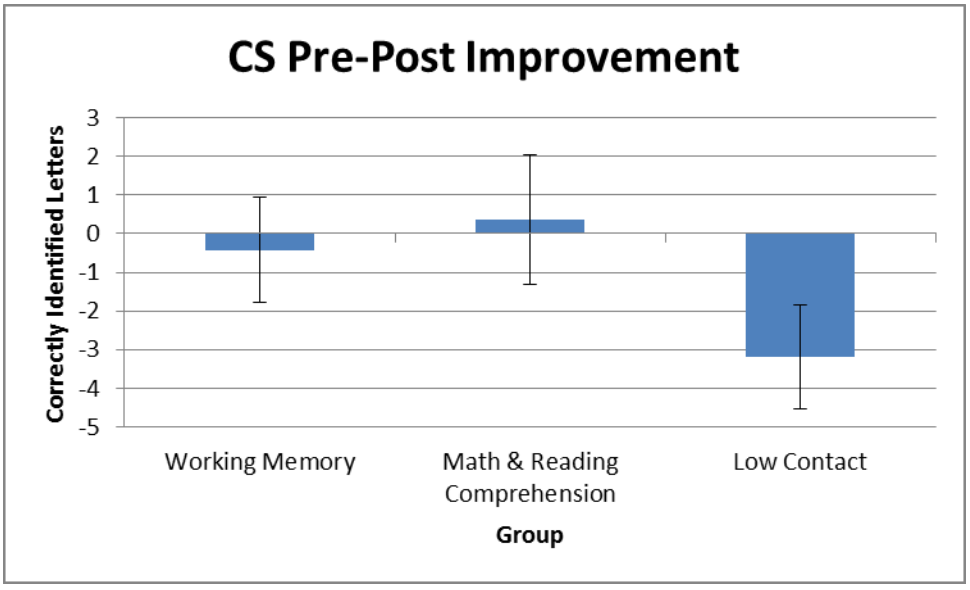


Figure 38: **Each group's improvement on Canceling Symbols from the pretest to the post-test.**



Stroop.

Because Stroop was scored using the average difference in response time between the incongruent trials and the baseline trials, a negative score or trend

actually shows improvement on this task. Participants response time was calculated as the average response time for an individual to correctly identify an incongruent trial minus the average response time for an individual to correctly identify a base trial. As seen in Figure 39, the Math and Reading Comprehension group was the only group that significantly improved within the group on Stroop from pretest to post-test $t(23) = 2.16$, $p=0.0421$. Between groups from the pretest to the post-test, the Math and Reading Comprehension group also improved relative to the Low Contact group, $t(29) = 2.24$, $p=0.0315$ (see Figure 40). There may be some training effect that led to improvement within the Math and Reading Comprehension group. Mathpiles may train a latent inhibition ability, requiring participants to inhibit previous target sums while trying to solve the current target sum. However, we suspect that Blocks and Shapes trains inhibition in a similar fashion, requiring participants to inhibit prior sequences, colors, and shapes while focusing on the current stimuli. An additional possibility is that the Sentencical task contributed to an interference resolution training effect through the garden-path items included (which require interference resolution). This was unexpected as we had originally included the Sentencical task as a placebo control task, expecting that this task would have no effect on the processes we were measuring.

The results relating to the Low Contact group could be a consequence of the expectations of the experimenters (Shipstead et al., 2010). The Low Contact group was told that the training would result in improvements on all of the pre and post-test measures. Since they failed to complete the training, the Low Contact group may

have performed worse because they believed they would. This is doubtful though because we saw little evidence of this on the other tasks.

Figure 39: **Each group's pretest and post-test scores on the Stroop task.**

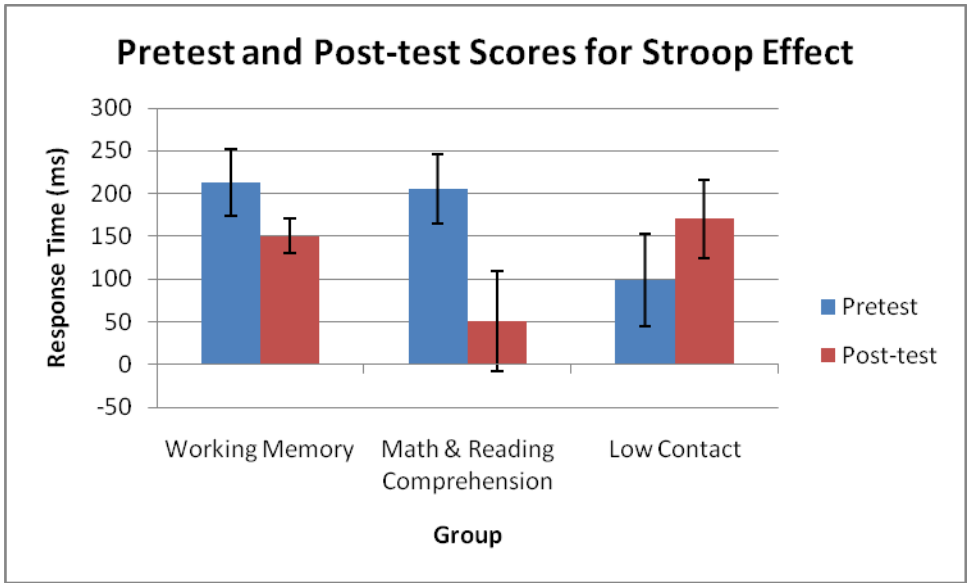
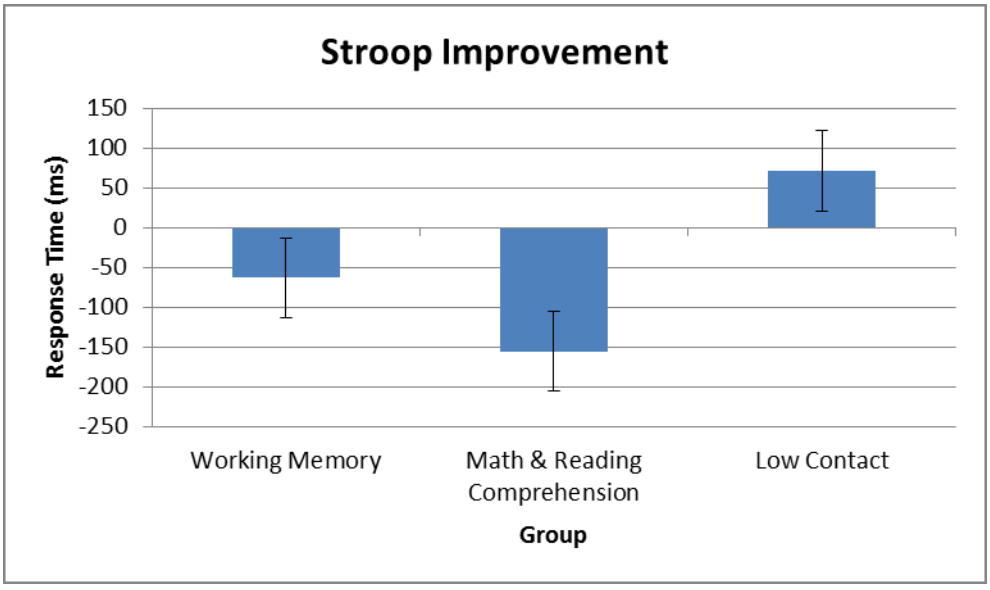


Figure 40: Each group**'s improvement on Stroop from the pretest to the post-test.**



Summary of Pre to Post-test Results – Effect Sizes

Table 14, Table 15, and Table 16 show the results of the t-test analyses and the effect size calculations that were performed on the data from the three separate groups.

Table 14: T-test analysis and effect size calculations for the Working Memory Group from pretest to post-test.

Working Memory Group								
						if p < 0.05		
	Task Variable	N	df = N-1	t-value	p-value	mean	SD	d = mean/SD
Quantitative Reasoning	ModRTEasydiff	20	19	-2.41	0.0260	-235	435.7	0.54
	ModRTMeddiff	20	19	-1.92	0.0698			
	ModRTHarddiff	20	19	-1.80	0.0874			
	GmathRTEasydiff	21	20	-1.32	0.2004			
	GmathRTHarddiff	21	20	-1.12	0.2748			
	MathpilesDiff	23	22	1.39	0.1781			
Verbal Learning	RecallL1diff	21	20	1.98	0.0605			
	RecallL2diff	21	20	1.40	0.1766			
	RecallL3diff	21	20	1.00	0.3251			
sWM Capacity / gF	RavensDiff	22	21	1.12	0.2744			
	BlocksDiff	23	22	6.39	<0.0001	860	644.8	1.33
	ShapesDiff	22	21	15.74	<0.0001	1527	454.9	3.36
vWM Capacity	RspanRecallDiff	22	21	2.65	0.0149	5.04	8.92	0.57
	RspanGrammarDiff	22	21	2.37	0.0272	1	1.97	0.51
	LNSDiff	22	21	4.10	0.0005	195	222.7	0.88
Perceptual Speed	LCDiff	24	23	8.08	<0.0001	10.54	6.38	1.65
	CSDiff	23	22	-0.21	0.8303			
	STDiff	24	23	-1.65	0.1120			
Stroop	StroopEffectDiff	22	21	-1.58	0.1279			

Table 14: T-test analysis and effect size calculations for the Math and Reading Comprehension Group from pretest to post-test.

Math and Reading Comprehension Group								
						if p < 0.05		
	Task Variable	N	df = N-1	t-value	p-value	mean	SD	d = mean/SD
Quantitative Reasoning	ModRTEasydiff	22	21	-6.68	<0.0001	-393.8	276.3	1.43
	ModRTMeddiff	22	21	-6.06	<0.0001	-661.1	513.8	1.29
	ModRTHarddiff	22	21	-1.75	0.0934			
	GmathRTEasydiff	23	22	-1.46	0.1567			
	GmathRTHarddiff	23	22	-5.21	<0.0001	-971	893.7	1.09
	MathpilesDiff	23	22	16.88	<0.0001	1172.17	333	3.52
Verbal Learning	RecallL1diff	23	22	-0.38	0.7070			
	RecallL2diff	23	22	2.21	0.0381	0.04	0.85	0.05
	RecallL3diff	23	22	2.12	0.0455	0.55	1.25	0.44
sWM Capacity / gF	RavensDiff	24	23	1.36	0.1872			
	BlocksDiff	23	22	2.98	0.0069	267.83	430.61	0.62
	ShapesDiff	23	22	1.76	0.0914			
vWM Capacity	RspanRecallDiff	23	22	2.98	0.0070	4.96	8	0.62
	RspanGrammarDiff	23	22	0.65	0.5197			
	LNSDiff	23	22	1.63	0.1170			
Perceptual Speed	LCDiff	23	22	7.33	<0.0001	10.78	7.05	1.53
	CSDiff	23	22	-0.70	0.4890			
	STDiff	23	22	-1.26	0.2216			
Stroop	StroopEffectDiff	23	22	-2.16	0.0421	-155.64	345.79	0.45

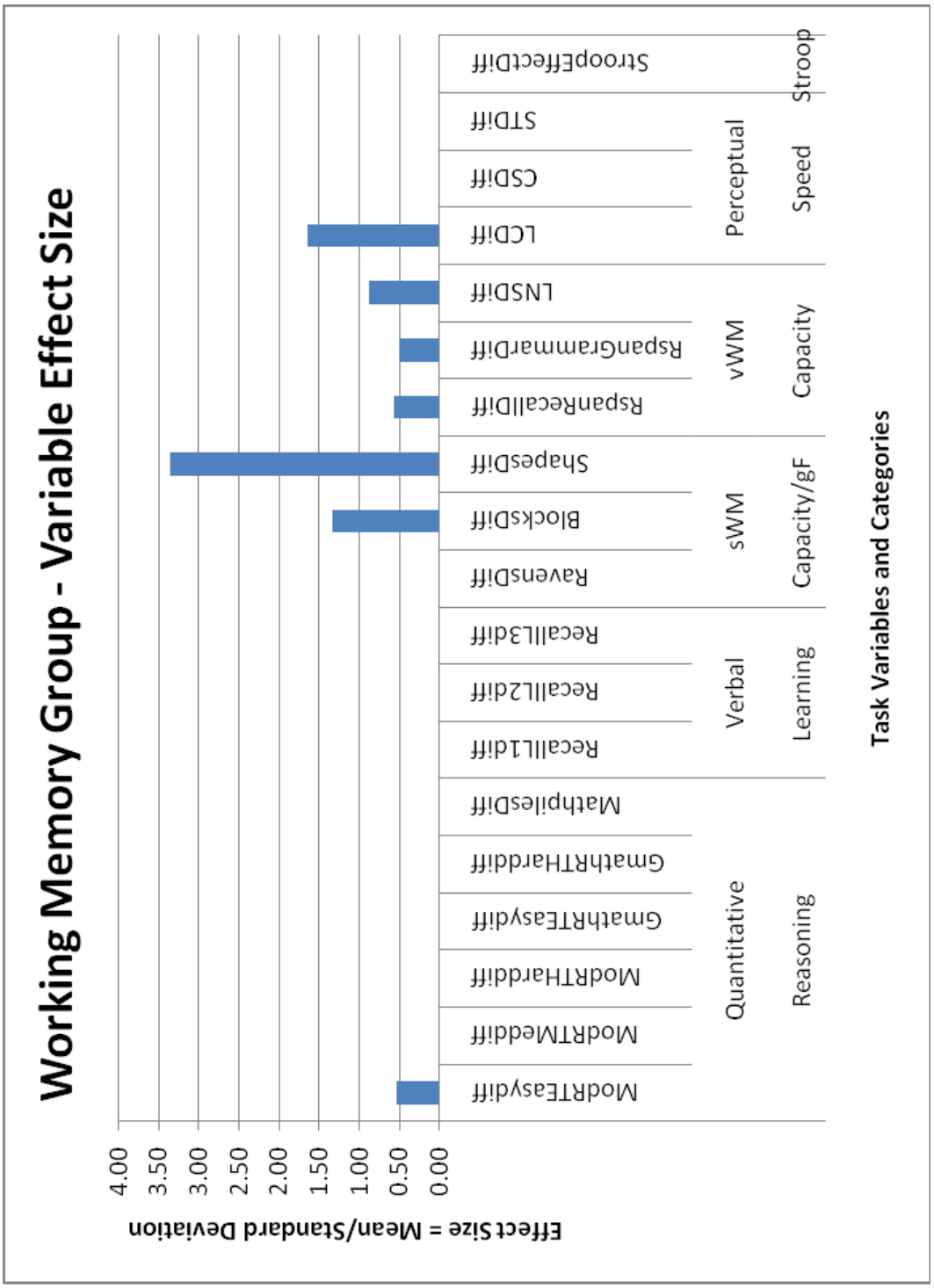
Table 15: T-test analysis and effect size calculations for the Low Contact Group from pretest to post-test.

Low Contact Group								
						if p < 0.05		
	Variable	N	df = N-1	t-value	p-value	mean	SD	d = mean/SD
Quantitative Reasoning	ModRTEasydiff	15	14	-1.60	0.1318			
	ModRTMeddiff	15	14	-0.77	0.4513			
	ModRTHarddiff	15	14	-1.88	0.0805			
	GmathRTEasydiff	16	15	-0.92	0.3702			
	GmathRTHarddiff	16	15	-1.79	0.0931			
	MathpilesDiff	16	15	3.18	0.0061	225	282.1	0.80
Verbal Learning	RecallL1diff	15	14	-3.93	0.0015	-1.03	1.01	-1.02
	RecallL2diff	15	14	-2.11	0.0528			
	RecallL3diff	15	14	-4.00	0.0013	-1.13	1.09	-1.04
sWM Capacity / gF	RavensDiff	16	15	1.53	0.1452			
	BlocksDiff	16	15	1.93	0.0721			
	ShapesDiff	16	15	1.65	0.1190			
vWM Capacity	RspanRecallDiff	15	14	2.32	0.0357	4.66	7.77	0.60
	RspanGrammarDiff	15	14	0.49	0.6289			
	LNSDiff	16	15	1.35	0.1955			
Perceptual Speed	LCDiff	16	15	6.40	<0.0001	8.43	5.26	1.60
	CSDiff	16	15	-2.48	0.0255	-6.37	10.28	-0.62
	STDiff	16	15	-2.49	0.0246	-2.81	4.5	-0.62
Stroop	StroopEffectDiff	16	15	1.12	0.2786			

As seen in Figure 41, the working-memory training group, which trained on the adaptive versions of the Block Span task and the Shape Builder tasks, mostly improved on measure of working memory capacity. From pretest to post-test, participants showed improvement on the two tasks classified as measures of visuo-spatial working memory capacity with a 1.33 standard deviation change on the Block Span task equating to a 60% score increase and a 3.63 standard deviation change on the Shape Builder task equating to a 100% score increase, indicating their improvement on the assessment versions of the tasks they trained on. They also showed improvement on the three variables classified as measures of verbal working

memory capacity with a 0.57 standard deviation change on the recall portion of the Reading Span task equating to five more correctly recalled words out of the 60 presented, a 0.51 standard deviation change on the grammar portion of the Reading Span task equating to one more correctly identified sentence out of the 60 presented, and a 0.88 standard deviation change on the Letter Number Sequencing task equating to a 50% score increase. They showed improvement on one perceptual speed task with a 1.65 standard deviation change for the Letter Comparison task equating to 10 more correctly identified identical letter sequences, and on one quantitative reasoning task with a 0.54 standard deviation change for the response time for correctly answering the easy Modular Arithmetic questions equating to a 235 millisecond faster response time on questions that initially took two seconds to correctly respond to.

Figure 41: Working Memory Group Variable Effect Sizes.

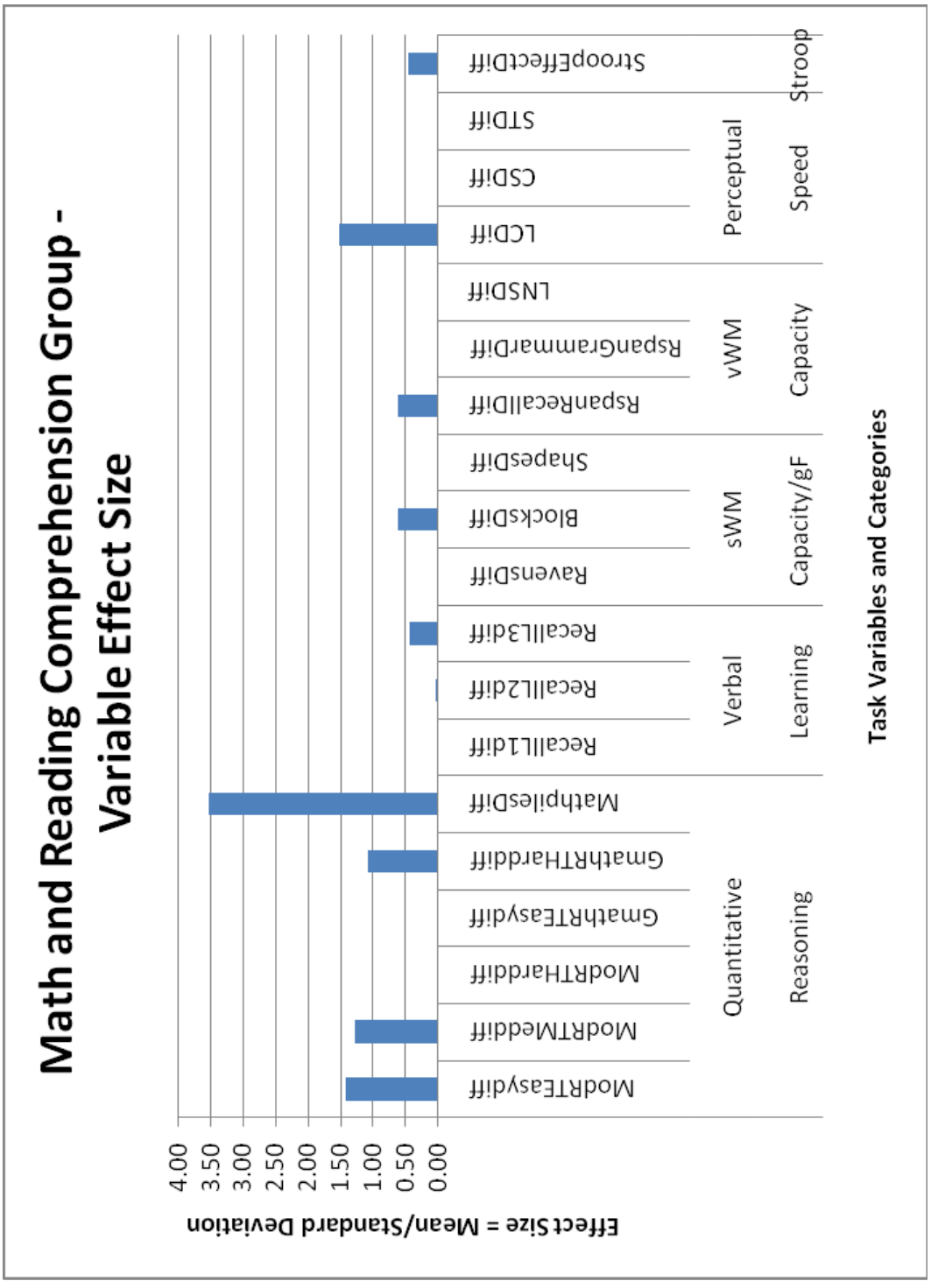


As seen in Figure 42, the Math and Reading Comprehension training group, which trained on the Number piles and Sentencical tasks, mostly improved on

measures of quantitative reasoning and interference resolution. From pretest to post-test, participants showed improvement on four of the variables classified as measures of quantitative ability with a 3.52 standard deviation change on the Number Piles task that they trained on equating to a 71% score increase, a 1.43 standard deviation change for the response time for correctly answering the easy Modular Arithmetic questions equating to a 394 millisecond faster response time on questions that initially took 1.8 seconds to correctly respond to, a 1.29 standard deviation change for the response time for correctly answering the medium Modular Arithmetic questions equating to a 661 millisecond faster response time on questions that initially took 2.8 seconds to respond to, and a 1.09 standard deviation change for the response time for correctly answering the hard G-math questions equating to a 971 millisecond faster response time on questions that initially took five seconds to respond to. They showed improvement on two of the variables classified as measures of the Verbal Learning task with a 0.05 standard deviation change for recalling the words from the second lists of the Verbal Learning task equating to 0.04 more words correctly recalled per eight word list where 4.7 words were initially recalled and a 0.44 standard deviation change for recalling the words from the third list of the Verbal Learning task equating to 0.5 more words correctly recalled per eight word list where 4 words were initially recalled. They improved on one variable classified as a measure of visuo-spatial working memory capacity with a 0.62 standard deviation change on the Block Span task equating to an 18% score increase, one variable classified as a measure of verbal working memory capacity with a 0.62 standard deviation change for the recall portion of the Reading Span task equating to five more

