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AN INVESTIGATION OF THE EFFECTS OF USING HANDHELDS TO INCREASE
COMPUTATIONAL SPEED BY ENHANCING WORKING MEMORY FOR
SECONDARY STUDENTS WITH LEARNING DISABILITIES

by

MARCEY A. KINNEY
B.S. University of Central Florida 2000
M.ED University of Central Florida 2003

A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
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Major Professor: Rebecca A. Hines

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ABSTRACT

Using a single subject research design, the effects of computer based brain training were examined to determine if computational fluency increased after completing the brain training activities. The study took place in a large public high school.

Participants were students with learning disabilities who were also below level in mathematics. During the baseline phase, all participants completed a timed math probe daily for 1 week. Because the timed math probes were timed, the researcher was looking for an average gain for each student. During week two students completed the brain age activities daily, prior to completing the math probe. Average gains for each student continued to be recorded. During week three the Brain Age activities were withdrawn and students continued to complete the timed math probes. During week four, the Brain Age activities were reinstated and data collection continued as the students completed the timed math probes. The data was analyzed visually, and the split middle technique was applied to determine a predicted slope of the data, followed by a binomial test to determine if there was a significant difference from baseline to intervention. The results of the current research have demonstrated that while computerized brain training may be effective for some students, the results are varied. While significant gains in computational speed and accuracy were noted for all participants during at least two of the phases, significant differences were only observed for one participant across all four phases.

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LIST OF ACRONYMS/ ABBREVIATIONS

ADHD	Attention Deficit Hyperactivity Disorder
AP	Advanced Placement
AT	Assistive Technology
AYP	Annual Yearly Progress
CAI	Computer Assisted Instruction
CNS	Central Nervous System
DF	Delayed Feedback
EHA	Education of the Handicapped Act
FAPE	Free Appropriate Public Education
FCAT	Florida Comprehensive Assessment Test
FLDOE	Florida Department of Education
fMRI	Functional Magnetic Resonance Imaging
GPA	Grade Point Average
IDEA	Individuals with Disabilities Act
IEP	Individualized Education Program
IF	Immediate Feedback
KR	Knowledge of Response Feedback
LD	Learning disability
MEE	Mandatory Exit Exams
MOT-R	Mathematics Operations Test Revised
MTF	Multiply Try Feedback

NCES	National Center for Education Statistics
NCLB	No Child Left Behind Act
NCTM	National Council for Teachers of Mathematics
OSEP	Office of Special Education Programs
RtI	Response to Intervention
TIMSS	Trends in International Mathematics and Science Study
WM	Working Memory

CHAPTER 1: INTRODUCTION

The capacity to learn mathematics has been identified as an essential component in the future success of today's students. According to the National Council for Teachers of Mathematics (NCTM, 2007),

“Students who take algebra and geometry go on to college at much higher rates than those who do not (83% vs. 36%), most four-year colleges require three to four years of high school math for admission, almost 90% of all new jobs require math skills beyond the high school level, entry-level automobile workers must use advanced mathematics formulas to wire a car's electrical circuits, and strong math skills are needed for understanding graphs, charts, and opinion polls in a newspaper, for calculating house and car payments, and for choosing a long-distance telephone service”(Mirra, 2004, p. 2).

Mastery of mathematics is undeniably important for all students, and often presents a challenge for students with learning disabilities (LD), particularly at the secondary level. These challenges have been well documented in the literature (Keeler & Swanson, 2001; Kroesbergen & Van Luit, 2003; Woodward and Montague, 2002). While students with LD face many mathematical challenges, computational fluency is an area of continuous concern (Brookhart, Andolina, Zuza, & Furman, 2004; Calhoun, Emerson, Flores, Houchins, 2007; Garnett, 1992; Greene, 1999). Many students with LD often have a basic understanding of math facts, yet they still continue to use strategies such as finger counting long past a point which is deemed acceptable by their teachers and peers (Garnett, 1992; Keeler & Swanson, 2001). The existing literature on computational fluency has recognized the need for effective interventions for students with LD

(Calhoone, Emerson, Flores, & Houchins, 2007; Fleishner, Garnett, & Shepard, 1982; Goldman, Pellegrino, & Mertz, 1988; Greene, 1999).