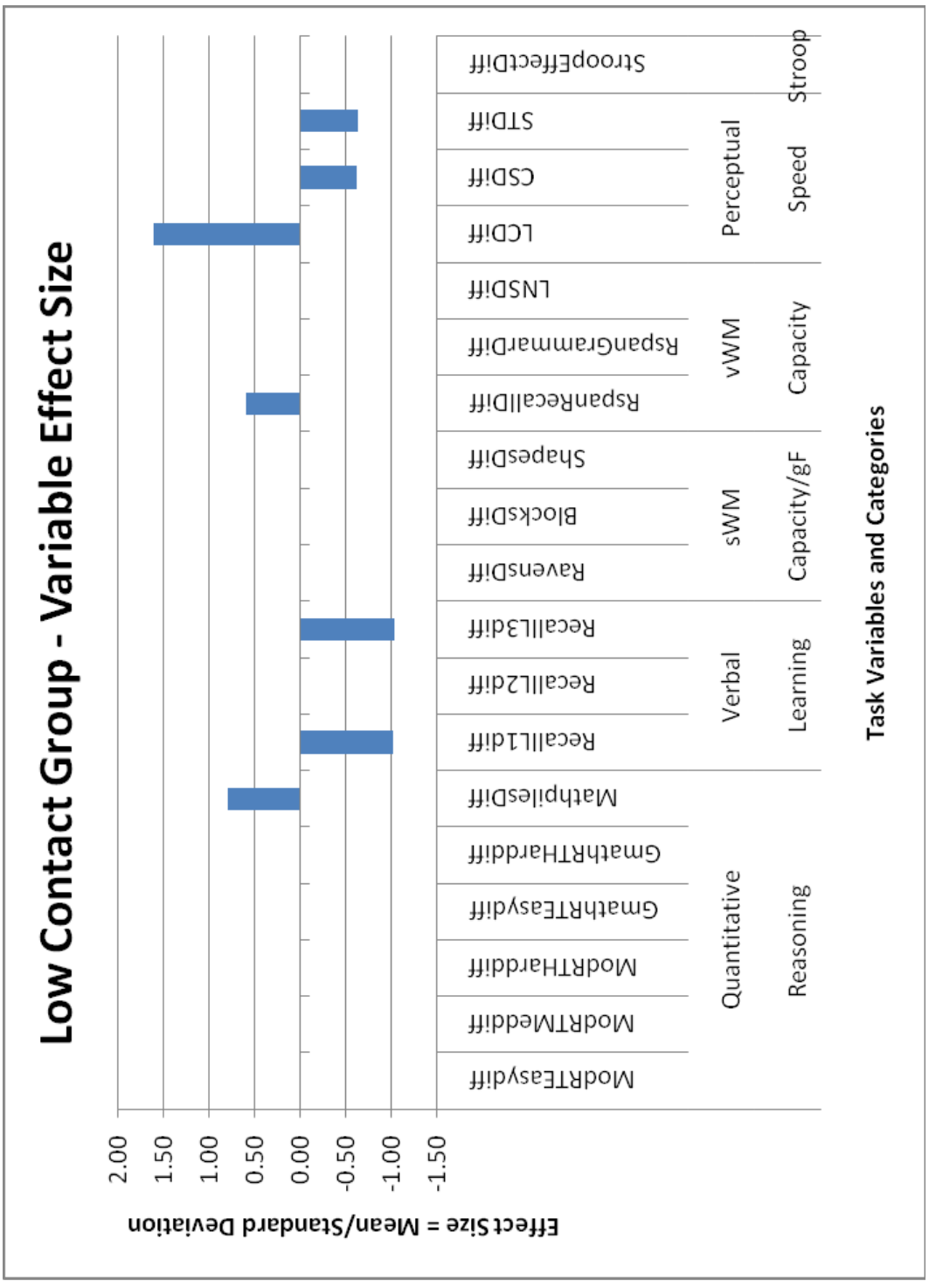
correctly recalled words out of 60 presented, and one variable classified as a measure of perceptual speed with a 1.53 standard deviation change on the Letter Comparison task equating to 10 more correctly identified identical letter sequences. They also showed improvement on the one variable classified as a measure of interference resolution, with a 0.45 standard deviation change on the Stroop task equating to a 155 millisecond faster difference in response time between the incongruent trials and the baseline trials, which had an initial difference of 200 milliseconds.

Figure 42: Math and Reading Comprehension Group Variable Effect Sizes.



As seen in Figure 43, the low contact group, which consisted of people who dropped out of the study before completing significant training (a maximum of 10 sessions and an average of 3.8 +/- 2.9), showed rather variable results from pretest to post-test. The participants showed improvement on one variable classified as a measure of quantitative reasoning with a 0.80 standard deviation change on the Number Piles task equating to a 14% score increase, one variable one variable classified as a measure of verbal working memory capacity with a 0.60 standard deviation change for the recall portion of the Reading Span task equating to five more correctly recalled words out of 60 presented, and one variable classified as a measure of perceptual speed with a 1.60 standard deviation change on the Letter Comparison task equating to 8 more correctly identified identical letter sequences. They showed a decrease in performance on two of the variables classified as measures of the Verbal Learning task with a -1.02 standard deviation change for recalling the words from the first lists of the Verbal Learning task equating to one fewer words correctly recalled per eight word list where six words were initially recalled and a -1.04 standard deviation change for recalling the words from the third list of the Verbal Learning task equating to one fewer words correctly recalled per eight word list where 4.8 words were initially recalled. They also showed a decrease in performance on two of the variables classified as measures of perceptual speed with a -0.62 standard deviation change on the Canceling Symbols task equating to six fewer *c*'s or *d*'s correctly identified and a -0.62 standard deviation change on the Summing to Ten task equating to three fewer pairs of numbers summing to 10 being correctly identified.

Figure 43: Low Contact Group Variable Effect Sizes.



In summary, the effect size graphs above indicate that the Working Memory group showed improvement mostly on working memory capacity tasks and a little

improvement on some measures of quantitative reasoning. The Math and Reading Comprehension group showed significant improvement on measures of quantitative reasoning and interference resolution and a little improvement on some measures of working memory capacity, perceptual speed, and the verbal learning task. The Low Contact group had mixed results, showing improvement on some measures of quantitative reasoning, verbal working memory capacity, and perceptual speed, but also showing decreases on measures of perceptual speed and the Verbal Learning task. It is important to note that all three groups showed similar improvement on the recall portion of the Reading Span task and on the Letter Comparison task, possibly indicating that either the training did not actually affect these (as the low contact group had the same improvement) or that there is some confounding variable that resulted in the Low Contact group improving as much as the training groups.

Chapter 5: Conclusion

In the present study, we compared two cognitive training paradigms for their effects on measures of quantitative reasoning, visuo-spatial and verbal working memory, perceptual speed, interference, and fluid intelligence. One training intervention targeted working memory with the adaptive working memory tasks Block Span and Shape Builder. The other targeted math and reading comprehension with the Sentencical and Number Piles non-adaptive reading comprehension and arithmetic tasks.

We used correlations and an exploratory factor analysis to identify relationships between previously validated measures of cognitive abilities (Letter Comparison, Canceling Symbols, Summing to Ten, Ravens Progressive Matrices, Reading Span, Verbal Learning, Stroop, and Modular Arithmetic), lesser-known measures of working memory (Block Span and Letter Number Sequencing), and three new tasks presented for the first time in this study (G-math, Number Piles, and Shape Builder). We confirmed that Block Span measures visuo-spatial working memory and Letter Number Sequencing measures verbal working memory. We validated G-Math and Number Piles as measures of quantitative reasoning. We also report Shape Builder as a tool to measure visuo-spatial working memory with elements of verbal working memory.

We constructed several correlation tables to identify tasks that would be affected by the training. The first correlation table, constructed with the non-quantitative reasoning tasks, validated Shape Builder and Block Span as measures of working memory. Shape Builder and Block Span both correlate with Letter Number

Sequencing, Verbal Learning, Summing to Ten, and Ravens Progressive Matrices. Individually, Shape Builder correlates with Rspan Grammar and Block Span correlates with Rspan Recall. Based on these relationships, we expected participants' performance on tasks correlated with the training tasks to improve.

Similarly, the second correlation table comparing the quantitative reasoning tasks show that G-math (easy and hard) and Number Piles correlate strongly with Modular Arithmetic, our previously validated quantitative reasoning task.

The third correlation matrix between the quantitative reasoning and non-quantitative reasoning tasks demonstrated the relationships between Number Piles and the non-math tasks as well as a relationship between Shape Builder and Block Span and the math measures. Number Piles correlates with Summing to Ten, Verbal List 1 and List 2 Recall, Rspan Recall, Letter Comparison, Ravens, Shapes, Blocks, and Letter Number Sequencing. Meanwhile, Shape Builder and Block Span correlate strongly with every math measure. Based on this, we expect participants training with Number Piles to improve on the above correlated measures. We also expect participants who trained with Shape Builder and Block Span to improve on the math measures. However, since Shape Builder and Block Span are adaptive working memory tasks, we expect the training gains from these tasks to be more significant and to show more significant transfer to the other correlated measures.

The exploratory factor analysis allowed us to group all of our measures by the cognitive constructs they taxed. We expect that tasks that load on the same construct will show even greater transfer than tasks simply identified through the correlation matrix. Based on the factor analysis, Shape Builder and Block Span load heavily on

the visuo-spatial working memory/general fluid intelligence factor, a factor shared with Ravens Progressive Matrices. Therefore, we expected to see an increase in performance on Ravens Progressive Matrices in participants who trained on Shape Builder and Block Span (Shelton, Elliott, Matthews, Hill, & Gouvier, 2010). In addition to the visuo-spatial working memory/fluid intelligence factor, Shape Builder also loads on verbal working memory. Rspan Recall, Rspan Grammar, and Letter Number Sequencing also load on this factor; therefore we expect to see improvement on these measures of verbal working memory through training on Shape Builder. Similarly, Number Piles loaded on the quantitative reasoning factor along with Modular Arithmetic (easy, medium, hard) and G-math (easy, hard) as well as partial loadings from Summing to Ten and Letter Comparison. Therefore, we expected participants' performance on these tasks to increase with improved performance on Number Piles.

The Block Span group improved performance on both the recall and grammar portions of Reading Span, Shape Builder, Block Span, Letter Number Sequencing, the easy difficulty problems of Modular Arithmetic, and Letter Comparison. Despite these improvements, they only showed greater improvement than the Sentencical group on Shape Builder and Block Span presumably because of the extensive training they received on the tasks. They improved more than the Low Contact group on Shape Builder, Block Span, and recalling the List 1, List 2, and List 3 words from Verbal Learning.

The Sentencical group improved performance on the recall portion of Reading Span, Block Span, Stroop, Number Piles, the easy and medium difficulty problems of

Modular Arithmetic, the hard difficulty problems of G-math, and recalling the List 2 and List 3 words from Verbal Learning. They only improved more than the Block Span group on Number Piles, presumably because of the extensive training they received on the task. They improved more than the Low Contact group on Number Piles, Stroop, and recalling the List 1, List 2, and List 3 words from Verbal Learning.

The Low Contact improved performance on the recall portion of Reading Span, Block Span, Number Piles, and Letter Comparison. They performed worse on Canceling Symbols, Summing to Ten, and recalling the List 1 and List 3 words from Verbal Learning. The Low Contact group did not improve more than any other group on any of the tasks.

Our study found transfer effects in all groups to be limited. Both adaptive working memory training and non-adaptive arithmetic training led to improvement on trained tasks, and near transfer to other measures of the trained constructs. The Working Memory group improved on five measures of working memory: two of which were the training tasks, and three of which were untrained tasks. The Math and Reading Comprehension group improved on four measures of math ability: one of which was the training task, and three of which were untrained. This provides further evidence for near transfer of working memory training found by previous studies (Chein et al., 2010). The Working Memory group improved more on the Block Span and Shape Builder tasks than either the Math and Reading Comprehension group or the Low Contact group. This was expected, as the Math and Reading Comprehension group did not train on these tasks and the Low Contact group did not receive as much training as the Working Memory group. Interestingly, both the Working Memory

group and the Math and Reading Comprehension group demonstrated more improvement on the Verbal Learning task than the Low Contact group, as the Low Contact group actually decreased performance on all measures of Verbal Learning. The training tasks, as well as the factors they loaded on, correlated well with the Verbal Learning recall variables and the Verbal Learning task factor. This, in combination with the results, led to the conclusion that training on either visuo-spatial working memory tasks or quantitative reasoning tasks can lead to improvement on the recall portion of the Verbal Learning task.

Recent literature reviews have outlined criteria specific to working memory training research, which we have attempted to take into account when designing our experiment. Multiple measures of various aspects of intelligence (working memory, fluid intelligence, quantitative reasoning, etc.) were utilized in accordance with criteria found in the literature in order to ensure the measurements were reliable across multiple testing administrations. Reviews suggested testing long-term effects of working memory training: however, our study lacked the resources for such an extended research program. Long-term maintenance of working memory training could be an interesting direction for future research. Criteria included controlling for history (events in the participants lives that occur between pre and post-tests) and maturation (changes in participants due to time). We attempted to control for these factors by recruiting mostly college students, increasing the similarity between participants in both age and environment. Reviews further suggest controlling for the test-retest effect, that participants will improve performance on the post-test simply because they already performed the tasks on a pre-test. This effect was controlled for

by including both the Math and Reading Comprehension group and the Low Contact group as a point of comparison for the Working Memory group. We were not simply measuring improvement, but comparative improvement between groups. (Shipstead et al., 2010).

One of our primary interests in this study was to demonstrate that working memory training improves performance on general cognitive abilities. We were especially interested in showing that working memory training improved quantitative reasoning, as this would demonstrate a tangible benefit of training beyond psychometric testing. We intended the Working Memory training condition to be our experimental intervention, with the Math and Reading Comprehension training condition to be an active control group and participants who dropped from the training portion of the study as a Low Contact condition. We believed the Math and Reading Comprehension condition would sufficiently control for placebo effects and any affect we would have on the participants by interacting with them (Shipstead, et al., 2010). Because these tasks failed to meet several of the criteria outlined in depth in our literature review, we did not originally expect these tasks to have a training effect. First, these tasks are not adaptive and thus do not continually challenge participants to perform at maximum capacity. Second, we did not believe these tasks would train general information processing abilities, such as working memory, to a significant extent. By not meeting these criteria, we felt that the tasks would adequately control for the placebo effect, the Hawthorne effect, the time spent with the experimenters and the perceived expectations of the experimenters without significantly training them.

Surprisingly, the non-adaptive Math and Reading Comprehension training did affect participants' performance on the quantitative reasoning measures. It is also possible that our quantitative reasoning measures were too simple and thus were merely measures of the participants' ability to perform mental arithmetic instead of a true quantitative reasoning task, which would place a greater load on working memory and fluid intelligence (Meyer et al., 2010; O'Boyle et al., 2005).

Future researchers should take note of the limitations of our study. The Low Contact group was not defined until they study was well under way, leaving it as an ambiguous condition. Because the group was defined post hoc, we cannot be sure of what types of people this group consists. The reasons the individuals in this group failed to complete the training are unknown: this could be due to a number of uncontrolled variables. The reasons could include some or all of the following; boredom, stress, excessive work load, etc. These participants may have fallen victim to negative expectations: since the participants were told they would improve with training, and did not complete the training, they may have performed according to the inverse expectation (poor performance). As both adaptive and non-adaptive training paradigms led to improvements on both trained tasks and near transfer, future research could investigate adaptivity as a potential variable in working memory training. Comparing adaptive and non-adaptive versions of the same training tasks could be an effective means of verifying whether adaptivity is the critical factor to improve general cognitive functioning. Although recent reviews of working memory plasticity literature suggest using an active (contact) control group, it would be prescient for future studies to include a no-contact control group as well to account

for any effect low-contact control training may have (Buschkuehl et al., 2010; Conway et al., 2010; Klingberg et al., 2010; Shipstead et al., 2010). The Math and Reading Comprehension group, originally intended to be an active control group, performed an arithmetic training task, which incidentally led to improvements on other math tasks. Future studies should include a control group without an arithmetic training task as a comparison. Our training schedule was very flexible. Participants were able to train at home on their own time at their own pace, as long they completed the required number of sessions. Perhaps future studies could test the effect of a more regulated training regimen, with strictly scheduled training in a controlled environment.

Our research provides further evidence of the efficacy of adaptive working memory training for improving working memory specifically; however, it also offers support for the ability of non-adaptive arithmetic and reading comprehension training to improve general math ability as well as interference resolution. Considering our sample – undergraduate students whose education and experience may result in less mutable working memory capacity and cognitive abilities, thus the least likely group to show change through training – even though significant transfer effects were not observed, the fact that some transfer effects were observed leads to the conclusion that working memory training is effective and may have a larger effect on other populations. As well as presenting Number Piles and G-math as measures of quantitative reasoning and Shape Builder as a measure of both visuo-spatial and verbal working memory, we are continuing to analyze the enormous amount of data we have obtained by using more complicated methods that look at interactions

between the obtained results, which make finding something significant much more likely. We are also continuing to examine each participant's individual training performance and its relation to their performance on the assessment tasks.

Appendices

IRB Application

Institutional Review Board
Initial Application for Research Involving Human Subjects

Name of Principal Investigator (PI) or Project Faculty Advisor *(NOT a student or fellow)* Michael Dougherty **Tel. No** 301-405-8423

Name of Co-Investigator (Co-PI) **Tel. No**

E-Mail Address of PI mdougherty@psyc.umd.edu **E-Mail Address of Co-PI**

Name and address of contact to receive approval documents

Name of Student Investigator Greg Iannuzzi **Tel. No.** 202-390-7837

E-Mail Address of Student Investigator greg_iannuzzi@hotmail.com

Check here if this is a student master's thesis or a dissertation research project

Department or Unit Administering the Project Gemstone Program

Project Title Cognitive Training.

Funding Agency:

ORAA Proposal ID Number:

Names of any additional Federal agencies providing funds or other support for this research project:

Target Population: The study population will include (Check all that apply):

- ☐ pregnant women
- ☐ minors/children
- ☐ human fetuses
- ☐ neonates
- ☐ prisoners
- ☐ students
- ☐ individuals with mental disabilities
- ☐ individuals with physical disabilities

Exempt or Nonexempt (Optional): You may recommend your research for exemption or nonexemption by checking the appropriate box below. For exempt recommendation, list the numbers for the exempt category(s) that apply. Refer to pages 6-7 of this document. Category 2 is exempt.

☐ **Exempt----List Exemption Category(s)** ***Or*** ☐ **Non-Exempt**

If exempt, briefly describe the reason(s) for exemption.

Date **Signature of Principal Investigator or Faculty Advisor**

Date **Signature of Co-Principal Investigator**

Date **Signature of Student Investigator**

Date **REQUIRED** Departmental Signature
Name _____, **Title**_____
(Please also print name of person signing above)

(PLEASE NOTE: The Departmental signature block should not be signed by the investigator or the student investigator's advisor.)

For Internal Use Only (to be completed by the IRB Office) Application #:

Instructions for Completing the Application

The Departmental Signature block should be signed by the IRB Liaison or Alternate IRB

Liaison unless there is a conflict of interest. If the Department or Unit does not have an IRB Liaison, the Department Head, Unit Head or Designee should sign the application.

Please provide the following information in a way that will be intelligible to non-specialists in your specific participant area.

1. Abstract: Provide an abstract (no more than 200 words) that describes the purpose of this research and summarizes the strategies used to protect human participants. For HHS sponsored or funded research, you must submit a copy of your grant application for review.

   Recent studies have demonstrated a relationship between visuo-spatial skills and quantitative reasoning ability. We seek to examine the extent to which training visuo-spatial working memory improves quantitative reasoning ability and math skill. Such information may have implications in remediating math deficits and performance gaps in the US education system. There are no known or anticipated risks associated with participation in this study. Confidentiality is maintained by assigning each participant a unique ID number. The list matching participant names to their ID numbers will be kept in a locked room in the Decision, Attention, and Memory Lab at the University of Maryland. Data will be kept confidential and individual names will not be directly associated with each participant's name.

2. Participant Selection:

   a. Who will be the subjects? How will you recruit them? If you plan to advertise for subjects, please include a copy of the advertisement.

      We will recruit participants within the University of Maryland student population and community at large in the College Park using the flyer displayed in Appendix A. We will perform this study with as large and diverse a participant pool as is feasible. We will post flyers in various locations throughout the campus.

   b. Will the subjects be selected for any specific characteristics (e.g., age, sex, race, ethnic origin, religion, or any social or economic qualifications)?

      Participants must be at least eighteen years of age to sign the informed consent form. Participants must have normal to corrected vision in order to be able to efficiently complete the computer tasks. Participants must have unimpaired use of their dominant hand and must be native English speakers. Participants can not currently be undergoing treatment or have a history of neurological, neuropsychiatric, or psychiatric disorders. Participants cannot have participated in any current or previous experiments on cognitive training.

      Participants will be asked to fill out a survey in order for us to screen potential participants based on this primary information. Please see

Appendix B.

c. State why the selection will be made on the basis or bases given in 2(b).

Impaired use of the dominant hand or a lack of proficiency in English can lead to varying response time when participants complete the computerized tests. People with mental disorders have different cognitive functions and need to be excluded from the study in order to maintain control over the constructs dictating performance on cognitive tasks. Individuals who have previously participated in a cognitive training experiment cannot participate again because they could have already been trained and obtained sufficient knowledge in the area from the previous study.

d. How many subjects will you recruit?

We hope to recruit a minimum of 50 participants and a maximum of 150 participants.

3. Procedures: What precisely will be done to the subjects? Describe in detail your methods and procedures in terms of what will be done to subjects. How many subjects are being recruited? What is the total investment of time of the subjects? If subjects will complete surveys and/or other instruments on more than one occasion, state this in the procedures section. If you are using a questionnaire or handout, please include a copy within each set of application documents. If you are conducting a focus group, include a list of the questions for the focus group. If you plan to collect or study existing data, documents, records, pathological specimens or diagnostic specimens, state whether the sources are publicly available and if the information will be recorded in such a manner that subjects can be identified, directly or through identifiers linked to the subjects. If you are collecting or studying existing data, describe the dataset and list the data elements that you will extract from the dataset.

Before participants begin the study, participants will be informed that they are participating in an experiment studying visuo-spatial working memory. Participants will be informed about the tasks they will complete and will be given a consent form to read and sign. Members of our research team will be available to answer any questions participants may have. Instructions for completing the tasks will be presented on the computer for each respective task. The study will require subjects to complete a pre-test, training regimen, and post-test. The pre and post-test will each last approximately 120 minutes, during which time they will complete a variety of cognitive tasks. See Appendix A for a list of tasks used.

Once participants have completed the pre-test Decision, Attention Memory Lab at the University of Maryland, they will be randomly assigned into the control and test groups. The test group will use the Adaptive Block Span Task (ABST). Participants are given a software copy of the ABST program on a flash drive in order to allow them to train on their own time for at least ten minutes a day for six

weeks at home. The program itself will log the hours the participant ran the program, completed the training, the participants' responses, and the participants' response times. Subjects will need to connect the flash drive to their computer and access the program from a file on the flash drive. The participant's performance on the ABST will be displayed to allow him/her to assess their performance and keep the participant motivated. These results will also be stored in a file on the flash drive. Upon completion of the training regimen, the participants will submit their flash drives to us so that we may compile all of their results. See Appendix B for a description of the ABST. The control group will complete a reading task during the training period to control placebo effects. We will have a follow up session in between the six-week period to touch base with each participant. The post-test will be administered on an individual basis at the Decision, Attention Memory Lab after each participant have completed the six-week training period.

All participants will receive a minimum of $50 for their participation in the study, and will have opportunity to win up to $100 in performance based prizes. See the charts below for participant compensation. Each participant is guaranteed the following:

	Session Hours	payment
Pre-test	2	$20
Follow up	1	$10
Post-test	2	$20

In addition to these above base pay, participants will have the opportunity to win additional money based on their performance. These performance-based incentives will be provided to 8 individuals based on how much their performance on the block-span assessment improves from pre-test to post-test. Because we anticipate the experimental group to show greater improvements, we will administer these performance based incentives separately for the experimental and control conditions: Four individuals in each condition will receive the one of the four prizes listed below based on their improvement on the block-span task.

Greatest Improvement	Experimental	Control
1st	$100	$100
2nd	$75	$75
3rd	$50	$50
4th	$25	$25

After subjects complete the post-test, they will be given the following debriefing statement: You have just participated in a cognitive psychological study. This purpose of this study is to determine the effects of working memory training on mathematical and quantitative reasoning ability. The outcome of this experiment will help us to better understand how the brain functions and will further promote research on enhancing cognitive function.

4. Risks and Benefits: Are there any risks to the subjects? If so, what are these risks including physical, psychological, social, legal and financial risks? Please do not describe the risk(s) as minimal. If there are known risks, please list them. If not, please state that there are no known risks. What are the benefits? If there are

known risks associated with the subject's participation in the research, what potential benefits will accrue to justify taking these risks?

One risk associated with this research is the potential risk of loss of confidentiality. In order to avoid the loss of confidentiality, data collected from this study will not contain any personal identifiers and all individual data will be coded with an anonymous subject identification number.

An additional risk is the potential frustration that might result form performing some of the tasks. Your participation in this research is completely voluntary; you may choose not to participate at any time.

The potential benefit for participants is improvements in mental awareness and cognitive ability. The results of the experiment could provide useful information to the field of cognitive psychology, as well as for education.

5. Confidentiality: Adequate provisions must be made to protect the privacy of subjects and to maintain the confidentiality of identifiable information. Explain how your procedures accomplish this objective, including such information as the means of data storage, data location and duration, description of persons with access to the data, and the method of destroying the data when completed. If the research involves audio taping, videotaping or digital recordings, state who will have access to the tapes or recordings, where the tapes or recordings will be kept, and state the final disposition of the tapes or recordings (i.e. Will the tapes or recordings be destroyed? If so, when will the tapes or recordings be destroyed?). Please note that as per the University of Maryland policy on records retention and disposal, all human subject files, including work done by faculty, staff, and students, must be retained for a period of no less than 10 years after the completion of the research and can then be destroyed. Human subject files include IRB applications, approval notices, consent forms, and other related documents. For more information on records retention, go to: http://www.dbs.umd.edu/records_forms/schedule.php (Faculty and Academic Records) or contact Michelle Solter Evers, Assistant to the Director of Business Services at 301.405.9277 or mevers@mercury.umd.edu.

The experiment will be a single-blind study since participants will not know the group in which they are placed. Each participant will be assigned a unique ID number that will be used for that particular participant throughout the study. Data and participants' identifying information will be kept confidential. We will maintain a log indicating each participants name and ID code. The master list of ID numbers will be stored in a locked room in the Decision, Attention, and Memory Lab at the University of Maryland. This log will be stored separately from the data, and will be destroyed at the conclusion of the study. Data will be archived in the PI's (Dr. Michael Dougherty's) laboratory for a minimum of 10 years after publication, in accordance with the American Psychological Association and NSF guidelines.

6. Information and Consent Forms: State specifically what information will be provided to the subjects about the investigation. Is any of this information deceptive? State how the subjects' informed consent will be obtained. Will you obtain informed consent in a language other than English? If so, list the language(s) in which you will obtain informed consent. Provide consent forms in all languages that will be used. Refer to the attached consent form template, sample consent form and additional consent form guidance on pages 9 to 18. If a consent form has more than one page, please add a signature and date line and the number of pages (*e.g.*, "1 of 2," "2 of 2") to each page. Please allow a 2-inch bottom margin to accommodate the IRB approval stamp. If you plan to obtain consent over the telephone (e.g. consent for a telephone survey), include a copy of the consent script.

Before participants begin the study, participants will be told that they are participating in an experiment studying visuo-spatial working memory. Participants will be informed about the tasks they will complete and will be given a consent form to read and sign. All participants will receive a copy of the consent form for their records. The consent form will be provided only in English. Members of our research team will be available to answer any questions participants may have. Instructions for completing the tasks will be presented on the computer for each respective task. Please refer to the consent form in Appendix

7. Conflict of Interest: Describe the potential conflict of interest, including how such a conflict would affect the level of risk to the study participants. Please consult the University of Maryland policy on conflict of interest as defined by the University of Maryland Policies and Procedures III-1.11and II-3.10. These may be viewed at: http://www.usmh.usmd.edu/Leadership/BoardOfRegents/Bylaws/SectionIII/III111.html. If there is no anticipated conflict of interest, please state "No conflict of interest." This section must be included in your application.

No conflict of interest.

8. HIPAA Compliance: State whether you are using HIPAA protected health information (PHI). Currently, researchers employed by the University of Maryland Center or who are working within or under the auspices of the University Health Center are subject to specific HIPAA requirements regarding the creation, use, disclosure, or access of PHI. Please consult the University of Maryland's Summary of HIPAA's Impact on University Research. For more information on HIPAA, go to: http://www.hhs.gov/ocr/hipaa/ If you are not using HIPAA protected health information, please state "Not Applicable." This section must be included in your application.

Not applicable.

9. Research Outside of the United States: Provide responses to the following questions. Separate responses are required for each country where the research will be conducted. If you are not conducting research outside the U.S., please state "Not Applicable." This section must be included in your application.
   a) Did the investigator(s) previously conduct research in the country where the research will take place? Briefly describe the investigator's knowledge and experience working with the study population.
   b) Are there any regulations, rules or policies for human subjects research in the country where the research will take place? If so, please describe and explain how you will comply with the local human subject protection requirements. The United States Department of Health and Human Services, Office for Human Research Protections (OHRP) has an International Compilation of Human Subject Research Protections with a listing of the laws, regulations and guidelines of over 50 countries. This compilation can be accessed on the OHRP website: http://www.hhs.gov/ohrp/international/HSPCompilation.pdf
   c) Do you anticipate any risks to the research participants in the country where the research will take place, taking into account the population involved, the geographic location, and the culture? If so, please describe, including any physical, psychological, social, legal and financial risks. Do you anticipate that subjects who participate in this research will be placed at risk of criminal or civil liability? If so, please describe.

   Not Applicable

10. Research Involving Prisoners: Provide responses to the following additional IRB criteria for research involving prisoners. If you are not conducting research involving prisoners, please state "Not Applicable." This section must be included in your application.
   a) the research under review represents one of the categories of research permissible described below;
      i. study of the possible causes, effects, and processes of incarceration, and of criminal behavior, provided that the study presents no more than minimal risk and no more than inconvenience to the subjects;
      ii. study of prisons as institutional structures or of prisoners as incarcerated persons, provided that the study presents no more than minimal risk and no more than inconvenience to the subjects;
      iii. research on conditions particularly affecting prisoners as a class (for example, vaccine trials and other research on hepatitis which is much more prevalent in prisons than elsewhere; and research on social and psychological problems such as alcoholism, drug addiction, and sexual assaults); or
      iv. research on practices, both innovative and accepted, which have the intent and reasonable probability of improving the health or well-being of the subject.
   b) any possible advantages accruing to the prisoner through his or her participation in the research, when compared to the general living conditions,

medical care, quality of food, amenities and opportunity for earnings in the prison, are not of such a magnitude that his or her ability to weigh the risks of the research against the value of such advantages in the limited choice environment of the prison is impaired;

c) the risks involved in the research are commensurate with risks that would be accepted by nonprisoner volunteers;
d) procedures for the selection of subjects within the prison are fair to all prisoners and immune from arbitrary intervention by prison authorities or prisoners. Unless the principal investigator provides to the Board justification in writing for following some other procedures, control subjects must be selected randomly from the group of available prisoners who meet the characteristics needed for that particular research project;
e) the information is presented in language which is understandable to the subject population;
f) adequate assurance exists that parole boards will not take into account a prisoner's participation in the research in making decisions regarding parole, and each prisoner is clearly informed in advance that participation in the research will have no effect on his or her parole; and
g) if there is a need for follow-up examination or care of participants after the end of their participation, adequate provision has been made for such examination or care, taking into account the varying lengths of individual prisoners' sentences, and for informing participants of this fact.

Not Applicable.

SUPPORTING DOCUMENTS

Each copy of the application must include the IRB application cover sheet, the information required in items 1-10 above, and all relevant supporting documents including: consent forms, letters sent to recruit participants, questionnaires completed by participants, and any other material germane to human subjects review.

For research funded by the Department of Health and Human Services (DHHS), submit a copy of your HHS grant application. If there are discrepancies between the research proposed in your IRB application and your grant application, include a memo listing these discrepancies and the rationale for them.

NUMBER OF COPIES

Please send 1 original application including the signed cover sheet and 1 copy of the signed, original application unless your research requires full Board Review. For applications which will require review of the full Board, please submit 1 signed original application and seventeen (17) copies. Full Board reviews are required for initial applications involving greater than minimal risk to the subjects (i.e. more risk than subjects would generally encounter in their routine daily activities).
IRB Campus Mailing Address: 2100 Lee Building, Zip -5125.

IRB MEETING DATES AND APPLICATION SUBMISSION DEADLINES

To view the dates for upcoming meetings and the final date for submission of applications to be considered for each meeting, please check the following URL: http://www.umresearch.umd.edu/IRB/IRBdates.html.

STATUS OF THE IRB APPLICATION

You may send an e-mail to irb@deans.umd.edu or call the IRB Office at 301-405-4212 to inquire about the status of an IRB application.

EXEMPTION CATEGORIES

(PLEASE NOTE: Exempt research must be approved by the IRB Manager, Assistant Manager or an IRB Co-Chair before data collection may begin.)

1. Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (a) research on regular and special education instructional strategies, or (b) research on the effectiveness or the comparison among instructional techniques, curricula, or classroom management methods. Research involving surveys or interviews with children does not qualify for exempt review. Also, this exempt category does not apply to research involving the collection of person identifiable data in which any disclosure of the data outside of the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability or reputation.

2. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (a) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (b) any disclosure of the human subject's responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation. Exemption category #2 does not apply to research with children, except for research involving observations of public behavior when the investigator(s) does not participate in the activities being observed. Also, this exempt category does not apply to research involving the collection of person identifiable data in which any disclosure of the data outside of the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability or reputation.

3. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (2) if: (a) the human subjects are elected or appointed public officials or candidates for public office; or (b) Federal statute(s) require(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter. E.g. the research is conducted for the Department of Justice under Federal statute 42 U.S.C. 3789g and the research conducted for the National Center for Education Statistics under Federal statute 20 U.S.C. 12213-1, which provide certain legal protections and requirements for confidentiality.

4. Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

5. Research and demonstration projects which are conducted by or subject to the approval of Department or Agency heads, and which are designed to study, evaluate, or otherwise examine: (a) public benefit or service programs; (b) procedures for obtaining benefits or services under those programs; (c) possible changes in or alternatives to those programs or procedures; or (d) possible changes in methods or levels of payment for benefits or services under those programs.

   If the research is funded by the United States Department of Health and Human Services, the following criteria must be met:

   a) The program under study must deliver a public benefit (e.g., financial or medical benefits as provided under the Social Security Act) or service (e.g., social, supportive, or nutrition services as provided under the Older Americans Act).
   b) The research or demonstration project must be conducted pursuant to specific federal statutory authority.
   c) There must be no statutory requirement that the project be reviewed by an Institutional Review Board (IRB).

   The project must not involve significant physical invasions or intrusions upon the privacy of participants.

6. Taste and food quality evaluation and consumer acceptance studies, if (a) wholesome foods without additives are consumed or (b) a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the U.S. Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

NOTE: The 6 exemption categories do not apply to research involving prisoners.

CONSENT FORM

Project Title	*Cognitive Training*
Why is this research being done?	*This is a research project being conducted by Team Cognitive Training at the University of Maryland, College Park. We are inviting you to participate in this research project because you are at least 18 years of age and meet the other eligibility requirements. The purpose of this research project is to examine the relationship between how much time people spend on mentally demanding tasks and their performance on measures of cognitive ability and mathematical reasoning.*
What will I be asked to do?	*The procedures involve completing a number of tasks that measure working memory capacity, speed of processing, general fluid intelligence, reading comprehension, and quantitative reasoning abilities.* *Sessions & Schedule:* *You will first be asked to complete a selection of tasks that will take approximately 2 hours. The tasks will be chosen from the following list:* *Testing Response Inhibition:* Stroop: The names of colors will be flashed on a display in various colored text. The color word and color font in which the word is written can be either congruent or incongruent. You must input the color font by rapidly pressing the key corresponding to the correct color font. You must inhibit the response to read the word. Only primary colors will be used. Several keys will be labeled R, B, or Y (for red, blue and yellow, respectively) for use by the dominant hand. Baseline trials will be conducted to determine the time it takes to identify the color. The baseline trials will have a number of characters corresponding to the number of letters in the word. X will be the only character used. Anti-Saccade: You focus on a cue in the center of the display. You must read a character, which is flashed quickly on either the leftmost or rightmost side of the display. This target cue is preceded by a distraction cue on the side of the display opposite the target. The target cue is quickly masked by the rapid succession of characters “H” and “8”. You must then identify the target cue by pressing the key corresponding to the correct character flashed. After you input the target cue, the center cue is displayed to begin the next trial. Time between the center cue and distracting cue is constant. The time

	between distracting cue, target cue, and successive cues is constant. This test will take approximately ten minutes.

	Testing Working Memory: Operation Span: You are presented with a mathematical equation. You are then required to confirm the validity of the solution. You select "true" or "false" to confirm the equation. Immediately following your response, you are shown a letter. After several equations, you are prompted with a screen displaying "?" to input the sequence of letters that were displayed following each equation. You will press T for true or F for false. The following screen will display the letter "N". The next screen will display another equation, followed by another letter. After several equations and letters, a screen displaying "?" will appear, prompting you to recall the letters in the sequence they appeared. This test will take approximately ten minutes. Reading Span: You will read a sentence and evaluates whether or not the sentence is grammatically correct. You will identify the sentence as T for sentences that are correct and F for sentences that are incorrect. After you input you response, a word is displayed on the following screen. Several of these sequences are shown to you before you are prompted to orally recall all the words in the order in which they were displayed. The words are randomized nouns. This test will take approximately ten minutes. *Testing Perceptual Speed:* Canceling symbols: You will scan the page for a single target figure among other simple target figures. This test will take ninety seconds. Summing to Ten: You will be presented with a page filled with a sequence of digits from π and are given five minutes to circle all adjacent pairs that sum to ten. The number of correct pairs found is recorded and the average number of pairs found per minute is calculated. This test will take approximately ninety seconds. Letter Comparison: Two equal length strings of consonant letters run side by side for 200 pairs. The strings are 3-7 letters in length and are either identical or vary by one letter. You will determine whether or not each string is identical for as many strings as can be evaluated in 90 seconds. This test will take approximately ninety seconds.

	Evaluating General Fluid Intelligence and general abilities: **Raven's Standard Progressive Matrices:** This test is a measure of abstract reasoning ability independent of language or schooling. You will be presented with figures and asked to identify the missing segment in order to complete a larger pattern. The missing piece is identified by determining the common theme between the existing figures. Matrices shown are frequently 2x2 or 3x3. This test will take fifteen minutes. **Air Force Officer's Qualifying Test (AFOQT):** The AFOQT will measure reading comprehension. You will read several passages and answer the corresponding questions. This test will take twenty five minutes. Armed Services Vocational Aptitude Battery (ASVAB): The ASVAB will be used as a measure of math ability. The math questions will range from algebra to trigonometry (similar to the SAT's). This test will take twenty five minutes. Math Assessment: This is an assessment of your math ability. The assessment will display several arithmetic computations which yield a single digit answer, 0-9. The test will use the four basic operations: addition, subtraction, multiplication, and division. You will input your answer and will immediately be taken to a screen displaying "Press any key when ready." This test will take ten minutes. **Gauss's M**odular Arithmetic Task: The object of modular arithmetic is to judge the truth value of problem statements such as $51 \equiv 19 \pmod 4$. To do this, the problem's middle number is subtracted from the first number (i.e., 51 – 19) and this difference is divided by the last number (i.e., 32 /4). If the dividend is a whole number (as here, 8), the problem is true. If it does not equal a whole number, the problem is false. SAT Math Questions: You will see questions taken from the math portion of prior SAT tests and SAT exam review guides. You will read the question and input your response. Conjunction Fallacy: You are given a brief description of a certain situation, and then presented with two conditions based on the situation: one more general, and one specific. You are then asked to choose which condition is more probable.

	You will then complete a training regimen over a period of six weeks. The time you spend on it is entirely up to you. The regimen will include the Adaptive Block Span Task or a reading comprehension. *For the Adaptive Block Span Task, you will be asked to perform the following:* You are required to remember the order in which a sequence of black blocks appear in a 4 x 4 grid. Each block will flash one at a time in one of the cells within the grid, and then the entire grid will flash for one second to indicate the end of one sequence and the beginning of a new sequence. After one set of sequences, you will be asked to recall the order of each sequence electronically using a mouse. *For the reading comprehension you will be asked to perform the following:* You will see a sentence on the computer screen, press a key to continue, and then be asked a comprehension question. *Four people who trained with your task will be selected to receive prizes based on your performance improvement in this study. Once the training is complete, you will perform another selection of tasks that will match those described above (see Tasks). The tasks will take approximately 2 hours to complete.*
What about confidentiality?	*We will do our best to keep your personal information confidential. To help protect your confidentiality, all data collected form this study will be associated with you only through your subject identification number. This number will be used to identify you in all paper and computer files, so there will be no means for identifying the responses you give as a part of this experiment with any of your personal information. Only researchers involved in the experiment will have access to subject identification numbers, and this information will be kept in a secure manner. Any data published resulting form this experiment will make no reference to individual subjects and there will be no means by which personal information about you could be acquired form such publications. If we write a report or article about this research project, your identity will be protected to the maximum extent possible. Your information may be shared with representatives of the University of Maryland, College Park or governmental authorities if you or someone else is in danger or if we are required to do so by law.*

What are the risks of this research?	*One risk associated with this research is the potential risk of loss of confidentiality. In order to avoid the loss of confidentiality, data collected from this study will not contain any personal identifiers and all individual data will be coded with an anonymous subject identification number.* *An additional risk is the potential frustration that might result form performing some of the tasks. Your participation in this research is completely voluntary; you may choose not to participate at any time.*
What are the benefits of this research?	*This research is not designed to help you personally, but the results may help the investigator learn more about working memory and quantitative reasoning. We hope that, in the future, other people might benefit from this study through improved understanding of the cognitive processes involved in quantitative reasoning.*
Do I have to be in this research? May I stop participating at any time?	*Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.*
What if I have questions?	*This research is being conducted by Dr. Michael Dougherty of the Department of Psychology at the University of Maryland, College Park. If you have any questions about the research study itself, please contact:* *Dr. Michael Dougherty, Dept of Psychology, 1145B Biology-Pscyhology Building, College Park, Md, 20742; (email) mdougherty@psyc.umd.edu; (phone) 301-405-0678* *If you have questions about your rights as a research subject or wish to report a research-related injury, please contact:* Institutional Review Board Office, University of Maryland, College Park, Maryland, 20742; (e-mail) irb@deans.umd.edu; (telephone) 301-405-0678 *This research has been reviewed according to the University of Maryland, College Park IRB procedures for research involving human subjects.*

Statement of Age of Subject and Consent	*Your signature indicates that:* *you are at least 18 years of age;,* *the research has been explained to you;* *your questions have been fully answered; and* *you freely and voluntarily choose to participate in this research project.*	
Signature and Date	NAME OF SUBJECT	
	SIGNATURE OF SUBJECT	
	DATE	

Informed Consent

Informed consent is a process, not just a form. Information must be presented to enable persons to voluntarily decide whether or not to participate as a research subject. Therefore, informed consent language and its documentation must be written in language that is understandable to the people being asked to participate. The University of Maryland, College Park Consent Form Template and Sample Consent Form contain the basic elements of informed consent as identified in and required by the Federal Policy for the Protection of Human Subjects, 45 CFR 46.

Research Involving Minors

For research involving individuals under the age of 18, include a Parental Permission Form to ask parents for consent to the participation of their child and an Assent Form to ask the minors if they agree to participate in the research, depending on whether the children are capable of assenting. The Parental Permission form should contain all of the elements of the sample consent form and the consent form template provided with the IRB application. However, the parental permission form should be written in language appropriate for parents granting permission for their child's involvement rather than as though they themselves will be participating (e.g. we are inviting your child to participate the risks to your child's participation include). When determining whether the children are capable of assenting, take into account the ages, maturity, and psychological state of the children involved. Assent forms should be written in age-appropriate language.

Research Involving Individuals with Impaired Decision-making Capacity

Using the Informed Consent Form Template, prepare a consent form to ask the research subject's authorized representative for consent to the participation of the research subject. Prepare an assent form to ask the research subjects if they agree to participate in the research, depending on whether the subjects are capable of assenting. When determining whether the subjects are capable of assenting, take into account the decision-making capacity of the research subjects.