Numerous reasons may be given for the computational fluency challenges faced by students with LD, but working memory deficits have been frequently identified as a potential reason for the difficulties faced by these students (Bull & Johnston, 1997; Hitch & McAuley, 1991; Keeler & Swanson, 2001; Siegal & Ryan, 1989; Swanson, 1993). Research has revealed that improving memory function (Keeler & Swanson, 2001; McNamara & Wong, 2003) may improve academic outcomes for students with LD. A number of strategies have been employed among students with LD to attempt enhancing working memory (Keeler & Swanson, 2001). In addition to rehearsal (Burns, 2005), chunking, association, and elaboration, technology has also been incorporated (Klingberg et al., 2005) with positive results. With this knowledge and the current trends towards integrating technology into classrooms, examining the use of technology for enhancing memory and computational fluency rates is appropriate.

Statement of the Problem

Secondary students with LD are not succeeding in the area of mathematics. According to the Nations Report Card (2007), only 17% of 12th grade students with disabilities scored at or above a basic level in mathematics. This score is compared to 64% of their peers without disabilities. In 2000, according to the U.S. Department of Education, National Center for Educational Statistics (NCES), U.S. students were lagging behind their peers globally. While the Trends in International Mathematics and Science Study (TIMSS) demonstrated slight improvements for American fourth and eighth

graders in mathematics nationally, they are still lagging behind several other developed countries (Mullis, Martin, Gonzalez, & Chrostowski, 2004). Additional studies have consistently reported the shortfalls of U.S. students (Lemke, Sen, Partelow, Miller Williams, et al., 2004; Mullis, Martin, Gonzolez & Chrostowski, 2004). While mathematics is a continuing national concern, many of the national and international studies fail to report disaggregated data on students with disabilities. According to the No Child Left Behind Act (NCLB), (2002), schools are required to ensure the success of all students, including those with disabilities.

For many students with LD, math continues to be a barrier to school success. In the state of Florida, during the 2004-2005 school years, only 4 of 67 school districts (6%) met Annual Yearly Progress (AYP) targets in math for students with disabilities (FLDOE, 2005). For many secondary students with LD, high school mathematics poses a tremendous challenge, particularly in the higher level math such as algebra and geometry. The expectations for students in mathematics are mounting. Algebra is on the horizon to become a graduation expectation for students (Witzel, Mercer, & Miller, 2003). Currently, Florida is recommending four years of mathematics, including Algebra as a requirement for graduation (FDOE, 2006). For students with learning disabilities who lack mastery of basic math concepts, their future choices remain limited.

Purpose of the Study

The purpose of this research was to determine the efficacy of using handheld computer activities to increase computational fluency by enhancing working memory for students with learning disabilities. The effectiveness of computerized brain training

activities was evaluated by monitoring student gains on timed math probes during various phases in which the intervention was present or not present. The effectiveness was measured across four phases.

Research Question

Is computational speed and accuracy of math facts increased for secondary students with learning disabilities after completing brain training activities on a handheld computer?

Dependent Measure

Rate of fluency gains on timed math probes were examined for each student. Each probe contained 50 problems and was timed for one minute. The probes consisted of single digit addition, subtraction, and multiplication. Both items correct and incorrect were counted and recorded and charted on a line graph.

Independent Measure

The independent measure identified for the present study is Brain Age, a computer program designed for the Nintendo Ds™ hand held computer system. Brain Age is a computerized version of Ryuto Kawashima's book *Train Your Brain: 60 Days to a Better Brain*, which is based on his research with Functional Magnetic Resonance Imaging (fMRI) and Working Memory (Yokoyama, et al., 2006). The program is made up of a series of brief reading and math activities which have been shown to increase the working memory of geriatric adults (Kawashima, et al., 2005). The activities were

completed daily and student progress was charted within their profiles. New activities were added based on the students' prior performance.