Certificate of Confidentiality

We will do our best to keep your personal information confidential. To help protect your confidentiality, _____ _____ *[Include a description of the procedures to maintain the confidentiality of the data, e.g. having locked filing cabinets and storage areas, using identification codes only on data forms, and using password-protected computer files.*
For anonymous records, state those names and other identifiers will not be placed on surveys or other research data. For coded identifiable information, state the following, if applicable (1) your name will not be included on the surveys and other collected data; (2) a code will be placed on the survey and other collected data; (3) through the use of an identification key, the researcher will be able to link your survey to your identity; and (4) only the researcher will have access to the identification key.] If we write a report or article about this research project, your identity will be protected to the maximum extent possible.

To help us further protect your privacy, we have obtained a Certificate of Confidentiality from _____ [Name of agency issuing the Certificate of Confidentiality]. With this Certificate, the researchers cannot be forced to disclose information that may identify you, even by a court subpoena, in any federal, state, or local civil, criminal, administrative, legislative, or other proceeding. We may, however, release identifying information in some circumstances. For example, the Certificate cannot be used to resist a demand for information from personnel of the United States Government that is used for auditing or evaluation of federally funded projects or for information that must be disclosed in order to meet the requirements of the federal Food and Drug Administration (FDA).

You should also understand that a Certificate of Confidentiality does not prevent you or a member of your family from voluntarily releasing information about yourself or your involvement in this research. If an insurer, employer, or other person obtains your written consent to receive research information, then the researchers may not use the Certificate to withhold that information.

The Certificate of Confidentiality also does not prevent the researchers from voluntarily disclosing identifying information, and the researchers may notify appropriate individuals and/or authorities if information comes to their attention concerning child abuse or neglect or potential harm to you or others. [Modify as needed to include any other conditions under which disclosure would be made (e.g., abuse or neglect of the developmentally disabled or vulnerable adults, reportable communicable diseases, etc.). If no such disclosures will be made, the researchers should provide an explanation in the IRB Application.]

Participant Survey

PARTICIPANT #:_____

Age:_____

Race/Ethnicity (please circle one): Black or African American
White
American/ Pacific Islander
Latino/a or Hispanic
Other or Not Reported

Education (please circle one): Some High School Major:
High School Diploma
Bachelor Degree
Masters Degree

How many hours per week do you engage in:

- Rubik's cube _____hours per week
- Online computer games _____hours per week
- Puzzle/visual games _____hours per week
- Gaming console (X-box, Playstation, Nintendo) _____hours per week
- Reading _____hours per week
- Mathematics _____hours per week

Have you ever participated in a cognitive training experiment? YES NO

Have you ever had head trauma or a concussion? YES NO

Have you been diagnosed with any psychotic disorder? (please circle all that apply)

- None
- Attention Deficit Disorder (ADD)
- Attention Deficit Hyperactive Disorder (ADHD)
- Depression
- Schizophrenia
- Bipolar Disorder
- Obsessive Compulsive Disorder (OCD)
- Other (please specify):_____

Do you own your own computer? YES NO

Do you have normal or normal to corrected vision? YES NO

Are you right or left handed? RIGHT LEFT

The Mental Challenge – Exit Survey

What strategies did you use while playing the game?

What motivated you to play the game?

Do you play chess, Tetris, or other spatial games?

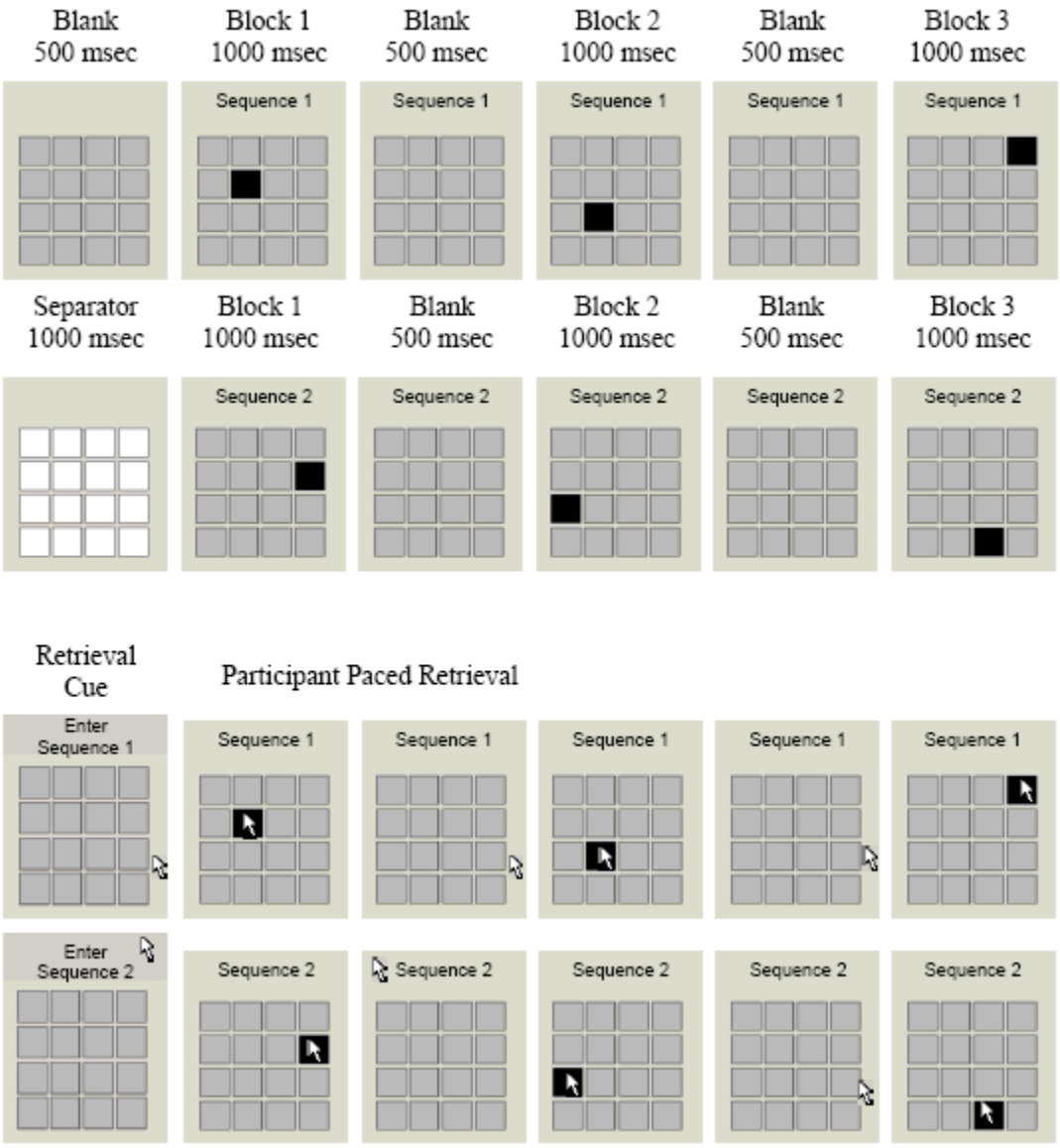
What did you enjoy about this study? Which games did like the most? Why?

What did you not enjoy about this study? Which games did you like the least? Why?

Additional Questions/Comments/Concerns:

Appendix A:

In the Adaptive Block Span Task (ABST), participants are required to remember the order in which a sequence of black blocks appear in a 4 x 4 grid. Each block will flash one at a time in one of the cells within the grid, and then the entire grid will flash for one second to indicate the end of one sequence and the beginning of a new sequence. After one set of sequences, participants will be asked to recall the order of each sequence electronically using a mouse. The ABST increases or decreases in difficulty according to the participant's performance. Participants are given a software copy of the ABST program in order to allow them to train on their own time for at least ten minutes a day for six weeks at home. The program itself will log the hours the participant ran the program, completed the training, the participants' responses, and the participants' response times. Participants will see screen such as:



In the control group, participants in the control condition will be given a simple reading task that requires reading several sentences and answering questions aimed at testing whether the participant correctly comprehended the sentence. This task will be administered in the same manner as the block-span training task. Participant will see a sentence on the computer screen, press a key to continue, and

then be asked a comprehension question. For example, participants will see a screen displaying the following sentence:

The gossipy neighbor heard the story had never actually been true.

Participants will press the Enter key and will then see a screen asking them:

Did the story turn out to be false?

Participants will press Y for yes and N for No

Appendix B:

Testing Response Inhibition:

Stroop: The names of colors will be flashed on a display in various colored text. The color word and color font in which the word is written can be either congruent or incongruent. The subject must input the color font by rapidly pressing the key corresponding to the correct color font. The subject must inhibit the response to read the word. Only primary colors will be used. Several keys will be labeled R, B, or Y (for red, blue and yellow, respectively) for use by the dominant hand. Baseline trials will be conducted to determine the time it takes to identify the color. The baseline trials will have a number of characters corresponding to the number of letters in the word. X will be the only character used. For example, XXX is the baseline trial for red. The test will consist of 75% congruence, 12.5% incongruence and 12.5% baseline trials. This test will take approximately ten minutes. The screens the participants will see will look like the following:

RED, the participant will need to press Y

GREEN, the participant will need to press R

RED, the participant will need to press R

YELLOW, the participant will need to press B

Anti-Saccade: The subject focuses on a cue in the center of the display. The subject must read a character, which is flashed quickly on either the leftmost or rightmost side of the display. This target cue is preceded by a distraction cue on the side of the display opposite the target. The target cue is quickly masked by the rapid succession of characters "H" and "8". The subject must then identify the target cue by pressing the key corresponding to the correct character flashed. After subject inputs the target cue, the center cue is displayed to begin the next trial. Time between the center cue and distracting cue is constant. The time between distracting cue, target cue, and successive cues is constant. This test will take approximately ten minutes.

Testing Working Memory:

Operation Span: The participant is presented with a mathematical equation. The participant is then required to confirm the validity of the solution. The participant selects "true" or "false" to confirm the equation. Immediately following their response, the subject is shown a letter. After several equations, the subject is prompted with a screen displaying "?" to input the sequence of letters that were displayed following each equation. For example, screen one will prompt:

Is 4 x 3 / 2 – 5 = 1?

True/False

Participant will press T for true or F for false. The following screen will display the letter "N". The next screen will display another equation, followed by

another letter. After several equations and letters, a screen displaying "?" will appear, prompting participants to recall the letters in the sequence they appeared. This test will take approximately ten minutes.

Reading Span: The subject reads a sentence and evaluates whether or not the sentence is grammatically correct. Subjects will identify the sentence as T for sentences that are correct and F for sentences that are incorrect. After the subject inputs their response, a word is displayed on the following screen. Several of these sequences are shown to the subject before they are prompted to orally recall all the words in the order in which they were displayed. The words are randomized nouns. This test will take approximately ten minutes. Participants will see screens such as:

Evaluate the following sentence for grammatical correctness.

The dog ran down the street and jumped the fence. Correct/Incorrect?

D

The cat walk into the house quietly. Correct/Incorrect?

K

Testing Perceptual Speed:

Canceling symbols: Subjects scan the page for a single target figure among other simple target figures. For instance, subjects can be asked to identify specific letters within a text. This test will take ninety seconds. For example, if participants were asked to locate the letter “s” within the first sentence of this paragraph, the response would be similar to this:

Canceling symbols: Subjects scan the page for a single target figure among other simple target figures

Summing to Ten: Participants are presented with a page filled with a sequence of digits from π and are given five minutes to circle all adjacent pairs that sum to ten. The number of correct pairs found is recorded and the average number of pairs found per minute is calculated. Two different sheets will be made from different selections of π digits. 50% of participants will use one sheet on the pre-test and 50% will use the other. On the post-test, participants will take the opposite sheet. This test will take approximately ninety seconds. Participants will be given papers that look like the following:

14159265358979323846264338327950288419716939937510582097494459230781640628620899862803482534211706798214808651328230664709384460955058223172535940812848111 7

Subjects will circle adjacent pairs as follows:

14159265358979323(46)2(64)338327950(28)84(19)7169399(37)5105(82)0974944592307(64)06(28)62089986(28)034(82)53421170679(82)148086513(28)2306(64)709384(46)09(55)05(82)2317253594081(28)481117

Letter Comparison: Two equal length strings of consonant letters run side by side for 200 pairs. The strings are 3-7 letters in length and are either identical or vary by one letter. The participant is asked to determine whether or not each string is identical for

as many strings as can be evaluated in 90 seconds. This test will take approximately ninety seconds.

Evaluating General Fluid Intelligence and general abilities:

Raven's Standard Progressive Matrices is a measure of abstract reasoning ability independent of language or schooling. Participants are presented with figures and asked to identify the missing segment in order to complete a larger pattern. The missing piece is identified by determining the common theme between the existing figures. Matrices shown are frequently 2x2 or 3x3. This test will take fifteen minutes.

Air Force Officer's Qualifying Test (AFOQT): The AFOQT will measure reading comprehension. Participants will read several passages and answer the corresponding questions. This test will take twenty five minutes.

Armed Services Vocational Aptitude Battery (ASVAB): The ASVAB will be used as a measure of math ability. The math questions will range from algebra to trigonometry (similar to the SAT's). This test will take twenty five minutes.

Math Assessment: We will develop an assessment of math ability for use in both the pre and post-tests. The assessment will display several arithmetic computations which yield a single digit answer, 0-9. The test will use the four basic operations: addition, subtraction, multiplication, and division. The participant will input their answer and will immediately be taken to a screen displaying "Press any key when ready." Time and accuracy will be used to evaluate the subject's performance. Results will be interpreted with respect to difficulty, which will be tentatively determined by the number of manipulations (total manipulations per problem is 3-7),

the types of manipulations, and the number of digits in each term. Guttmann scaling will be used to make final adjustments to problem difficulty after the tests have been administered. This test will take ten minutes.

Gauss's modular arithmetic task: The object of modular arithmetic is to judge the truth value of problem statements such as $51 \equiv 19 \pmod 4$. To do this, the problem's middle number is subtracted from the first number (i.e., 51 – 19) and this difference is divided by the last number (i.e., 32 /4). If the dividend is a whole number (as here, 8), the problem is true. If it does not equal a whole number, the problem is false.

SAT Math Questions: Questions will be taken from the math portion of prior SAT tests and SAT exam review guides. These questions will be used to assess performance on a variety of mathematical reasoning skills covered by the SAT. Questions may be altered so that responses are open ended rather than multiple choice.

Conjunction Fallacy: The participant is given a brief description of a certain situation, and then presented with two conditions based on the situation: one more general, and one specific. The participant is then asked to choose which condition is more probable.

CITI Collaborative Institutional Training Initiative

Course In The Protection of Human Subjects Curriculum Completion Report
Printed on 1/28/2011

Learner: Jacob Buchanan (username: abuttfor)
Institution: University of Maryland Baltimore
Contact Information Department: Psychology
Phone: (301) 405-8276
Email: jbuchanann@gmail.com

Group 2.Social / Behavioral Research Investigators and Key Personnel:

Stage 2. Refresher Course Passed on 01/14/10 (Ref # 3971751)

Required Modules	Date Completed	Score
Refresher Course 101 Introduction	01/13/10	no quiz
SBR 101 REFRESHER MODULE 1. History and Ethics	01/13/10	5/5 (100%)
SBR 101 REFRESHER MODULE 2. Regulatory Overview	01/13/10	5/5 (100%)
SBR 101 REFRESHER MODULE 3. Fundamental Issues.	01/14/10	3/5 (60%)
SBR 101 REFRESHER MODULE 4. Vulnerable Subjects	01/14/10	4/4 (100%)
SBR 101 REFRESHER MODULE 5. Additional Topics	01/14/10	4/5 (80%)
How to Complete The CITI Refresher Course and Receive the Completion Report	01/14/10	no quiz

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

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

Return

Jacob Buchanan (Member ID: 1559857)

CITI Collaborative Institutional Training Initiative

Modules Completed

You have viewed all the modules listed in the table below. The modules shown in green are complete; you have taken the exam or the module does not have an exam. Modules shown in black have an exam, but you have not taken it.

Module ID	Module	Module Completed	Date Last Completed	Exam ID	Exam Date	Date Module Viewed
943	How to Complete The CITI Refresher Course and Receive the Completion Report	Yes	1/14/2010 3:45:14 PM	no module exam		01/14/10
960	Refresher Course 101 Introduction	Yes	1/13/2010 1:23:36 PM	no module exam		01/13/10
936	SBR 101 REFRESHER MODULE 1. History and Ethics	Yes	1/13/2010 1:43:05 PM	31865348	01/13/10	01/13/10
937	SBR 101 REFRESHER MODULE 2. Regulatory Overview	Yes	1/13/2010 2:00:57 PM	31866453	01/13/10	01/13/10
938	SBR 101 REFRESHER MODULE 3. Fundamental Issues.	Yes	1/14/2010 12:58:04 PM	31904879	01/14/10	01/14/10
939	SBR 101 REFRESHER MODULE 4. Vulnerable Subjects	Yes	1/14/2010 1:28:56 PM	31906406	01/14/10	01/14/10
940	SBR 101 REFRESHER MODULE 5. Additional Topics	Yes	1/14/2010 3:40:40 PM	31914352	01/14/10	01/14/10

CITI Collaborative Institutional Training Initiative

Students conducting no more than minimal risk research Curriculum
Completion Report
Printed on 1/27/2011

Learner: Timothy Briner (username: tbriner)
Institution: University of Maryland College Park
Contact Information Department: Psychology
Email: tbriner@umd.edu

Students - Class projects: This course is appropriate for students doing class projects that qualify as "No More Than Minimal Risk" human subjects research.

Stage 1. Basic Course Passed on 01/22/10 (Ref # 4012247)

Required Modules	Date Completed	Score
Belmont Report and CITI Course Introduction	01/17/10	3/3 (100%)
Students in Research - SBR	01/22/10	10/10 (100%)
You want to be an IRB Community Member, Now what?	01/21/10	4/5 (80%)
University of Maryland College Park	01/21/10	no quiz

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Professor, University of Miami
Director Office of Research Education
CITI Course Coordinator

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CITI Collaborative Institutional Training Initiative

Social & Behavioral Research - Basic/Refresher Curriculum Completion Report
Printed on 1/27/2011

Learner: Timothy Briner (username: tbriner)
Institution: University of Maryland College Park
Contact Information Department: Psychology
Email: tbriner@umd.edu

Social & Behavioral Research - Basic/Refresher: Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.

Stage 1. Basic Course Passed on 01/21/10 (Ref # 3987777)

Required Modules	Date Completed	Score
Belmont Report and CITI Course Introduction	01/17/10	3/3 (100%)
Students in Research - SBR	01/18/10	6/10 (60%)
History and Ethical Principles - SBR	01/18/10	4/4 (100%)
Defining Research with Human Subjects - SBR	01/18/10	5/5 (100%)
The Regulations and The Social and Behavioral Sciences - SBR	01/18/10	5/5 (100%)
Assessing Risk in Social and Behavioral Sciences - SBR	01/18/10	5/5 (100%)
Informed Consent - SBR	01/20/10	4/4 (100%)
Privacy and Confidentiality - SBR	01/20/10	3/3 (100%)
Research with Prisoners - SBR	01/20/10	4/4 (100%)
Research with Children - SBR	01/20/10	1/4 (25%)
Research in Public Elementary and Secondary Schools - SBR	01/20/10	4/4 (100%)
International Research - SBR	01/20/10	3/3 (100%)
Internet Research - SBR	01/21/10	5/5 (100%)
Research and HIPAA Privacy Protections	01/21/10	1/2 (50%)
Workers as Research Subjects-A Vulnerable Population	01/21/10	4/4 (100%)
Conflicts of Interest in Research Involving Human Subjects	01/21/10	2/2 (100%)
You want to be an IRB Community Member, Now what?	01/21/10	4/5 (80%)
University of Maryland College Park	01/21/10	no quiz

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Social & Behavioral Research - Basic/Refresher Curriculum Completion Report
Printed on 12/12/2010

Learner: Vadim Kashtelyan (username: vkashtelyan)
Institution: University of Maryland College Park
Contact Information Department: Pyschology
Email: vkashtelyan@gmail.com

Social & Behavioral Research - Basic/Refresher: Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.

Stage 1. Basic Course Passed on 01/23/10 (Ref # 3889126)

Required Modules	Date Completed	Score
Belmont Report and CITI Course Introduction	12/27/09	2/3 (67%)
Students in Research - SBR	12/28/09	6/10 (60%)
History and Ethical Principles - SBR	01/23/10	3/4 (75%)
Defining Research with Human Subjects - SBR	01/23/10	4/5 (80%)
The Regulations and The Social and Behavioral Sciences - SBR	01/23/10	5/5 (100%)
Assessing Risk in Social and Behavioral Sciences - SBR	01/23/10	5/5 (100%)
Informed Consent - SBR	01/23/10	4/4 (100%)
Privacy and Confidentiality - SBR	01/23/10	2/3 (67%)
Research with Prisoners - SBR	01/23/10	4/4 (100%)
Research with Children - SBR	01/23/10	4/4 (100%)
Research in Public Elementary and Secondary Schools - SBR	01/23/10	3/4 (75%)
International Research - SBR	01/23/10	3/3 (100%)
Internet Research - SBR	01/23/10	5/5 (100%)
Research and HIPAA Privacy Protections	01/23/10	2/2 (100%)
Workers as Research Subjects-A Vulnerable Population	01/23/10	3/4 (75%)

Conflicts of Interest in Research Involving Human Subjects	01/23/10	1/2 (50%)
You want to be an IRB Community Member, Now what?	01/23/10	5/5 (100%)
University of Maryland College Park	01/23/10	no quiz

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CITI Collaborative Institutional Training Initiative

Social & Behavioral Research - Basic/Refresher Curriculum Completion Report
Printed on 2/15/2011

Learner: Sy-yu Chen (username: syyuchen)
Institution: University of Maryland College Park
Contact Information Department: Psychology
Email: syyu.chen@gmail.com

Social & Behavioral Research - Basic/Refresher: Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.

Stage 1. Basic Course Passed on 01/21/10 (Ref # 4004477)

Required Modules	Date Completed	Score
Belmont Report and CITI Course Introduction	01/08/10	3/3 (100%)
Students in Research - SBR	01/08/10	9/10 (90%)
History and Ethical Principles - SBR	01/20/10	3/4 (75%)
Defining Research with Human Subjects - SBR	01/20/10	4/5 (80%)
The Regulations and The Social and Behavioral Sciences - SBR	01/20/10	5/5 (100%)
Assessing Risk in Social and Behavioral Sciences - SBR	01/20/10	5/5 (100%)
Informed Consent - SBR	01/21/10	4/4 (100%)
Privacy and Confidentiality - SBR	01/21/10	2/3 (67%)
Research with Prisoners - SBR	01/21/10	4/4 (100%)
Research with Children - SBR	01/21/10	4/4 (100%)
Research in Public Elementary and Secondary Schools - SBR	01/21/10	4/4 (100%)
International Research - SBR	01/21/10	2/3 (67%)
Internet Research - SBR	01/21/10	3/5 (60%)
Research and HIPAA Privacy Protections	01/21/10	2/2 (100%)
Workers as Research Subjects-A Vulnerable Population	01/21/10	4/4 (100%)

Conflicts of Interest in Research Involving Human Subjects	01/21/10	1/2 (50%)
You want to be an IRB Community Member, Now what?	01/08/10	5/5 (100%)
University of Maryland College Park	01/08/10	no quiz

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CITI Collaborative Institutional Training Initiative (CITI)

Social and Behavioral Responsible Conduct of Research Curriculum Completion Report
Printed on 2/15/2011

Learner: Sy-yu Chen (username: syyuchen)
Institution: University of Maryland College Park
Contact Information Department: Psychology
Email: syyu.chen@gmail.com

Social and Behavioral Responsible Conduct of Research: This course is for investigators, staff and students with an interest or focus in Social and Behavioral research. This course contains text, embedded case studies AND quizzes.
Stage 1. Basic Course Passed on 01/21/10 (Ref # 4004478)

Elective Modules	Date Completed	Score
Introduction to the Responsible Conduct of Research	01/21/10	no quiz
Research Misconduct 2-1495	01/21/10	5/5 (100%)
Data Acquisition, Management, Sharing and Ownership 2-1523	01/21/10	3/5 (60%)
Publication Practices and Responsible Authorship 2-1518	01/21/10	4/5 (80%)
Peer Review 2-1521	01/21/10	5/5 (100%)
Mentor and Trainee Responsibilities 01234 1250	01/21/10	6/6 (100%)
Conflicts of Interest and Commitment 2-1462	01/21/10	6/6 (100%)
Collaborative Research 2-1484	01/21/10	6/6 (100%)
The CITI RCR Course Completion Page.	01/21/10	no quiz
University of Maryland College Park	01/08/10	no quiz

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

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Professor, University of Miami
Director Office of Research Education

CITI Course Coordinator

CITI Collaborative Institutional Training Initiative

CITI Good Clinical Practice Curriculum Completion Report
Printed on 1/24/2010

Learner: Sydnee Chavis (username: schavis3)
Institution: University of Maryland College Park
Contact Information
6901 Preinkert Dr Apt 6510B
College Park, MD 20740 US
Department: Psychology
Phone: 410-303-6125
Email: schavis@umd.edu

CITI Good Clinical Practice Course: This course is for investigators and staff who conduct FDA regulated research or international research with investigational drugs and devices according to ICH Guidelines.

Stage 1. Basic Course Passed on 01/08/10 (Ref # 3812148)

Required Modules	Date Completed	Score
GCP Introduction	01/08/10	3/3 (100%)
Overview of New Drug Development	01/08/10	4/5 (80%)
International Conference on Harmonisation (ICH): GCP Requirements	01/08/10	2/4 (50%)
FDA Regulated Research and ICH for Investigators	01/08/10	4/5 (80%)
International Conference on Harmonisation - ICH for Investigators	01/08/10	no quiz
Conducting Investigator-Initiated Studies According to FDA Regulations and Good Clinical Practices	01/08/10	2/3 (67%)
Investigator Obligations in FDA-Regulated Clinical Research	01/08/10	3/5 (60%)
Managing Investigational Agents According to GCP Requirements	01/08/10	3/5 (60%)
Conducting Clinical Trials of Medical Devices	01/08/10	3/3 (100%)
Informed Consent-An Ongoing Process	01/08/10	4/4 (100%)
Detection and Evaluation of Adverse Events	01/08/10	4/4 (100%)
Reporting Serious Adverse Events	01/08/10	4/4 (100%)
Audits and Inspections in Clinical Trial	01/08/10	5/5 (100%)
Monitoring of Clinical Trials by Industry Sponsors	01/08/10	7/8 (88%)
Completing the CITI GCP Course	01/08/10	no quiz
University of Maryland College Park	01/08/10	no quiz

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CITI Collaborative Institutional Training Initiative

Students conducting no more than minimal risk research Curriculum
Completion Report
Printed on 1/24/2010

Learner: Sydnee Chavis (username: schavis3)
Institution: University of Maryland College Park
Contact Information
6901 Preinkert Dr Apt 6510B
College Park, MD 20740 US
Department: Psychology
Phone: 410-303-6125
Email: schavis@umd.edu

Students - Class projects: This course is appropriate for students doing class projects that qualify as "No More Than Minimal Risk" human subjects research.

Stage 1. Basic Course Passed on 01/22/10 (Ref # 4009947)

Required Modules	Date Completed	Score
Belmont Report and CITI Course Introduction	01/22/10	2/3 (67%)
Students in Research - SBR	01/22/10	10/10 (100%)
You want to be an IRB Community Member, Now what?	01/22/10	4/5 (80%)
University of Maryland College Park	01/08/10	no quiz

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CITI Collaborative Institutional Training Initiative

Students conducting no more than minimal risk research Curriculum
Completion Report
Printed on 2/27/2011

Learner: Greg Iannuzzi (username: giannuzz)
Institution: University of Maryland College Park
Contact Information Department: Gemstone
Email: giannuzz@umd.edu

Students - Class projects: This course is appropriate for students doing class projects that qualify as "No More Than Minimal Risk" human subjects research.

Stage 1. Basic Course Passed on 01/07/10 (Ref # 3914565)

Required Modules	Date Completed	Score
Belmont Report and CITI Course Introduction	01/07/10	3/3 (100%)
Students in Research - SBR	01/07/10	10/10 (100%)
You want to be an IRB Community Member, Now what?	01/07/10	4/5 (80%)
University of Maryland College Park	01/07/10	no quiz

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

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CITI Course Coordinator

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IRB Addendum

UNIVERSITY OF MARYLAND COLLEGE PARK
Institutional Review Board
Addendum Application

Protocol Number	09-0363
Protocol Title	Cognitive Training
Risk Classification *(check one)*	☐ Greater than Minimal Risk X ☐ Minimal Risk

Principal Investigator	Dr. Michael Dougherty	Email Address	mdougherty@psyc.umd.edu
Address for Approval Letter	Dr. Michael Dougherty Department of Psychology BPS1147	Telephone Number	301-405-8423

Student/Co-Investigators	Greg Iannuzzi, Vadim Kashtelyan, Timothy Briner, Jacob Buchanan, Sydnee Chavis, Sy-yu Chen	Email Address	giannuzzi1@gmail.com
Telephone Number	301 728 1760		

To ensure an accurate and streamlined review of your Addendum Application, please provide the following information:

1) State what is being proposed and where in the protocol and/or consent what was changed.

We propose four modifications to our original proposal:

Modification 1:

In our prior application (pg. 4), we proposed paying participants $20 for their first testing session, $10 for a mid-point testing, and $20 for a post-test. In addition, we proposed to award prizes to the top 4 performers in each condition based on how much they improved their performance from pre-test to post test. The top performers would receive $100, 75, 50, and 25.

Our revised proposal requests permission to change this incentive in the following way. Compensation for the pre-test and post-test will be redistributed so that participants receive $10 for completing the pre-test and $40 for completing the post-test. The mid-point test will be removed from the study entirely. A new incentive will be awarded to encourage participants to purposefully complete the training sessions in timely manner. The new scheme will award ten $50 prizes to the experimental group and to the control group. Participants in each group will earn a ticket to the random drawing for these prizes every time they earn a new high score. Participants will be eligible to win multiple prizes.

Modification 2:

In our prior application, we proposed to post fliers around campus to recruit subjects. In our revised application, we request permission to distribute fliers over e-mail. We would also like to request permission to extend our recruitment to include older adults, including elderly over the age of 65. There is no additional risk associated with using older participants, and there is the potential that these subjects can benefit considerably by improving their memory and attentional awareness through working memory training.

Modification 3:

A new flyer for recruitment has been created as well as an email advertisement to recruit from listserves. A preliminary questionnaire has been added to more efficiently screen participants for eligibility.

Modification 4:

We request permission to send e-mail reminders daily to participants to remind them to stay current in the study and to continue practicing the computer games. The e-mail will include a list of high scores. All scores posted in the e-mail will be anonymous and will not have any identifying information associated with them.

Modification 5:

All participants will receive an information sheet, which provides information about the study, their training task, their log-in and password, requirements for remaining in the study and a compensation scheme.

2) Provide the rationale/justification for the change.

Our previous compensation package does not provide sufficient incentive for participants to complete the individual training program. We hope that adding this incentive will increase the number of training sessions each participant completes and will better demonstrate the benefits of this program. A new flyer will be used to attract participants who have not been interested by our current advertisement. The new flyer will not emphasize computer gaming and will appeal more to the general public. An advertisement on listserves will also reach a wider audience. The preliminary questionnaire will determine subjects' eligibility prior to scheduling appointments.

3) State what impact the change has on risks to participants. Please state the number of currently enrolled participants and if the change in risk will require re-consent. If the changes will not require re-consent, please state why.

The modifications will be implemented in future experiments, so the new incentives and recruitment changes will have no impact on participants currently enrolled in the study. There are currently 39 participants enrolled in our study. The incentive will not increase their risk but will ideally motivate participants to complete the study in a timely manner (approx. 6 weeks).

The new advertisements create no risk for participants.

The questionnaire will make the enrollment process more convenient for participants and allow us to pre-screen the participants.

The e-mail will provide feedback to the participants on their performance in relation to other participants completing the study. The e-mail does not change the risk to the participants in any way.

The inclusion of the information sheet will not pose any additional risk to participants.

*Re-consent will not be necessary as these changes will apply only to future participants.

4) State whether the change has an impact on the scientific integrity of the study, (i.e. decreases, increases, no impact).

The change will INCREASE the scientific integrity of the study by increasing the number of participants who complete the study.

5) List the documents included with the application that have been modified (consent forms, flyers, data collection forms, surveys). State what has been changed in each modified document.

Questionnaire: We are including a questionnaire to screen participants for eligibility.

Flyer: The emphasis on computer games has been removed in favor of emphasis on improved cognitive abilities in order to appeal to a wider audience. We have created two fliers, one for students and one for adults.

Web Announcement text: We are including a web announcement text in order to recruit new participants from campus listserves.

E-mail template: We will be sending individual e-mails to provide feedback to the subjects.

Information sheet.

*A modified IRB application is attached.

IRB Renewal

UNIVERSITY OF MARYLAND COLLEGE PARK
Institutional Review Board
Renewal Application Cover Sheet

Protocol Expiration Date	06/13/10
Protocol Number	09-0363
Protocol Title	Cognitive Training
Risk Classification *(check one)*	☐ Greater Than Minimal Risk ☒ Minimal Risk

Principal Investigator	Michael Dougherty	Email Address	mdougherty@psyc.umd.edu
Address for Approval Letter	1145B Biology-Psychology Building, College Park, MD, 20742	Telephone Number	301-405-0678

Student/Co-Investigators	Greg Iannuzzi	Email Address	giannuzzi1@gmail.com,
Telephone Number	301-728-1760		

REQUIRED SIGNATURES

The Principal Investigator, Co-Investigator, and Student Investigator, in signing this renewal application, certify that they have conducted research in accordance with the IRB-approved protocol and that any consent forms used in connection with the project have been retained by the Principal Investigator unless otherwise indicated in this renewal application.

_____ _____
Principal Investigator or Faculty Advisor Date

_____ _____

Co-Investigator (if applicable) Date

_____ _____

Student Investigator (if applicable) Date

University of Maryland College Park
Institutional Review Board
Renewal Application

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1) Participant Enrollment to Date

– This is required to ensure equitable subject selection according to the populations identified in the approved IRB protocol. If race was not collected as a demographic, please include recruitment numbers in the All Races Included Row. If gender was not collected, please include recruitment numbers under the Total Column. If race and gender were not collected, please include recruitment numbers in the All Races Included/Total cell.

Population (If known)	Adults		Children/Adolescents		Total
	Male	Female	Male	Female	
All Races Included					
White/Caucasian					18
African American					6
Hispanic					
Native American					
Asian/ Pacific Islander					7
Other					12
TOTAL					43

2) Data and Safety Monitoring

- Required for protocols presenting greater than minimal risk. State if project was monitored during the previous approval period and provide a summary of the reviews findings, if any.

Protocol is minimal risk. Project was not monitored during the previous approval period.

3) Open to Enrollment

- State if protocol will remain open to participant enrollment. If not, please state why. Also state the number of participant withdrawals, if any, and the reason for withdrawal.

Protocol will remain open to participant enrollment. 24 participants withdrew from the study because they could not meet the time commitment of the training program.

4) Project Summary

- Provide a summary of the study progress to date. This should include any interim findings (positive/negative), problems encountered, goals for upcoming approval period and a projected completion date (i.e. March 2011).

Thus far, 43 participants have enrolled in the study, 19 of which completed the study. Data from these participants is currently being scored. The primary problem encountered is getting participants to complete the training, which requires continued data collection. By December 2010, wish to have 100 participants complete the training.

5) Problem History

- Provide a summary of any adverse events and/or unanticipated problems involving risks to participants or others. This should also include any participant complaints. Please discuss how these problems were handled.

No adverse events or effects have been encountered or reported by the participants. Participants' only complaint is the time commitment (20 hours over a 6 week period). This has been addressed by allowing participants withdraw from the study without prejudice. Participant enrollment is voluntary, so participants who could not meet the commitment withdrew from the study.

6) Additional Information

- Provide a summary of any relevant literature, additional risks to participation that have been identified and any other relevant information.

No additional risks to participation have been identified.

7) Deviations

- Indicate whether there were deviations to the currently IRB Approved protocol and why these occurred. A deviation is any difference in study conduct from the criteria or activities prescribed in the IRB Approved protocol, which may or may not affect the participants' rights, safety, welfare and/or the integrity of the study.

There were no deviations from the currently IRB Approved protocol which affected the participants' rights, safety, welfare and/or the integrity of the study.

8) Request for Approval of New Changes

- The IRB Office does not recommend submitting Addendum requests during the Continuing Review process as this will increase the turnaround time for these applications. However, if the requested modifications are minor (for example: editorial or research staff changes) please make the changes to the appropriate section of the protocol and clearly identify the changes in the box below.

The IRB Addendum Request for this protocol has already been approved. No additional changes are requested.

9) Conflict of Interest

- Indicate if any conflict of interest (COI) issues exist that were not previously reported to the IRB Office. If there is a new COI issue, describe the potential COI, including a plan to mitigate the conflict and how the conflict may affect the level of risk to study participants. Please see the UMCP policy on COI at: http://www.usmh.usmd.edu/leadership/BoardOfRegents/Bylaws/SectionIII/III111.html

No conflict of interest issues exist in this study.

10) Funding Sources/Research Support

- Provide the names of any organization, including Federal agencies, providing funding/support for the research protocol.

ACCIAC Fellows in Creativity and Innovation Program provided $4000 to support this research. Office of Navel Research, awarded to Dr. Michael Dougherty (PI) National Science Foundation, awarded to Dr. Michael Dougherty (PI)

11) Protocol/Consent Forms

- If changes have been made during this Renewal Application a copy of the update documents (protocol, surveys, advertisements, etc.) must be included with the application. A copy of the consent form must be submitted as well. The consent should be the version the IRB will stamp when the project is ready for approval. If more than one consent form (Parent Consent, Assent, Group A, Group B, etc.) will be used for this protocol please list them below:

Please note that missing information and documents will result in a delay of IRB review. Please DO NOT include a copy of your IRB Approval Letter or stamped consent form with your Renewal Application.

No changes have been made during this Renewal Application.

PLEASE SEND RENEWAL APPLICATIONS TO:
IRB Office
2100 Lee Building
College Park, MD 20742

Methodology Protocol

Master Protocol Pre-Test

1. Go into DAM lab. Take key to 0140 (key has squiggly paper clip).
    a. Write the amount of money present, the amount you take, and the amount left on the accounting sheet.
    b. Take the "Gemstone" binder.
2. Go to 0140. Take out green bag (with pens, highlighters, lab notebook, tape).
    a. Determine if today's participants are experimental or control. Write the date.
    b. Take out 1 packet for each participant from the correct group.
    c. Copy the participant's name and email into the next available ID on the corresponding spreadsheet (BS2_subject IDS for experimental group, (NP2_subject IDS for control). Save to flash drive. Also write the name and email on the printed version of these documents in the binder.
    d. Write the participant's name and ID number on a Post-It note and put it on top of each packet.
    e. Pull up all of the necessary programs (math test, Direct RT, website) on the computers including the website: http://thehygeneproject.org/damlab/index.php/increaseintellect/login
3. Participants arrive:
    a. Thank them for participating and ask them to please have a seat at the center table.
    b. When all participants arrive, tell them:

First we'd like to explain a bit about our study. We are testing the effects of playing a computer game on your mental ability. We would like you to practice playing our game for 45 minutes a day for the next 6 weeks. We believe that playing this game will improve your mental ability, but for this to occur, it requires a lot of practice.

Our study consists of three-parts. Today is the first part that will last for 2.5 hours. You will complete a battery of tests that will give us a baseline of your mental ability before playing the game. The second part involves playing the computer game for 45 minutes a day over the next 6 weeks. To help you keep up with the training, we would like you to come in once a week to do some of your training with us. We'd like everyone to put in a total of 20 hours of playing the game, so if you cannot keep up with the time commitment, you will be dropped from the study. After you've finished playing the game for 20 hours, you will come here for another 2.5 hour testing session.

We will compensate you for your time at the pre and post tests and you will also be rewarded based on your improvement during the study.

If you don't think you can make the commitment, you are free to go. If you would like to make the commitment and you think you can complete all phases of our study, we have the paperwork for you to complete.

Alright, so if you're all willing to participate, the first thing we need to do is determine if you qualify. Please complete the survey on the top sheet of your booklet.

Double-check the Participant Surveys as they are completed.

The second thing we need you to do is take a look at the informed consent form. This is the second form in your packet. This form describes the nature of the study, what is expected of you, and the potential risks and benefits of participating. Basically, this form tells you that you'll be completing a bunch of tasks that measure memory, language, mathematical ability, and attention. Please initial and date each page and **sign the last page. Don't** waste too much time looking at the individual tasks, they will be explained as you complete them and you will not be doing them all.

If you're ready to begin, lets start. If you need to take a little break or get some water or anything else now or during the study, just let me know.

Please silence and put away all electronic devices.

Task/ Cognitive Focus	Time Allotted
Paper Tasks:	5 minutes total
Letter Comparison	90 seconds
Sum to 10	90 seconds
Canceling Symbols	90 seconds
Java Task	10 minutes
G-Math	10 minutes
Direct RT Tasks:	60 minutes total
R-Span	15 minutes
Modular Arithmetic Task	10 minutes
Verbal Learning Task	15 minutes
Stroop	10 minutes
Raven's Progressive Matrices	10 minutes
Internet Tasks:	54 minutes total
Letter-Number Sequencing	10 minutes
Number Piles	10 minutes
Adaptive Block Span Assessment	10 minutes
Shapebuilder Assessment	10 minutes
Training	7 minutes
Training	7 minutes

The first task is the Letter Comparison Task. Please double-check that this is the title at the top of the page. Here you will determine if the pairs of letter sequences are identical. If the pair of letter sequences is identical, circle the pair. You will be given 90 seconds to circle as many pairs as you can. Do you have any questions?

Next is the Summing to 10 Task. Please double-check the title on this page. In this task, you will circle adjacent number pairs that sum to 10. You will have 90 seconds to circle as many pairs as you can. Do you have any questions?

The next task you will complete is the Canceling Symbols Task. Please double-check that this is the title. In this task, you will you will have 90 seconds **to circle as many C's and D's as you can. Do you have any questions?**

You will complete the remaining tasks on the computer. Please tear out **the last sheet in your packet titled, "Game Login" and have a seat at any odd** numbered computer.

Put their sticky note next to their keyboard!

(If there are 5 or more participants, split them into 2 groups and seat them on opposite sides of the room. Have 1 administrator run each group.)

G-math:

For this next task, you must complete the presented arithmetic problems. The only operations are multiplication, division, addition, and subtraction. You must use order of operations to obtain the correct response. All answers will be single digit. You must use the number pad to input your answer. Do you have any questions?

Reading Span Task:

Before you open R-span, put T sticker on M key. Put F sticker on Z key!

In this next task, you will read a sentence and evaluate whether or not it is grammatically correct. After you input your response, a word is displayed on the following screen. After several sentences are shown to you, you must recall the words in the order they were displayed. Do you have any questions?

When the task says to get the test administrator, press the "1" key to continue.

Modular Arithmetic Task:

In this next task, you will see some equations and be asked to evaluate whether they are true or false. The instructions on the screen will teach you how evaluate the equations. Please complete these instructions.

After practice problems: Do you have any questions? In the middle of the task, you will see another set of instructions asking you to switch the T/F keys. Please call me over when you see these instructions.

Go and switch the tape for the participant when prompted!

Verbal Learning Task:

Remove the tape from the keys before you load the program!

In this next task, you will be presented with a list of words followed by a list of numbers. You must enter the sum of the numbers and then recall as many words from the most recent list as you can. Do you have any questions?

Stroop Task:

Put stickers R, B, Y, G on keys A, S, K, L!

In this next task, the names of several colors will be shown on the screen in different colored fonts. You must input the font color by quickly pressing the key corresponding to that correct color. Do you have any questions?

Raven's Progressive Matrices:

Remove the tape from the keys before you load the program!

In this next task, you will be presented with figures and asked to identify the missing segment in order to complete a larger pattern by selecting the appropriate number on the number pad. The missing piece is identified by determining the common theme between the existing figures. Do you have any questions?

Letter-Number Sequencing:

In this task you will be shown a sequence of alternating letters and numbers. You will be asked to recall the numbers in ascending order, 1-9, and the letters in alphabetical order, a-z. Later in the task, you will be shown multiple sequences of letters and numbers. Three asterisks will appear in this window *(point to the window)* to designate the end of one sequence and the beginning of the next. You must enter the numbers from the first sequence in ascending order. Then, enter the letters from that sequence in alphabetical order. Then you enter the numbers from the second sequence, then the letters from the second sequence in order, and so on until you've entered all of the sequences. Do you have any questions?
After the practice problems: Did that make sense? Do you have any questions?

Number Piles task:

In this task, a target value will be displayed here *(point to target value on screen)* and a number of boxes will be displayed here *(point to number of boxes on screen)*. You must click the number of boxes that sum to the target value. You want to make sure the blocks do not pile up to the dotted line. If they, do the screen will explode and you will be sent to the next level.

Block Span task:

For this task, you are required to remember the order in which a sequence of blocks appear in a 4 x 4 grid. Each block will flash one at a time and

then the entire grid will flash to indicate the end of a sequence. You then must recall the sequences in order. Do you have any questions?