Research Design

The research methodology used for this study was a single-subject design, using the ABAB design method (Kazdin, 1982). According to Horner, Carr, Halle, Mcgee, Odum, and Wolery (2005), single-subject research has become important when examining educational interventions for the individual student, and many of the current interventions being practiced in school evolved through the single subject design. The data was gathered through daily timed math probes. The probes were a measure of the daily instruction the students were receiving. Students completed the probes for one week to determine baseline (Kazdin, 1982). The researcher was looking for average gains on the probes. After an average baseline was determined, all students began the intervention phase and the daily probes continued. After one week of the intervention phase the intervention was withdrawn, but completion of the daily probes was maintained. During the final phase, the intervention was reinstated and data continued to be collected.

Significance of the Study

There is considerable evidence to support the need for interventions which will increase working memory for students with LD (Bull & Johnston, 1997; Hitch & McAuley, 1991; Keeler & Swanson, 2001; Siegal & Ryan, 1989; Swanson, 1993). While brain training has not been well researched for use with school age children, positive

results have been reported on its effectiveness within the adult community (Kawashima, 2005; Olsen, Westerberg, & Klingberg, 2004). If computerized brain training proves to be effective for secondary students with LD, teachers could have a valuable tool which can easily be incorporated into their instructional routine. Because adolescents are already immersed in technology, computerized brain training would be a natural learning extension for them. The Brain Age activities are readily available for students to use in or out of school on a learning platform which is easily accessible to many students.

Assumptions

Because they have spent their lives surrounded by technology including computers, digital games, cellular phones, hand held organizational systems, and mp3 players, there is an assumption that today's students may be more receptive to learning on a computer, a tool which they already use to find information pertinent to their lives on a daily basis.

Definition of Terms

ABAB Design Method

ABAB Design Method is a single subject design in which performance is assessed over time and in which changes are made to the specific conditions which the subject is exposed to (Kazdin, 1982).

Baseline Phase

The baseline phase is the initial phase in a single subject design. During this phase data is collected for several days and describes the participants' present level of performance (Kazdin, 1982).

Brain Age

Brain Age is a Nintendo game based on the work of a prominent Japanese Neuroscientist, Ryuto Kawashima. The game is a series of brain training activities designed to enhance the working memory capabilities of those who play it.

Binomial Test

A binomial test is designed to assess the likelihood of a specific outcome when two possible outcomes exist (Lomax, 2001).

Brain Training

Brain training is the practice of completing cognitive exercises for the purpose of rewiring neural pathways to improve memory functions.

Computational Fluency

According to NCTM (2000), computational fluency means having flexible, efficient, and accurate methods for computing

Correlation Coefficient

The correlation coefficient is used to measure the linear relationship between two variables and is computed by dividing the covariance of the two variables by the product of their standard deviation (Lomax, 2001).

Digital Natives

Digital Natives refer to students born after 1990. These students represent the first group of individuals to grow up in a completely digital world (Prensky, 2001).

Functional Magnetic Resonance Imaging (fMRI)

fMRI's refer to a type of imaging machine with the capabilities to map brain activity by showing the bath of blood flow to different regions of the brain (Columbia University Medical Center, 2008).

Handheld Computer

A handheld computer refers to any small electronic device containing computer technologies.

Intervention Phase

The phase in a single subject research design when the environment changes due to an added variable(s), usually referred to as the intervention (Kazdin, 1982).

Learning Disability (LD)

According to the National Center for Learning Disabilities (2008), a learning disability is a neurological disorder which occurs in individuals with average or above average intelligence. LD affects a person's ability to process information, and can affect their abilities in reading, writing, and mathematics.

Long Term Memory

Long term memory refers to the brains ability to hold onto memories for an extended period of time up to an entire lifetime (Baddeley, 2000).

Neuroplasticity

Neuroplasticity refers to the brains ability to rewire itself by continuously creating new neural pathways as a result of learning (Ludlow et al., 2008).

Nintendo Ds™

The Nintendo Ds™ is a dual screen, handheld video game console with both speech and handwriting recognition technology..

Prefrontal Cortex

The prefrontal cortex is the front region of the frontal lobes of the human brain. The prefrontal cortex is responsible for decision making, memory, and problem solving (Olsen, Westerberg, & Klingberg, 2004).

Split Middle Technique

A method for evaluating single subject data. The data is split by a line which is plotted at the median level in each phase. This technique is used to compare data across phases (White, 1974).