Shapebuilder:

For this task, you are required to remember the order in which a sequence of objects appear in a 4 x 4 grid. The objects will flash one at a time and then the entire grid will flash to indicate the end of a sequence. You must remember the color, location and shape of each object. You will then recall the sequences in the order in which they appeared. Do you have any questions?

After testing:

So now you've completed the pretest. Over the next 6 weeks, we want you to practice playing XXX & XXX games. We believe that practice on this game will improve your mental ability, but in order for this to actually occur, it requires a lot of practice. As a bit of motivation for playing the game, we're offer prizes to those who show the greatest improvement in their mental ability. At the completion of the study, the person who shows the most improvement will receive $100, the second most improvement will receive $75, the third, $50, and the 4th $25. In addition, every time you achieve a new high score while playing the game, you will receive a raffle ticket. We will make 5 raffle drawings each worth $50. This is on top of the $10 you'll receive for today, and the $40 we'll pay you when you complete the study."

Now, log on with the ID and password on your sheet at this website and complete your first training session and then you're finished. Thanks again for participating!

Have the participant fill out the receipt at the back of their packet BEFORE giving them the money.

Back up the data on all computers onto the flash drive (log file and regular data file). Do NOT delete data on the computers.

E-mail Sy-yu each participant's name, password, log in.

Reference

For computers in Psyc440
Login ID: psyc440
Password: psyc440

thementalchallenge@gmail.com
Login ID: thementalchallenge
Password: cognitivetraining

Below are the "styles" settings in DirectRT for the Verbal Learning Task.. To check the styles, select Edit-> Edit Default styles. Rows 70-72 should read:

70	Verbal Learning 1	0	Times New	16777088	24	1	0	0	center	1-2000
71	Verbal Learning 2	0	Times New	16777088	24	1	0	0	center	1-1000
72	Verbal Learning 3	0	Times New	16777088	24	1	0	0	center	0

If Verbal Learning or any DirectRT task gives the error "row 70 not found" or some similar error message, open the style editor and check to make sure the above rows are there. If they aren't there, type them in. If they are there, copy all three rows and paste them again. This usually fixes the problem.

Participant Questionnaire

In order to determine whether you qualify for this study, please answer Yes or No to the following questions:

Are you age 18 or older?

Are you left or right-handed?

Are you color blind?

Do you play video games more than 3 times a week? If yes, how often?

Have you ever participated in a cognitive training experiment?

Have you ever had head trauma or a concussion?

Have you ever been diagnosed with one or more of the following mental disabilities?
Attention Deficit Disorder (ADD)
Attention Deficit Hyperactive Disorder (ADHD)
Depression
Schizophrenia
Bipolar Disorder
Obsessive Compulsive Disorder (OCD)
Other

Do you own your own computer and have access to internet from home?

Debriefing statement

"The purpose of this experiment was to examine the impact of extensive practice on a mentally challenging task on people's ability to perform other (non-practiced) tasks. Specifically, we are interested in testing whether people's cognitive ability will increase following practice. We believe that people can improve their mental function by practicing mentally challenging tasks. If you would like to find more information out about this study or other studies like this, please feel free to contact Dr. Michael Dougherty (mdougherty@psyc.umd.edu)."

Tasks Descriptions

Letter Comparison

The subject is presented with 200 pairs of random letter sequences. Half of the pairs are identical, half are incongruent. The subject is given 90 seconds to circle as many identical pairs of letter sequences as possible. Both the number of correct and incorrect responses are counted in scoring the task. This task was manually typed, and using a random letter sequence generator to create the sequences. In a sample of 240 adults between the ages of 19 and 82, the Letter Comparison task had an immediate test-retest correlation of r=.58 (Salthouse, 1996). In a sample of 131 adults between the ages of 17 and 79, the Letter Comparison task had a test-retest correlation of r=.60 (Salthouse, 1996).

Summing to 10

The subject is presented with one page of randomly generated digits. The subject is then instructed to circle as many adjacent pairs of numbers that sum to 10 as possible in 90 seconds. Both the number of correct and incorrect responses is counted in scoring the task. A portion of pi was used as the random number sequence. Test-retest correlation for Summing to 10 is r=.74 (Ackerman, 2000).

Canceling Symbols

The subject is presented with one page of randomly generated lowercase letters. The subject is then instructed to circle as many target letters as possible in 90 seconds. In our experiment the letters “c” and “d” were chosen as target letters. Both the number of correct and incorrect responses is counted in scoring the task. A random letter sequence generator was used

to create the letter sequence. Test-retest correlation for Canceling Symbols is r=.66 (Ackerman, 2000). Test-retest correlations for a similar perceptual speed task, "Finding a and t", is r=.72 (Ackerman, 2000).

G-Math

Overview of the task:

The G-Math task was developed in order to test subjects' basic quantitative ability. Subjects were required to solve equations that were composed of the four basic operations: multiplication, division, addition, and subtraction. The questions were divided into two categories: easy and difficult. The difficulty level was based on how many digits were in the equation. Equations that included two or three digits were classified as easy and equations that included four or five digits were classified as difficult. For example, the equation 7/7*3*3-4 has five digits. Roughly fifty percent of the problems generated were easy and the other fifty percent were difficult. The math that the subjects were required to do in their heads was always an integer, however the final answer was always a whole number between zero and nine, zero and nine included.

Design of the task:

The program is a sequence of two variables, one dependent upon the next. The first step is for the program to choose a number from one to four. This number indicates how many digits will be in the equation. The number one meant two digits, the number two meant three digits, the number three meant four digits, and the number four meant five digits. The program then chose again a number from one to four. In this case, each number indicated a different operation. The number one meant multiplication, the number two meant division, the number three meant addition, and the number four meant subtraction. The program would select the correct number of operations based on how many digits were in the equation. The task was designed so the operations appeared in an order that forced subjects to solve the equation using the order of operations.

Thus, the program always chose multiplication and division first, followed by addition and subtraction. These two steps formulated the equation presented to the subject. The computation the subject performed was an integer value; however, program was designed to make the final answer a whole number between zero and nine, zero and nine included. Subjects were required to use the number pad; the remainder of the keyboard was de-activated. The number pad was used to ensure accurate and consistent reaction time measurement.

Completing the task:

Subjects were first presented with a screen that described the task and provided detailed instructions. Subjects then completed five practice problems to ensure they understood the task. The entire task consisted of fifty questions and was divided into two sections. After completing the first twenty five questions, subjects had a thirty second break and then completed the remaining twenty five problems. After the subject inputted their response, they were required to press the enter key when they were ready to proceed to the next question.

Coding the task:

The program generated an excel spreadsheet with a list of the subjects' questions, the subjects' responses, the correct responses, and the reaction time for each question. The raw data was coded as follows: percent correct overall, percent easy correct, percent easy incorrect, percent hard correct, percent hard incorrect. The reaction time for each of these categories was calculated as well as the natural log of each of the reaction times.

Reading Span

Overview of the task:

The Reading Span Task is one of the first widely accepted tasks of assessing working memory capacity; a dual task that consists of both storage and processing components. Dual

tasks measure aspects of high-level cognition used in the real world and correlate with cognitive tasks such as following directions, language comprehension, reasoning, and note taking (Engle, Kane, et al., 1999). The task is used in our experiment to measure general fluid intelligence and visuo-spatial working memory.

Design of the task:

The Reading Span Task asks participants to evaluate whether or not a sentence is grammatically correct. They will verify the sentences by entering M for sentences that are correct and Z for sentences that are incorrect. A random word is then displayed on the following screen. Several of these sentences are shown before the participant is prompted to recall all the words in the sequence they were displayed. The task has a practice session to ensure that participants fully understand the directions. The performance in the Reading Span Task in which participants can accurately recall the sequence of words in order is linked to their working memory capacity, while the sentences serve as a distracter.

The sentences and words are randomly selected by the program. Therefore, the sequences are different for each participant. It is apparent when a sentence is grammatically incorrect so there is no confusion in verifying each sentence.

Completing the task:

Subjects were first presented with a screen that described the task and provided detailed instructions. A practice trial followed where the subjects completed 3 sequences to ensure they understood the task. Participants read a series of two to six sentences and recall, in the correct order, the last word for each of the sentences read. A series consists of N sentences that have to be read before the subject is asked to recall the words. Our task specifically begins with 2 sentences per series. The numbers of sentences increase incrementally by 1 after 3 series, and

goes up to 6 sentences per series. The task has a total of 60 sentences and 60 words and takes approximately 15 minutes.

Coding the task:

The number of words a participant is able to correctly recall in order is called their reading span. In analyzing the data, a total span score is given, with a total of 60 points possible. One point is given for each word that is correctly recalled in the sequence and if the sentence displayed before is correctly identified as correct or incorrect. However, no point will be given if the sentence is incorrectly identified, even if the word is correctly recalled. This ensures that the participant is not only focused on recalling the sequence of words correctly, but focused on the sentences as well.

Listed below are the sentences displayed in the task

The test was very difficult.
I need to take a nap this afternoon.
My radio broke yesterday.
I lost my glasses.
My pencil broke.
I was sick yesterday with the flu.
Christmas is my favorite holiday.
Basketball is my favorite sport.
Phone broken is yesterday.
Where is too funny laugh?
Too much eating hurted stomach.
Yours eye are blue.
Did he are a first aid kit.
I am very annoyed at she.
My backpack is heavy.
I auditioned for American Idol and did really well.

Are he afraid of the blinded darkness?

I so stressing.

My birthday is tomorrow.

My sister are graduate to college already.

My class was very bored.

The mall closing early is tonight.

We ate frozen yogurt after dinner.

Hike for on the Grand Canyon.

The lemonade too sore.

My research paper is due tomorrow.

What do you want for your birthday?

I eated a lemon pie.

I am shocked by his decision.

I am a civil engineering major.

I am stressed during exam week.

No man alone too house are.

Awarding the plate is grate.

She be not take out the trash.

Gym later to exercise many.

Is you go home tomorrow?

Plane tickets are expensive.

Gossip Girl is a good show.

My bicycle are messier.

The trashcan is far away.

Your room is messy.

Stop broken mine television remote.

I read the newspaper everyday.

I need to prepare for an interview.

The soup is still warm.

I like coke better than pepsi.

Dog are as men's best friend.

Is song most really horrible that is bad.

There is a free tennis class at the gym.

She yelled at me.

Super Bowl commercials are boring.

I am thirsty.

She is creative.

I ate pepperoni pizza tonight.

That is an funniest joke that ever heard with me.

Being is a good part community service committee.

I can cook steak really well.

The book are written good.

You no good more at basketball.

Nicer is she than her.

Listed below are the words displayed in the task

METRO	MUSEUM	GAME
COLLEGE	CAMERA	TOWEL
HAIRCUT	APPLE	STREET
CHICKEN	CAR	ARTIST
ROAD	GLASSES	BOTTLE
ANIMAL	BASKET	PEAR
PICTURE	POT	RADIO
PENCIL	HOUSE	SKY
POSTER	NAP	LEMON
JACKET	WOMAN	MEETING
CAKE	SUN	TISSUE
CURTAIN	BLANKET	WOOD
BREAD	MIRROR	CARD
JEANS	TAXI	FRAME
ELEVATOR	WINDOW	SHIP
ART	ARM	POEM
BASEBALL	RESUME	BOOK

PLANE

STORE

RESUME

TOWEL

STORE

RADIO

TAXI

SHIP

MEETING

Gauss's Modular Arithmetic Task

Overview of the Task:

The object of modular arithmetic is to judge the truth value of a problem statement such as 51 ~ 19 (mod 4). It was used as a measure participants' math ability. To do this, the problem's middle number is subtracted from the first number (i.e. 51 – 19 = 32) and this difference is divided by the last number (i.e. 32/4 = 8). If the dividend is equal to a whole number (as here, 8), then the problem is true. If it does not equal a whole number, the problem is false.

Design of the Task:

The Modular Arithmetic task was programmed using the DirectRT software and program. Below is the text of the instructional screens listed in the order and with the formatting which they were displayed to the participant. Any notes that need to be added but were not displayed on the screen will be stated in square brackets, i.e. […]. The title of each stimuli (text file) will be stated in squiggly brackets, i.e. {…}, for use when viewing the ".csv" file format.

{mod_welcome}

Welcome to the Modular Arithmetic Task

Press the spacebar to continue

{mod_instruct1_b}

During this experiment, you will be solving a

series of problems on the computer.

You are going to see problems on the screen
that look like the following:

17 ~ 5 (mod 6)

Your job is to judge whether the problems are
"true" or "false" as quickly and accurately as

possible.

Press the spacebar to continue.

[Note: Normally the triple equals sign "≡" is used to indicate congruency, but the DirectRT software would only display this as a box, so we instead used "~" to indicate congruency.]

{mod_instruct2_b}
There are two steps involved in solving problems
such as:
17 ~ 5 (mod 6)
First: Subtract 5 from 17
Second: Divide this answer by the mod #
Here are a few examples.
Press the spacebar to continue.

{mod_instruct3_b}
Is the following statement true?
26 ~ 4 (mod 11)
First: subtract 4 from 26.
26 - 4 = 22

Second: does 11 divide evenly into 22?

Yes, 11 goes into 22 twice, with no
remainder.
So, the statement is true.
Press the spacebar to continue.

{mod_instruct4_b}
Is this statement true?
29 ~ 5 (mod 7)
Well:
29 - 5 = 24
But, 7 does not divide evenly into 24.
So, the statement is false.
Press the spacebar to continue.

{mod_instruct5_b}
When you start, you will see a series of plus
signs in the middle of the screen, that is a
fixation point letting you know the equation
is about to appear.
The plus signs will disappear, and an equation
similar to those you have already seen will
appear on the screen.
Press the spacebar to continue.

{mod_instruct6_b}
Please work through the equation as quickly

and accurately as you can. Try not to guess.

If the answer is true, press the "m" key, if
the answer is false, press the "z" key. Then
the computer will let you know whether you
answered correctly.

Press the spacebar to continue
[Note: Keyboard covers with the letters “T” for true and “F” for false were placed over the “m” and “z” keys, respectively, so as to help the participant remember which key corresponded with which answer.]

{mod_instruct7_b}
You will go through a series of practice equations
and at the end you will come to a screen that says,
"Stop." At that point, take a few seconds to relax.

Also, please keep your fingers on the "m" (true)
and "z" (false) keys so you can respond as quickly
as possible.

And remember, please work through the equations
as quickly and accurately as you can. It is
really important that you try your best so that
we can precisely gauge how people perform on
these types of equations.

Press the spacebar to continue

{mod_instruct9_b}
Please get the test administrator to continue.
[Note: At this point, we designated the “1” key as the key that had to be pressed before the participant could continue so that the test administrator would have the opportunity to confirm that the participant understood the instructions.]

[Note: We then displayed the following ten practice problems, always in the order they appear, with “+++++” being displayed for 0.5 seconds in the position the problem would appear immediately preceding each problem being displayed. Using a call line function, the program displayed either “correct” or “incorrect” based on their answer so that they would have feedback during this practice portion of the task.]

$9 \sim 6 \pmod 3$
$7 \sim 3 \pmod 3$
$8 \sim 4 \pmod 4$
$9 \sim 6 \pmod 2$
$4 \sim 2 \pmod 3$
$5 \sim 3 \pmod 2$
$7 \sim 3 \pmod 4$
$8 \sim 4 \pmod 3$
$4 \sim 2 \pmod 2$

5 ~ 3 (mod 3)

[Note: These practice problems were administrated for three purposes: to ensure the participant's understanding of the problem, to acclimate the participant to responding appropriately to the problem using the keyboard, and to give us a baseline reaction time for each participant.]

{mod_instruct8_b}

STOP!

Please take a moment to relax.

YOU CAN PRESS THE SPACEBAR

TO BEGIN SOME MORE PROBLEMS

[Note: Using the DirectRT program, one of the four problem lists (more will be explained later) was then randomly chosen and displayed to the participant. This was followed by mod_instruct8_b, the second problem list, and mod_instruct8_b again.]

{mod_instruct10_b}

For testing purposes, we are now going to
change what key corresponds to each answer.

If the answer is true, press the "z" key, if
the answer is false, press the "m" key. Then
the computer will let you know whether you
answered correctly.

Press the spacebar to continue.

[Note: The corresponding key covers were switched so the participant would have a reference as to which key corresponded with which answer.]

{mod_instruct11_b}

You will go through a series of practice equations
and at the end you will come to a screen that says,
"Stop." At that point, take a few seconds to relax.

Also, please keep your fingers on the "z" (true)
and "m" (false) keys so you can respond as quickly
as possible.
And remember, please work through the equations
as quickly and accurately as you can. It is
really important that you try your best so that
we can precisely gauge how people perform on
these types of equations.

Press the spacebar to continue

[Note: We then displayed the same ten practice problems given previously in the same order to acclimate the participant to the new key arrangement followed by mod_instruct8_b.]

[Note: Using the DirectRT program, the third of the four problem lists was then randomly chosen and displayed to the participant. This was followed by mod_instruct8_b, the fourth problem list, and mod_instruct8_b again.]

{mod_debrief}
You have now completed the modular arithmetic task. Thank you for your participation. We think that the results of this experiment will really contribute to our understanding of the brain.

Please get the test administrator at this time.

Listed below are the four problem lists (designated by the second number in the name), separated into groups of three problems by level of difficulty (easy, medium, and hard designated by "_e", "_m", and "_h" respectively) and conjugates (groups of true statements have no letter following the group designation whereas groups of the conjugate false statements have an "f" following the group designation).

{mod2_e1}
~5 ~ 2 (mod 3)
~9 ~ 4 (mod 5)
~9 ~ 3 (mod 6)

[Note: The first "~" is so that the DirectRT program recognizes each problem as a separate line.]

{mod2_e1f}
~5 ~ 2 (mod 2)
~9 ~ 4 (mod 4)
~9 ~ 3 (mod 5)

{mod2_m1}
~15 ~ 12 (mod 3)
~18 ~ 11 (mod 7)
~23 ~ 18 (mod 5)

{mod2_m1f}
~15 ~ 12 (mod 2)
~18 ~ 11 (mod 6)
~23 ~ 18 (mod 4)

{mod2_h1}
~28 ~ 13 (mod 3)
~46 ~ 11 (mod 5)
~76 ~ 20 (mod 7)

{mod2_h1f}
~28 ~ 13 (mod 2)
~46 ~ 11 (mod 4)

~76 ~ 20 (mod 6)
{mod2_e2} ~6 ~ 2 (mod 4) ~8 ~ 3 (mod 5) ~9 ~ 5 (mod 4)
{mod2_e2f} ~6 ~ 2 (mod 3) ~8 ~ 3 (mod 4) ~9 ~ 5 (mod 3)
{mod2_m2} ~16 ~ 11 (mod 5) ~19 ~ 13 (mod 6) ~24 ~ 17 (mod 7)
{mod2_m2f} ~16 ~ 11 (mod 4) ~19 ~ 13 (mod 5) ~24 ~ 17 (mod 6)
{mod2_h2} ~34 ~ 14 (mod 4) ~54 ~ 19 (mod 7) ~63 ~ 15 (mod 6)
{mod2_h2f} ~34 ~ 14 (mod 3) ~54 ~ 19 (mod 6) ~63 ~ 15 (mod 5)
{mod2_e3} ~6 ~ 3 (mod 3) ~8 ~ 5 (mod 3) ~9 ~ 2 (mod 7)
{mod2_e3f} ~6 ~ 3 (mod 2) ~8 ~ 5 (mod 2) ~9 ~ 2 (mod 6)
{mod2_m3} ~16 ~ 13 (mod 3) ~20 ~ 14 (mod 6) ~26 ~ 19 (mod 7)
{mod2_m3f} ~16 ~ 13 (mod 2) ~20 ~ 14 (mod 5) ~26 ~ 19 (mod 6)
{mod2_h3} ~37 ~ 16 (mod 3) ~47 ~ 12 (mod 5) ~65 ~ 17 (mod 6)

{mod2_h3f} ~37 ~ 16 (mod 2) ~47 ~ 12 (mod 4) ~65 ~ 17 (mod 5)
{mod2_e4} ~7 ~ 2 (mod 5) ~8 ~ 2 (mod 6) ~7 ~ 4 (mod 3)
{mod2_e4f} ~7 ~ 2 (mod 4) ~8 ~ 2 (mod 5) ~7 ~ 4 (mod 2)
{mod2_m4} ~17 ~ 13 (mod 4) ~21 ~ 18 (mod 3) ~28 ~ 21 (mod 7)
{mod2_m4f} ~17 ~ 13 (mod 3) ~21 ~ 18 (mod 2) ~28 ~ 21 (mod 6)
{mod2_h4} ~39 ~ 18 (mod 3) ~48 ~ 20 (mod 4) ~52 ~ 16 (mod 6)
{mod2_h4f} ~39 ~ 18 (mod 2) ~48 ~ 20 (mod 3) ~52 ~ 16 (mod 5)

The syntax for the Modular Arithmetic task in DirectRT and the randomization and organization scheme for each group of problems is shown below. (This can be done using Microsoft Excel and saving it as a comma delimited (".csv") file.)

Completing the Task:

The object of modular arithmetic is to judge the truth value of a problem statement such as 51 ≡ 19 (mod 4). It was used as a measure of mathematical ability of participants. To do this, the problem's middle number is subtracted from the first number (i.e. 51 – 19 = 32) and this difference is divided by the mod number (i.e. 32/4

= 8). If the dividend is equal to a whole number (as here, 8), then the problem is true. If it does not equal a whole number, the problem is false. Because of formatting difficulties we used the symbol "~" instead of the normally used symbol "≡." We presented 10 practice problems, followed by two sets of 6 easy problems, 6 hard problems, then 6 medium problems with their right hand recording true answers and their left hand recording false answers. We then repeated that with their left hand reporting true answers and their right hand reporting false answers. Every true problem had a conjugate false problem within the same problem set where the mod number was either 1 more or 1 less than the true answer (ex. true problem: 9 ~ 6 (mod 3), conjugate false problem: 9 ~ 6 (mod 4)). For the practice and easy problems, the first two numbers were single digit and the mod number was the exact difference between those numbers (ex. 9 ~ 6 (mod 3)). For the medium problems, the first two numbers were double digit and the mod number was a single digit number that was the exact difference between those numbers (ex. 23 ~ 19 (mod 4)). For the hard problems, the first two numbers were double digits and the mod number was a single digit number that divided into the first difference (ex. 28 ~ 13 (mod 3)).

Coding the Task:

We recorded the subjects' responses to each trial and whether they were correct or incorrect as well as their response times. We coded the data by selecting only the correct answers and taking the average of the subject's response times to (a) the hard problems, (b) the medium problems, and (c) the easy problems. These are the values that we used for data analysis.

Verbal Learning

Overview of the Task:

The Verbal Learning task assesses subjects' verbal working memory span and interference resolution. Subjects are presented a list of eight words followed by a list of ten integers. Subjects are then prompted to enter the sum of the digits, followed by as many words from the previous list as they can remember.

Design of the Task:

The task was programmed in Microsoft Excel for Direct RT. Word lists and integers were created in lists that would be randomly presented to participants as they work through the task in Direct RT.

Completing the Task:

Subjects were shown the following instructions in the beginning of the task:

> You will be shown a list of eight words followed by a sequence of positive and negative numbers. Afterwards, you will be prompted to input the sum of the number sequence. You will then be prompted to list all of the words from the most recent set that you can remember.
>
> Here are a few examples. Press any key to continue.

After pressing any key, subjects are shown three items randomly selected from the following list of weather-themed words:

> HURRICANE, TORNADO, RAIN, SNOW, HAIL, SLEET, STORM, WIND, CYCLONE, CLOUDS.

Each word displays for two seconds, with a one second blank screen between items. Subjects are then shown three items randomly selected from the following set of integers and operations:

-10, -9, -8, -7, -6, -5, -4, -3, -2, -1, -0, +0, +1, +2, +3, +4, +5, +6, +7, +8, +9, +10.

Each of the three items displays for one second with a one second blank screen in between. Subjects are then prompted to "enter the sum of all digits", followed by a second prompt asking subjects to "recall as many words as [they] can from the most recent list".

After recalling the words, subjects are shown the following text:

> You will now begin.
>
> In each set, you will be presented with eight words followed by ten arithmetic problems.
>
> Press any key to continue.

After pressing any key, the task begins. Subjects are presented ten lists of eight vocabulary items. Each list of vocabulary items is followed by a list of ten integers from the above set. Just like the example, subjects must enter the sum of the ten integers followed by as many words as they can remember from the most recent list. The first, second, and third lists contain items randomly selected from the following set of fruits:

> PEAR, BANANA, PEACH, GRAPE, CHERRY, PLUM, GRAPEFRUIT, LEMON, TANGERINE, APRICOT, PINEAPPLE, LIME, STRAWBERRY, BLACKBERRY, WATERMELON, PRUNES, CANTALOUPE, RASPBERRY, POMEGRANATE, BLUEBERRY, MANGO, BOYSENBERRY, FIG, RAISIN

After a subject inputs the items recalled from the third list, the following instructions are displayed:

You will now begin the next set. Press any key to continue.

These instructions are displayed between each vocabulary set. Upon pressing any key, the fourth list of vocabulary items begins. The fourth, fifth, and sixth lists contain items randomly selected from the following set of body parts:

LEG, ARMS, HEAD, EYE, FOOT, NOSE, FINGER, EAR, HAND, TOE, MOUTH, STOMACH, HAIR, NECK, HEART, KNEE, CHEST, LIVER, BRAIN, LUNGS, TOOTH, ELBOW, SHOULDER, FACE.

The seventh, eighth, and ninth lists contain items randomly selected from the following set of boats:

SAILBOAT, DESTROYER, BATTLESHIP, CRUISER, SUBMARINE, ROWBOAT, YACHT, CANOE, FREIGHTER, TUGBOAT, STEAMSHIP, SCHOONER, LINER, MOTORBOAT, CARGOSHIP, CLIPPERSHIP, TANKER, BARGE, SLOOP, OUTRIGGER, SPEEDBOAT, DINGHY, RAFT, WARSHIP.

The tenth list contained items randomly selected from the following list of home stuff:

WINDOW, DOOR, ROOF, WALL, FLOOR, CEILING, ROOM, BASEMENT, HEARTH, HALL, CORRIDOR, ELEVATOR, CHIMNEY, FOUNDATION, STEP, STAIRWAY, ATTIC, CUPBOARD, BEDROOM, BATHROOM, CLOSET, DORMER, FOYER, LOBBY.

After the subject inputs the final vocabulary list, the following instructions are displayed:

You have now completed the task. Press any key to end.

Coding of the Task:

For each of the ten vocabulary lists we summed the items correctly recalled, the items recalled from prior lists, and any items recalled which were never presented to the subjects.

Raven's Progressive Matrices

Overview of the Task:

The Raven's Progressive Matrices Test was utilized within the context of this research to gauge and evaluate the general fluid intelligence abilities and levels of participants. It is a copyright protected task that consists of themed images with a segment of the image missing within the field of the overall image. Raven's Progressive Matrices is highly correlated to other multiple construct intelligence tasks. While this task utilizes imagery to present a problem-solving scenario and engages the participant to extract and understand information from the presented images, the task correlates highly with other intelligence tasks that encompass psychological domains other than visual non-verbal. This task provides for evaluation of a baseline of participants' general fluid intelligence and improvement or change in general fluid intelligence following participant training. (Goel, Kunda, & McGreggor, 2009)

Design of the Task:

To utilize this task within the realm of the study, it was converted into a computer program to be run in DirectRT. DirectRT is a software used for psychology experimental data collection; it records precise reaction time as well as correctness of responses by participants for a given task. The input data for the program is a MicrosoftExcel document spreadsheet. Following the DirectRT style guidelines, the excel spreadsheet was written and customized for the Ravens Progressive Martices stimuli. The specific images we separated into two different folders for pre-test and post test stimuli. Pre-test stimuli consists of the even numbered images (24 images) and post test stimuli consists of odd numbered images (24 images). The "stim" column contains the file name of the Ravens Progressive Matrices image for each trial, or the written stimulus that will appear on screen for that trial, and the "time" column contains a list of all possible input answers for that trial (the codes for keys one through eight on the number pad), with the code for the correct answer listed first within each trial.

After participants completed the task within the experiment the data was extracted into a MicrosoftExcel file titled with the participants' subject identification number. Within the output data file, each trial will be marked as "TRUE" or "FALSE", indicating whether the participant answered that trail correctly or incorrectly. The data output file also provides the reaction time for the participants' response to each trial. To score the data for each participant the number of answers correct, number of answers incorrect, the average of the response times for correct and incorrect answers, and the natural log of the average response times for correct and incorrect answers were computed. This is the scored data that was utilized to

analyze and evaluate the general intelligence level of each participant compared to the psychological domains tested and evaluated in the other tasks of the experiment.

Completing the task:

When completing the task, the participant is required to examine the image, determine the overall pattern, then select the missing segment from eight possible choices. The participant chooses the correct answer by selecting the appropriate number of the answer on the number pad of his or her keyboard. As the participant progresses, the geometric matrices (the overall images) become more intricate, and the general theme of the image becomes more complicated. Therefore the images, or problems, presented to the participants, get increasingly more difficult to solve. The task is not timed and participants have as much time as needed to complete the task.

Coding the task:

The raw participant data was extracted from DriectRT to an Microsoft Excel file. Each participant generated an individual data sheet. For each participant data was coded for the number of correct and incorrect responses as well as the average response time for correct answers, average response time for incorrect answers, and the natural log of average response time for correct and incorrect responses.

Block Span Task

Overview of the Task:

This task was used as a primary measure for visuo-spatial working memory. It was used as a task for the pre-test and post-test as well as a training task in its adaptive form. The task required participants to remember the sequence in which blocks flashed within a four by four square grid.

Design of the Task:

The task was programmed by Michael Donovan and administered online through www.thehygeneproject.org.

Completing the Task:

For this tasks, participants were given individualized log-in IDs and passwords (which applied for all of the online tasks) and asked to complete the assessment version of the task. The task instructed participants to remember the sequence of blocks that flashed in a four by four square grid. As the task progressed, the number of blocks in each sequence increased and then the amount of sequences the subject was required to recall increased. In the adaptive training version of the task, the speed at which the blocks flashed increased as the subjects performance increased. If the subject was not able to correctly recall the sequences, the task regressed to an easier level.

Coding the Task:

Participants' scores were calculated using the following formula:

Score per trial=10n, n= the number of correct responses.

The formula re-starts every trial and every time the participant inputs an incorrect response.

The subjects' scores from all of their trials were summed to form an overall score. The scoring scheme was the same in the training version of the task. The combined score of all of the trials completed in the seven-minute training session was the sessions score.

Letter Number Sequencing Task

Overview of the Task:

This task was used as a primary measure for working memory. It was used as a task for the pre-test and post-test as a measure of a participant's working memory capability.

Design of the Task:

The task was programmed by Michael Donovan and administered online through www.thehygeneproject.org.

Completing the Task:

The task required participants to remember letters and numbers and enter the letters in alphabetical order, followed by the numbers in ascending order. As the task progressed, multiple sequences would be displayed. Participants had to enter the letters followed by the numbers for each individual sequence.

Coding the Task:

Participants' scores were calculated using the following formula:

Score per trial=10n, n= the trial number.

Subjects were required to enter the entire sequence of letters and numbers correctly to receive the points from the trial. If the entire sequence was not entered correctly, the subjects received zero points and progressed to the next trial. The subjects' scores from all of their trials were summed to form an overall score.

Number Piles Task

Overview of the Task:

This task was used as another measure of quantitative reasoning/ math ability. It was used as a task for the pre-test and post-test.

Design of the Task:

The task was programmed by Michael Donovan and administered online through www.thehygeneproject.org.

Completing the Task:

The task required participants to select a given number of integer blocks to sum to a designated number. As each level progressed the blocks would pile up. If the blocks stacked up to a dotted line on the task screen, the participant would "lose a life" and the task would proceed to the next level. Participants clicked the blocks to sum to the given number. After the blocks were correctly selected they would be removed from the task screen.

Coding the Task:

Participants' scores were calculated using the following formula:

Score per trial=10n, n= the number of blocks.

Subjects received the points every time they successfully reached the target sum. If the blocks piled up to the dotted line or a specified amount of time passed, the subject was progressed to the next level. The subjects' scores from all of their trials were summed to form an overall score. The scoring scheme was the same in the training version of the task. The combined score of all of the trials completed in the seven-minute training session was the session score.

Shape Builder Task

Overview of the Task:

This task was used as an additional measure for visuo-spatial working memory and verbal working memory. It was used as a task for the pre-test and post-test as a measure of a participant's capability, which allowed us to gauge capability improvement.

Design of the Task:

The task was programmed by Michael Donovan and administered online through www.thehygeneproject.org.

Completing the Task:

For this tasks, participants were instructed to remember the sequence in which a series of different colored shapes flashed in a four by four square grid. The sequences became progressively more difficult as the task proceeded. Participants were required to remember and recall the location, shape, and color of each of the sequences.

Coding the Task:

If the location, shape, and color of the presented stimuli was correctly recalled, the subject was awarded 15 points. If just the location and shape of the presented stimuli was correctly recalled, the subject was awarded 10 points. If just the location of the presented stimuli was correctly recalled, the subject was awarded 5 points. The difficulty continued to increase throughout the session. The subjects' scores from all of their trials were summed to form an overall score. The scoring scheme was the same in the training version of the task. The combined score of all of the trials completed in the seven-minute training session was the session score.

Sentencical Training Task

Overview of the Task:

This task was used as a training task and as a measure of participant reading comprehension ability. Participants in the Sentencical group trained on this task, as well as the training version of the Number Piles Task.

Design of the Task:

The task was programmed by Michael Donovan and administered online through www.thehygeneproject.org.

Completing the Task:

For this tasks, participants were instructed to read a series of sentences and answer questions about the sentences. The training sessions lasted for seven minutes. Participants were required to complete 80 sessions of training on this task to complete the study.

Coding the Task:

Every time a question was answered correctly, the subject was awarded 10 points. The subjects' scores from all of their trials were summed to form an overall score. The combined score of all of the trials completed in the seven-minute training session was the session score.

Training data for each participant was averaged to yield the training curve for each experimental group. The scores for each training session number were averaged to provide an overall training curve for the group. The raw score data itself was used in our analysis to gauge task improvement.

Introduction

As a preliminary step to commencing our study we completed a pilot study. This study was used to pinpoint any shortcomings in our methods and ameliorate any problems we may have preemptively. Once the protocol received IRB approval, we ran the study to assess the validity and accuracy of the methodology and associated tasks. The pilot study used the Adaptive Block Span training task to evaluate the effects of visuo-spatial working memory training on the pilot participants' cognitive abilities. The purpose of this pilot study was to streamline the methodology of the study and ensure efficient and substantial data collection. We were able to test the logistics of the experiment and make the necessary adjustments to our protocol and assessment tasks. Logistical and technical issues were modified, and any other information about the experiment design was incorporated into our primary study.

Methodology

Participants were recruited for this study within the student population and community at large in the College Park area through fliers placed around campus. The flier contained the following information: contact information, compensation for participation, and a catch phrase to participate in the study (APPENDIX). Interested participants were communicated via e-mail, and were required to fill out a questionnaire. The questionnaire determined if the individual qualified for the study. Participants were screened based on these criteria. Participants must

- be at least eighteen years of age for legal purposes.
- have normal to corrected vision and not be colorblind
- be right-handed
- have not participated in a cognitive psychology study previously

- never had head trauma or a concussion
- never been diagnosed with mental disabilities
- must not regularly play videogames, either online or on a gaming console.

Participants can not currently be undergoing treatment or have a history of neurological, or psychiatric disorders. These limitations are necessary in order to not compromise the validity and reliability of the results. People with mental disorders have different cognitive functions and need to be excluded from the study in order to maintain control over the constructs dictating performance on cognitive tasks.

Those who qualified for the study and agreed to the terms of the experiment were scheduled to come in for a two hour pre-test appointment. A gemstone team member would administer the experimental session and was required to follow a specific protocol (APPENDIX). Before participants begin the study, participants were told that they are participating in an experiment testing the effects of playing a computer game on your mental ability. They would need to practice playing our game for 45 minutes a day for the next 6 weeks. Participants were also informed about the tasks they will complete and will be given a consent form to read and sign. Members of our research team will be available to answer any questions participants may have.

Participants were randomly assigned to the experimental group or the control group. All participants completed the same pre-test consisting of a battery of tasks administered via paper and pen, a computer program file, or online. The pre-test took approximately 2 hours to complete. The following tasks, which cover a variety of psychological domains, were utilized:

Paper assessments:
Letter Comparison- processing speed

Summing to 10- processing speed
Cancelling Symbols- processing speed
Computer assessments:
G-Math
Reading Span
Modular Arithmetic
Verbal Learning
Stroop
Raven's Progressive Matrices
Online assessments:
Adaptive Block Span
Letter-Number Sequencing

After participants completed the pre-tests, they were provided with an individualized login IDs based on their assigned group. Those in the experimental group were provided login IDs to train using the Adaptive Block Span Task, while those assigned to the experimental group were provided with login IDs to train using the Sentencical Task. Both tasks could be accessed via a provided URL web address.

Participants were compensated for the pre-test session in accordance with the compensation scheme and instructed to train for six weeks using his or her assigned task. They were scheduled to a mid-point test three weeks after their pre-test, or when they completed half of the required training.

The mid-point test consisted of the G-Math assessment and the two online assessments - Adaptive Block Span Task, and Letter-Number Sequencing and took approximately one hour to complete. Participants were compensated $10 for coming in. The mid-point test allowed us to touch base with participants and to encourage training in order to complete the study.

Following six weeks of training (a total of 20 hours on the assigned online task), participants were scheduled to come back to the lab for a post-test session. The post-test consisted of the different versions of the same assessments from the pre-test.

Upon completion of the study participants were compensated in accordance with the compensation schedule and debriefed.

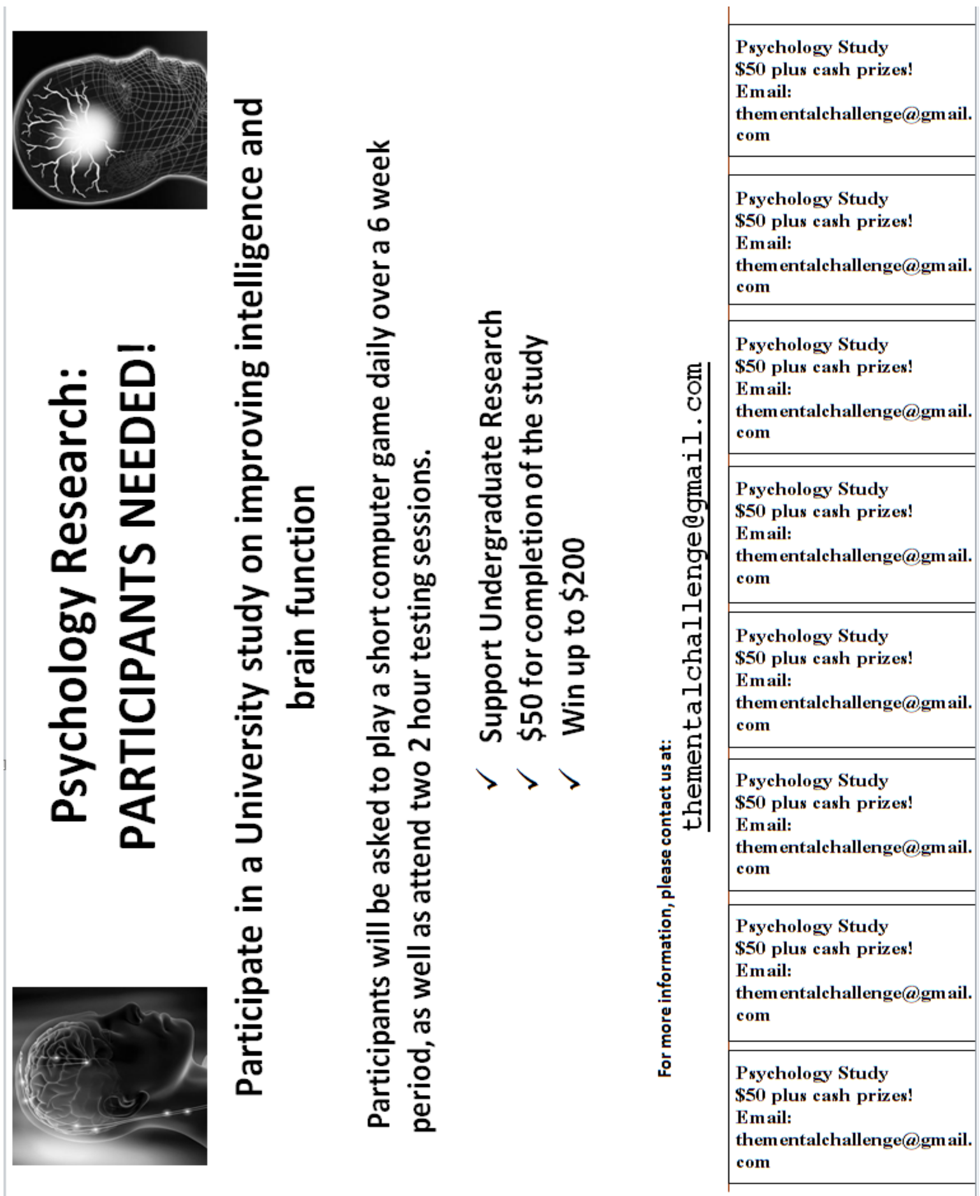
Pre-test data was collected for 43 participants, and 19 participants completed the study. Data was compiled for each assessment (pre and post-test), and training data was logged and collected each time a participant logged in to his or her training account. The data was aggregated for all of the assessments and used to examine trends and relevant correlations using SAS. Due to the low levels of participant completion and training, the data was not analyzed , but used to validate the assessments used.

Discussion

The pilot study allowed our team to pinpoint flaws in the methodology and compensation schedule. The primary problem encountered was getting participants to complete the training. Participants were not training sufficiently to collect meaningful data. We suspect a lack of incentive and the time requirements of the training as the main reason participants do not finish and thus drop from the study. We were able to modify our participant protocol and methodology to complete the study more effectively.

Our team found it difficult to recruit participants via fliers and needed to think of other ways to recruit. We also noticed that the most interested participants played video games frequently, but they were eliminated because it was against the criteria. We decided to reevaluate this policy in our main study.

Recruitment Flyers



Participants Wanted

For study on Computer Games and Cognition

We are currently recruiting participants for a study investigating the relationship between computer games, cognitive ability, mathematical reasoning.

Participants will be asked to play a short computer game on a daily basis over a 6 week period, as well as attend three testing sessions (approx. 2 hours/session) over a 6 week period.

You will be compensated $10/hour for the two hour testing sessions and interim session, and have the chance to win a cash prize of $100, $75, $50, or $25.

To participate, you must be 18 years old, a native English speaker, and have no history of neurological or psychiatric disorders.

Study location: Decision, Attention, and Memory lab, 0140 Biology-Psychology Building (BPS).

Primary Investigator: Sy-yu Chen

For more information, please contact us at:

thementalchallange@gmail.com

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$10/hour plus cash prizes!
Email:
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Psychology Research: Improving Intelligence

PARTICIPANTS NEEDED

Participants will be asked to play a short computer game daily over a 6 week period, as well as attend two 2 hour testing sessions.