Stroop Test

An assessment created by J. Riley Stroop in which participants are shown a list of color words which are all printed in various colors (not the color of the word). For example, the word blue might be printed in red ink. Participants are asked to say the color

that the word is printed in, not the word itself. The assessment is designed to measure interference in thought processes.

Working Memory

Working memory is a part of the brain designated to temporarily store and manipulate information related to language, learning, and reasoning (Baddely, 2000).

CHAPTER 2: REVIEW OF THE LITERATURE

Introduction

Working memory problems have been consistently identified as a cause of learning problems for students with LD, particularly in the areas of reading and mathematics (Bull & Johnston, 1997; Keeler & Swanson, 2001; Swanson, 1993). Researchers are gaining a new understanding of how important working memory is to mathematics (Ashcraft, Krause, 2007; LeFevre, DeStefano, Coleman, and Shanahan, 2005). According to Keeler & Swanson (2001), children with mathematics disabilities have difficulty answering math facts from memory and will often revert to primitive methods such as finger counting.

Students with Learning Disabilities

Characteristics of Students with Learning Disabilities

Learning disabilities are typically used to describe those students who lag behind their peers in specific academic areas even though they apparently have the aptitude and have received effective instruction (Lyon et al, 2001). The term learning disability was coined by Samuel A. Kirk in 1962 (Halahan & Mercer, 2002), when he described LD as “a retardation, disorder, or delayed development in one or more of the processes of speech, language, reading, spelling, writing, or arithmetic resulting from a possible cerebral dysfunction and not from mental retardation, sensory deprivation, or cultural or instructional factors” (Lyon et al., 2001, p. 261). Due to the dedication of parents and

other advocates for this unique group of learners, Lyons' initial description eventually evolved into the definition being currently used. The state of Florida, however, is currently following a growing national trend and changing the way students with learning disabilities are identified by implementing a response to intervention (RTI) definition for students with LD. These changes have not come quickly for this unique group of learners. Advocates for children with LD rallied tirelessly for more support for these students, and ultimately became the force behind the legislation which changed the way students with LD receive their education (Lyon, et al., 2001).

Legislation and Students with Learning Disabilities

The initial copy of the Education of the Handicapped Act (EHA), passed in 1966, did not include provisions for students with LD (Halahan & Mercer, 2002). With the Children with Specific Learning Disabilities Act of 1969, LD was finally recognized and defined by the federal government. It was not until 1975, when the U.S. Government passed Public Law 94-142, the Education for All Handicapped Children Act that LD received the status to be awarded funding under the disability laws (Lyon, et al., 2001).

The new definition for learning disabilities, employed by The US Office of Education in 1977, read:

“The term “specific learning disability” means a disorder in one or more of the psychological processes involved in understanding or in using language, spoken or written, which may manifest itself in an imperfect ability to listen, speak, read, write, spell, or to do mathematical calculations. The term includes such conditions as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia and developmental aphasia. The term does not include children who have learning disabilities which are primarily the result of visual, hearing, or motor handicaps, or mental retardation, or emotional disturbance, or of environmental, cultural, or economic disadvantage.” (USOE, 1977, p. 65083).

This definition has remained the accepted classification for LD until recently. With the current interest in Response to Intervention (RTI), both the definitions as well as the formula used to identify students with LD have come under fire (Hallahan, et al., 2007). The controversy over identification of students with LD may be due, in part, to the increase in students currently being identified with LD.

According to the 27th Annual Report to Congress on the Implementation of the Individuals with Disabilities Education Act (2005), the number of students served under the category of LD is on the rise. In 2003, students with LD made up 47.4% of students with disabilities nationally. In the 10 years between 1993 and 2003, the prevalence of LD rose from 4.1%- 4.3% of the total population of school age children. While this increase may appear slight, the only other categories to show an increase in those 10 years were other health impairments (0.1%-0.7%), Autism (less than 0.05%-.2%), and developmental delays (0.05%-0.1%). Of all the students with LD, the greatest increase in identification occurred in the 12-17 year age group. This increase rose from 6.0%-6.9%. The distribution of LD by ethnicity is American Indian/Alaskan Native (54.5%), Asian/Pacific Islander (39.5%), Black /Not Hispanic (44.9%), Hispanic (57.3%), and White/Not Hispanic (45.6%). The variability of LD across ethnicity is fairly equitable, as well as across states (Hallahan et al., 2007).