- ✓ $50 for completion of the study
- ✓ Earn up to $200

For more information, please contact us at:

thementalchallenge@gmail.com

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$50 plus cash prizes!
Email:
thementalchallenge@gmail.
com

Psychology Study
$50 plus cash prizes!
Email:
thementalchallenge@gmail.
com

Subject Demographics

WebsiteID	Subject	Age	Race/Ethnicity	Education	Major	Rubik's Cube	Online Games	Puzzle	Gaming Console	Reading	Math
1003gem2train0101	1	21	Latino	college	biochemistry	0	0	2	1	0	0
1003gem2train0102	2	18	asian	college	communications	0	0	0	0	7	0
1003gem2train0103	3	23	black	college	hearing and speech sciences	0	30	3	0	24	4
1003gem2train0104	4	20	asian	college	biology	0	0	2	0	2	3
1003gem2train0105	5	19	black	college	Engineering	0	10	2	0	5	3
1003gem2train0106	6	19	asian	college	Economics	0	4	0	0	7	4
1003gem2train0107	7	18	white	college	Chemical Engineering	0	0	1	0	1	5
1003gem2train0108	8	18	white	college	civil engineering	0	1	0	0	4	6
1003gem2train0109	9	18	white	college	Letters and Sciences	0	1	1	2	4	8
1003gem2train0110	10	23	Latino	college	Psychology	0.5	2	0	0	5	2
1003gem2train0111	11	19	white	college	biology	0	1	2	0	15	4
1003gem2train0112	12	18	white	college	Computer Engineering	0	0	3	5	10	7
1003gem2train0113	13	19	Pacific Islander	college	Kineseology	0	0	2	0	15	2
1003gem2train0114	14	19	Other	college	Electrical Engeineering	0	3	0.5	10	10	10
1003gem2train0115	15	18	white	college	Neurophysiology	0.5	0	1	0	6	7
1003gem2train0116	16	19	Pacific Islander	college	Neurophysiology	0	7	5	6	4	20
1003gem2train0117	17	23	black	Bachelors		0	0	1	0	2	1
1003gem2train0118	18	19	Pacific Islander	college	Business	0	21	6	3	5	6
1003gem2train0119	19	18	Hispanic	college		0	1	0	0	3	6
1003gem2train0120	20	18	white	college	Neurophysiology	0	3	7	3	2	4
1003gem2train0121	21	19	white	college	Aerospace Enginering	0	2	3	0	1	12
1003gem2train0122	22	21	black	college	Psychology	0	0	0	0	15	0
1003gem2train0123	23	18	white	college	Aerospace Enginering	0	8	3	0	5	10
1003gem2train0124	24	18	asian	college	History/Secondary Education	0	0	0	0	7	0
1003gem2train0125	25	19	white	college	Mechanical Engineering	0	4	0	2	2	13
1003gem2train0126	26	19	white	college	Mathematics	0	0.5	2	1	3	6
1003gem2train0127	27	19	white	college	Community Health	0	0	0	1	1	1
1003gem2train0128	28	20	black	college	Psycholgoy	0	0	1	0	15	1
1003gem2train0129	29	20	Pacific Islander	college	Neurophysiology	0	0	5	0	5	1

1003gem2train0130	30	21	asian	college	biology	0	7	1	2	14	1.5
1003gem2train0131	31	20	white	college	Psyhcology	0	10	1	5	4	1.5
1003gem2train0132	32	24	white	Bachelors	Computer Science/Philosphy	0	0	1	2	10	3.5
1003gem2train0133	33	21	white	college	Crimonology	0	2	1	0	7	1
1003gem2train0134	34	19	black	college	Economics	0	0	0	19	27	20
1003gem2train0135	35	18	White	College	Undecided	0	0	2	0	3	5
1003gem2train0136	36	18	White	College	Psycology	0	0	1	0	3.5	2
1003gem2train0137	37	18	White	College	Psycology	0	0	0	7.5	12	3
1003gem2train0138	38	19	Black	College	Sociology	0	0	0	0	2.5	1.5
1003gem2train0139	39	21	Black	College	Computer Science	0	12	5	6	4	7
1003gem2train0140	40	18	White	College	Computer Science	0	2	0	2	7	7
1003gem2train0141	41	18	Black	College	Undecided	0	1	2	2	7	5
1003gem2train0142	42	20	Black	College	Criminal Justice	0	2	0	0	40	0
1003gem2train0143	43	19	White	College	Business	0	6	0	2	2	1
1003gem2train0144	44	19	Other	College	Neurophysiology	0	0	0	0	18	2
1003gem2train0145	45	19	Other	College	Biology	0	0	0	0	21	10
1003gem2train0146	46	21	white	college	animal science	0	18	3	8	8	1
1003gem2train0147	47	20	Black	College	Anthropology	0	5	1	6	8	10
1003gem2train0148	48	18	Other	College	Music	0	4	2	3	2	1
1003gem2train0149	49	18	White	College	Business	0	0	0	0	5	3
1003gem2train0150	50	19	Latino	College	Marketign	0	0	0	0	4	1
1003gem2train0151	301	19	Black	College	Electrical Engeineering	0	2	0.5	10	5	5
1003gem2train0152	302	21	Other	College	Business	0	6	4	0	6.5	5
1003gem2train0153	303	18	White	College	English	0	0	0	0	5	0
1003gem2train0154	304	19	Asian	College	Letters and Sciences	0	2	0	0	5	4
1003gem2train0155	305	20	White	College	Economics	0	2	2	3	6	3
1003gem2train0156	306	18	Other	College	Aerospace Enginering	0	2	0	1	3	3
1003gem2train0157	307	20	White	College	Dietetics	0	10	0	0	8	0
1003gem2train0158	308	18	Other	College	Bio-Chemistry	0	0	0	0	4	1
1003gem2train0159	309	18	White	College	Finance	0	5	2	7	7	5
1003gem2train0160	310	23	White	College	Community Health	0	20	5	7	10	15
1003gem2train0201	51	23	White	College	Finance	0	2	2	2	15	2
1003gem2train0202	52	19	American/Pacific	College	Psychology	0	2	0	3	5	0

			Islander								
1003gem2train0203	53	21	White	College	Psychology and Philosophy	0	0	0	0	7	2
1003gem2train0204	54		Black	College	Undecided	0	5	0	0	2	0
1003gem2train0205	55	30	Asian	Masters		0	0	0	0	5	5
1003gem2train0206	56	21	White	College	Biology	0	0	0	0	7	0
1003gem2train0207	57	18	America	College	Business	0	1	0	0	5	0
1003gem2train0208	58	19	American	College	Computer Engineering	0	2	1	0	2	10
1003gem2train0209	59	18	White	College	general business	0	7	0	20	4	0
1003gem2train0210	60	18	White	College	Math and Education	0	0	7	0	14	8
1003gem2train0211	61	19	White	College	Chemistry	0	0	0	10	5	10
1003gem2train0212	62	19	White	College	History	0	1	2	0	6	2
1003gem2train0213	63	19	Pacific Islander	College	General Bio	0	0	0	0	2	1
1003gem2train0214	64	21	Other	College	CCJS	0	2	2	3.5	2	1
1003gem2train0215	65	18	Black	College	Biology	0	0	0	0	14	1
1003gem2train0216	66	18	White	College	Undecided	0	0	0	0	10	6
1003gem2train0217	67	20	Asian	College	Special Education	0	3	1	8	3	2
1003gem2train0218	68	20	Other	College	Neurophysiology	0	2	2	0	10	10
1003gem2train0219	69	18	White	College	Engineering	0	0	1	0	3	2
1003gem2train0220	70	20	White	College	Biology	0	0	0	1	5	1
1003gem2train0221	71	18	Latino	College	Letters and Sciences	0	0.5	0	0	10	0
1003gem2train0222	72	18	White	College	Engineering	0	1	2	0	2	4
1003gem2train0223	73	19	White	College	Journalism and History	0	5	10	4	15	1
1003gem2train0224	74	18	White	College	Chemical Engineering	0	1	1	0	4	5
1003gem2train0225	75	19	Indian	College	Neurophysiology	0	2	2	0	5	5
1003gem2train0226	76	19	Black	College	Biochemistry	0	0	0	0	5	0
1003gem2train0227	77	18	American/ Pacific Islander	College		0	14	7	14	18	8
1003gem2train0228	78	20	white	College	Biochemistry	0	0	0	1	15	7
1003gem2train0229	79	20	white	College	psychology	0	0	5	0	2	6
1003gem2train0230	80	25	black	College	cell biology/ Arabic	0	0	2	10	10	2
1003gem2train0231	81	21	Latino	College	Economics	0	2	0	1	5	3
1003gem2train0232	82	19	Latino	College	Neurophysiology	0	2	2	2.5	5.5	5.5
1003gem2train0233	83	20	white	College	animal science	0	3	0	0	23	20

1003gem2train0234	84	22	white	College	Electrical Engeineering	0	3	0	8	2	10
1003gem2train0235	85	19	other	College	astronomy	0	2	0	6.5	3	3
1003gem2train0236	86	21	Other	College	Finance	0	6	3	2	25	5
1003gem2train0237	87	18	White	College	Math and Computer Science	1	5	0.5	7	5	5
1003gem2train0238	88	19	Other	College	Criminology	0	0	0	0	5	2
1003gem2train0239	89	20	Other	College	Finance	0	0	2	4	9	3
1003gem2train0240	90	19	American/Pacific Islander	College	Computer Engineering	0	0	1	2	2	5
1003gem2train0241	91	19	Black	College	Letters and Sciences	0	0	0	1	10	2
1003gem2train0242	92	18	White	College	Chemical Engineering	0	0	0	0	2	10
1003gem2train0243	93	19	White	College	Engineering	0	0	2	3	8	4
1003gem2train0244	94	19	Latino	College	English	0	0	0	2.5	5	0.5
1003gem2train0245	95	19	White	College	Art and Education	0	0	1	0	10	1
1003gem2train0246	96	19	Other	College	Undecided	0.5	0.5	0	0	5	5
1003gem2train0247	97	18	White	College	Journalism	0	2	2	0	10	4
1003gem2train0248	98	18	White	College	Computer Engineering	0	3	1	3	1.5	6
1003gem2train0249	99	18	White	College	Government and Arabic	0	0	1	3	5	1
1003gem2train0250	100	18	Asian	College	Electrical Engeineering	0	5	0	2	2	10
1003gem2train0251	401	19	White	College	Mathematics	0	1	1	0	5	15
1003gem2train0252	402	18	White	College	Computer Science	0	5	2	10	3	7
1003gem2train0253	403	19	White	College	Undecided	0	3	0	0	1	1
1003gem2train0254	404	21	White	College	Philosophy	0	7	0	5	10	0
1003gem2train0255	405	31	White	Bachelors	Japanese	0	0	0	0	5	0
1003gem2train0256	406	18	Other	College	Computer Science	0	7	1	3	4	1
1003gem2train0257	407	19	Other	College	Environmental Science	0	1	3	2	5	1
1003gem2train0258	408	22	White	Associates	Journalism	0	2	1	2	6	0
1003gem2train0259	409	19	White	College	Marketing	0	3	1	5	5	1
1003gem2train0260	410	20	White	College	Chemistry	0	1	1	2	10	4

Participant Gender and Exercise

	ID	Group	Gender	Hours Exercise Per Week
1	1003gem2train0103	BS	Female	2-3 hours
2	1003gem2train0105	BS	Female	2-3 hours
3	1003gem2train0109	BS	Female	4-5 hours
4	1003gem2train0111	BS	Female	2-3 hours
5	1003gem2train0112	BS	Male	2-3 hours
6	1003gem2train0116	BS	Male	2-3 hours
7	1003gem2train0115	BS	Female	2-3 hours
8	1003gem2train0119	BS	Female	2-3 hours
9	1003gem2train0124	BS	Female	2-3 hours
10	1003gem2train0130	BS	Male	0-1 hour
11	1003gem2train0131	BS	Male	0-1 hour
12	1003gem2train0133	BS	Female	0-1 hour
13	1003gem2train0136	BS	Female	0-1 hour
14	1003gem2train0138	BS	Female	4-5 hours
15	1003gem2train0142	BS	Female	2-3 hours
16	1003gem2train0147	BS	Female	0-1 hour
17	1003gem2train0148	BS	Female	2-3 hours
18	1003gem2train0149	BS	Female	2-3 hours
19	1003gem2train0151	BS	Male	2-3 hours
20	1003gem2train0153	BS	Female	2-3hours
21	1003gem2train0158	BS	Male	2-3 hours
22	1003gem2train0159	BS	Male	2-3 hours
23	1003gem2train0160	BS	Male	4-5 hours
24	1003gem2train0204	SS	Female	4-5 hours
25	1003gem2train0210	SS	Female	4-5 hours
26	1003gem2train0213	SS	Female	0-1 hour
27	1003gem2train0215	SS	Female	2-3 hours
28	1003gem2train0217	SS	Female	2-3 hours
29	1003gem2train0219	SS	Female	2-3 hours
30	1003gem2train0223	SS	Female	2-3 hours
31	1003gem2train0224	SS	Male	4-5 hours
32	1003gem2train0225	SS	Female	4-5 hours
33	1003gem2train0232	SS	Male	2-3 hours
34	1003gem2train0233	SS	Female	2-3 hours
35	1003gem2train0234	SS	Male	4-5 hours
36	1003gem2train0235	SS	Male	4-5 hours
37	1003gem2train0236	SS	Male	5 hours
38	1003gem2train0241	SS	Male	0-1 hour
39	1003gem2train0243	SS	Male	0-1 hour

40	1003gem2train0246	SS	Male	6 and more hours
41	1003gem2train0248	SS	Male	2-3 hours
42	1003gem2train0249	SS	Male	4-5 hours
43	1003gem2train0250	SS	Male	2-3 hours
44	1003gem2train0251	SS	Female	2-3 hours
45	1003gem2train0253	SS	Female	0-1 hour
46	1003gem2train0257	SS	Female	0-1 hour

Gender		**# of Participants**	**%**
	Male	19	**41.30%**
	Female	27	**58.70%**
	Total	46	
Hours Exercise Per Week			
	0-1 hour	10	**21.74%**
	2-3 hours	24	**52.17%**
	4-5 hours	11	**23.91%**
	6 or more hours	1	**2.17%**
	Total	46	

Supporting Analyses: t-test tables

Table 13
Paired t-tests analyzing improvement within the Block Span group.

				if p < 0.05	
Variable	df	t-value	p-value	mean	SD
RecallL1diff	20	1.98	0.0605		
RecallL2diff	20	1.40	0.1766		
RecallL3diff	20	1.00	0.3251		
RspanRecallDiff	21	2.65	0.0149	5.0	8.9
RspanGrammarDiff	21	2.37	0.0272	1.0	1.9
StroopEffectDiff	21	1.58	0.1279		
LCDiff	23	8.08	<0.0001	10	6.3
CSDiff	22	0.21	0.8303		
STDiff	23	1.65	0.1120		
RavensDiff	21	1.12	0.2744		
ShapesDiff	21	15.74	<0.0001	1527	454
BlocksDiff	22	6.39	<0.0001	860	644
LNSDiff	21	4.10	0.0005	195	222
MathpilesDiff	22	1.39	0.1781		
ModRTEasydiff	19	2.41	0.0260	-235	435
ModRTMeddiff	19	1.92	0.0698		
ModRTHarddiff	19	1.80	0.0874		
GmathRTEasydiff	20	1.32	0.2004		
GmathRTHarddiff	20	1.12	0.2748		

Note: $p<0.05$ is significant.

Table 14
Paired t-tests analyzing improvement within the Low Contact group.

				if p < 0.05	
Variable	df	t-value	p-value	mean	SD
RecallL1diff	14	3.93	0.0015	-1.0	1.0
RecallL2diff	14	2.11	0.0528		
RecallL3diff	14	4.00	0.0013	-1.1	1.0
RspanRecallDiff	14	2.32	0.0357	4.6	7.7
RspanGrammarDiff	14	0.49	0.6289		
StroopEffectDiff	15	1.12	0.2786		
LCDiff	15	6.40	<0.0001	8.4	5.2
CSDiff	14	2.71	0.0168	-4.2	6.0
STDiff	15	2.49	0.0246	-2.8	4.5
RavensDiff	15	1.53	0.1452		
ShapesDiff	15	1.65	0.1190		
BlocksDiff	15	1.93	0.0721		
LNSDiff	15	1.35	0.1955		
MathpilesDiff	15	3.18	0.0061	225	282
ModRTEasydiff	14	1.60	0.1318		
ModRTMeddiff	14	0.77	0.4513		
ModRTHarddiff	14	1.88	0.0805		

GmathRTEasydiff	15	0.92	0.3702		
GmathRTHarddiff	15	-1.79	0.0931		

Note: p<0.05 is significant.

Table 15
Paired t-tests analyzing improvement within the Sentencical group.

				if p < 0.05	
Variable	df	t-value	p-value	mean	SD
RecallL1diff	22	0.38	0.7070		
RecallL2diff	22	2.21	0.0381	0.04	0.85
RecallL3diff	22	2.12	0.0455	0.55	1.25
RspanRecallDiff	22	2.98	0.0070	4.9	7.9
RspanGrammarDiff	22	0.65	0.5197		
StroopEffectDiff	22	2.16	0.0421	-155	345
LCDiff	22	7.33	<0.0001	10	7.0
CSDiff	21	0.16	0.8735		
STDiff	22	1.26	0.2216		
RavensDiff	23	1.36	0.1872		
ShapesDiff	22	1.76	0.0914		
BlocksDiff	22	2.98	0.0069	267	430
LNSDiff	22	1.63	0.1170		
MathpilesDiff	22	16.88	<0.0001	1172	332
ModRTEasydiff	21	6.68	<0.0001	-393	276
ModRTMeddiff	21	6.06	<0.0001	-661	513
ModRTHarddiff	21	1.75	0.0934		
GmathRTEasydiff	22	1.46	0.1567		
GmathRTHarddiff	22	5.21	<0.0001	-971	893

Note: p<0.05 is significant.

Table 16
Equal variance t-tests analyzing improvement between the Block Span group and the Sentencical group.

				BS if p < 0.05		SS if p < 0.05	
Variable	df	t-value	p-value	mean	SD	mean	SD
RecallL1diff	43	1.80	0.0788				
RecallL2diff	43	0.62	0.5363				
RecallL3diff	43	0.05	0.9577				
RspanRecallDiff	42	0.09	0.9281				
RspanGrammarDiff	42	1.17	0.2491				
StroopEffectDiff	43	1.11	0.2728				
LCDiff	45	0.12	0.9027				
CSDiff	44	0.32	0.7496				
STDiff	45	0.49	0.6266				
RavensDiff	44	0.31	0.7566				
ShapesDiff	43	8.01	<0.0001	1527.27	454.93	227.39	617.88
BlocksDiff	43	3.95	0.0003	900.45	629.48	267.83	430.61
LNSDiff	43	1.51	0.1376				
MathpilesDiff	44	8.75	0.0000	129.57	446.66	1172.17	332.99

ModRTEasydiff	40	1.42	0.1628				
ModRTMeddiff	40	0.22	0.8246				
ModRTHarddiff	40	1.03	0.3082				
GmathRTEasydiff	42	0.04	0.9677				
GmathRTHarddiff	42	1.77	0.0841				

Note: $p<0.05$ is significant. All t-values are absolute values. If significant, note the means of the two groups. For Stroop, Mod, and G-math negative values show better performance.

Table 17
Equal variances t-tests analyzing improvement between the Block Span group and the Low Contact group.

				BS if p < 0.05		LC if p < 0.05	
Variable	df	t-value	p-value	mean	SD	mean	SD
RecallL1diff	35	3.53	0.0012	0.73	1.73	-1.03	1.02
RecallL2diff	35	2.37	0.0234	0.65	1.80	-0.58	1.06
RecallL3diff	35	3.20	0.0029	0.58	1.86	-1.13	1.10
RspanRecallDiff	34	0.18	0.8579				
RspanGrammarDiff	34	1.21	0.2353				
StroopEffectDiff	36	1.88	0.0677				
LCDiff	38	1.09	0.2816				
CSDiff	37	1.82	0.0763				
STDiff	38	0.60	0.5545				
RavensDiff	36	0.45	0.6581				
ShapesDiff	36	10.42	<0.0001	1527.27	454.93	135.31	327.38
BlocksDiff	36	4.28	0.0001	900.45	629.48	160.00	330.80
LNSDiff	36	1.05	0.3012				
MathpilesDiff	36	0.53	0.5968				
ModRTEasydiff	33	0.06	0.9535				
ModRTMeddiff	33	0.38	0.7047				
ModRTHarddiff	33	0.39	0.6993				
GmathRTEasydiff	35	0.09	0.9277				
GmathRTHarddiff	35	0.59	0.5577				

Note: $p<0.05$ is significant. All t-values are absolute values. If significant, note the means of the two groups. For Stroop, Mod, and G-math negative values show better performance.

Table 18
Equal variance t-tests analyzing improvement between the Sentencical group and the Low Contact group.

				SS if p < 0.05		LC if p < 0.05	
Variable	df	t-value	p-value	mean	SD	mean	SD
RecallL1diff	36	2.24	0.0314	-0.11	1.37	-1.03	1.02
RecallL2diff	36	3.12	0.0036	0.39	0.85	-0.58	1.06
RecallL3diff	36	4.26	0.0001	0.55	1.25	-1.13	1.10
RspanRecallDiff	36	0.11	0.9127				
RspanGrammarDiff	36	0.10	0.9188				
StroopEffectDiff	37	2.24	0.0315	-112.81	252.50	87.83	236.74
LCDiff	37	1.13	0.2667				
CSDiff	35	1.87	0.0700				
STDiff	37	1.18	0.2467				
RavensDiff	38	0.12	0.9087				
ShapesDiff	37	0.54	0.5898				
BlocksDiff	37	0.84	0.4050				
LNSDiff	37	0.19	0.8487				
MathpilesDiff	37	9.28	<0.0001	1172.17	332.99	225.00	282.18
ModRTEasydiff	35	1.02	0.3125				
ModRTMeddiff	35	0.66	0.5107				
ModRTHarddiff	35	1.46	0.1539				
GmathRTEasydiff	37	0.20	0.8414				
GmathRTHarddiff	37	1.46	0.1519				

Note: $p<0.05$ is significant. All t-values are absolute values. If significant, note the means of the two groups. For Stroop, Mod, and G-math negative values show better performance.

Glossary

BS	BS refers to subjects in the working memory training condition. These subjects trained with the Block Span and Shape Builder tasks.
Crystallized intelligence	Crystallized intelligence refers to a persons ability to reason through learning, education, and culture. Contrast this with fluid intelligence.
DirectRT	DirectRT is the computer program used to administer the R-span, Mod, Verbal, Ravens, and Stroop tasks.
Executive functioning	Also known as the central executive, this construct is a part of Baddeley's model of working memory and governs the maintenance and manipulation of information stored in the phonological loop and visuo-spatial sketchpad of working memory.
Factor analysis	Factor analysis is a statistical method used to analyze variance in a data set. This tool is commonly used to express the variance in a data set as several factors, such that four measures of arithmetic could all be used
Fluid intelligence	Fluid intelligence is a person's abstract reasoning ability. This is the type of reasoning a person uses when they do not know what to do. Contrast this with crystallized intelligence.
G	G is a general factor of intelligence identified using factor analysis of psychometric test data by Charles Spearman in 1904.
Inhibition	Inhibition is the ability to focus attention and ignore distracting information while performing a task. It is closely related to an individual's working memory capacity.
Latent variables	Latent variables are the underlying c
Low Contact	The Low Contact condition was a group comprised of participants who had began our study in either of the experimental conditions, but were dropped from the study for low/no training performance after the post test. Participants who returned to take the post-test after being dropped were included in this group.
Parietal and Prefrontal cortex	The parietal and prefrontal cortex are regions of the brain believed to house complex reasoning abilities, such as working memory and fluid intelligence.
Psychometric	Psychometric tests are used to obtain a quantitative measure of a person's cognitive abilities.
Sentencical	The sentencical task is a reading comprehension task used to train participants in the SS group.
SS the sentensical group	Active control group. Uses Sentencical and MathPiles tasks.
Working memory	The ability to simultaneously maintain, store, and manipulate information.
Central	The component of working memory that controls all other

executive	components and manipulates information.
Phonological loop	Dedicated memory buffer for verbal information in working memory
Visuo-spatial sketchpad	Dedicated memory buffer for visual and spatial information in working memory
T-test	A t-test is a statistical measure which compares the mean difference between groups.

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