Identifying Students with Learning Disabilities

The identification of students with LD has been controversial from its origins in the 1960's (Hallahan et al., 2007; Lyon et al., 2001). While many have argued that variability across states indicates a problem with the identification process of students

with LD (Reschly, 2002; Reschly & Hosp, 2004), Hallahan and his colleagues (2007) recently conducted an analysis of prevalence of viability across all states from 1984 to 2002. They discovered that of all the disability categories, LD displays the least variability from state to state. The process of identifying a student with LD is usually conducted using a formula that seeks out a discrepancy between the student's ability and achievement levels (Hallahan & Mercer, 2002). The current identification process has come under fire (Lyon et al., 2001; Seigal, 1989, 1992), and a new method of identification is beginning to gain acceptance. Response to Intervention (RTI) may become a method for identifying students as low achieving instead of having LD (Hallahan et al., 2007). Regardless of the method of identification or the label bestowed upon this group of learners there will always be challenges for these students, particularly at the secondary level.

Challenges for Secondary Students with Learning Disabilities

As students with LD get older, the challenges associated with school increase, particularly in the area of academics. While the answers are not completely clear on what causes these seemingly average students to lag so far behind their peers academically, researchers have spent half a century trying to find a definitive answer. From the uniform standards of the No Child Left Behind Act (2001), to the already overwhelming challenges of being an adolescent in the 21st century, it is no small surprise that secondary students with learning disabilities may suffer from a myriad of problems as they navigate their way through high school (Stodden, Galloway, & Stodden, 2003) . Deshler et al. (2001) reported that secondary students with LD suffer from (a) higher rates of

absenteeism, (b) lower grade point averages (GPA), (c) higher failure rates, (d) self esteem issues, (e) problems with social behaviors, and (f) higher dropout rates than the general population. For students with LD, legislature designed to help them may qualify as both friend and foe.

The Individuals with Disabilities Education Act (1997), explicitly addressed students with disabilities and access to the general education curriculum. This mandate specifically required schools to identify learning goals based on the general education curriculum, include general education teachers in IEP planning, and include students with disabilities on statewide assessments. NCLB was created on the belief that too many children were failing in American public schools, and no child should be left behind or left in a failing school. With the passage of NCLB and the reauthorization of IDEA (2004), many high school students have struggled under the rules of high stakes testing, particularly those with LD. For numerous secondary students with LD, Mandatory Exit Exams (MEE) have become obstacles to receiving a high school diploma. MEEs are exams which require students to show a certain level of skill on specific academic tasks before receiving their high school diploma. According to the Center on Educational Policy (2004), 20 states had implemented MEE's. While many students pass these assessments on the first try, this is not the case for numerous students with disabilities. In many states, the scores on MEE's for students with disabilities are significantly lower than their peers (Katsiyannis, Hang, Ryan & Jones, 2007). The academic struggles faced by these students may manifest themselves in a variety of social emotional issues.

Social Emotional Issues

For many years, researchers have been exploring the emotional well being of students with LD. Many have pondered the question of whether or not students with LD have a lower self esteem or self concept than their non disabled peers (Bear, Clever, & Proctor, 2001; Rogers & Saklofski, 1985). Based on an analysis of 61 studies (conducted between 1986 and 2000) analyzing self concept for students with disabilities, Bear, Minke, & Manning (2003) came to two generalizations. One generalization was that students with LD appear to have a lower self worth in the academic areas than their peers. The second generalization, however, did not find significant differences between students with LD and those without in the areas of social and behavioral self concepts. These findings were further verified by a second meta-analysis conducted by Nowicki (2003). Nowiki also found that for students with LD, their peers found them less desirable than students without LD. While this indicates a hindrance to social acceptance from their peers, students with LD appear oblivious to this lack of approval.

Dropout Rates

When children are diagnosed with LD early in their school career, they may only be a year or two behind their peers. As they get older they fall farther behind, making it more and more difficult for them to catch up. This is known as the performance gap (Warner, Shumaker, Alley, & Deshler, 1980). Often, the older the student becomes the larger the gap becomes, and the more frustrated the student feels; in time they become tired of failing and give up (Deshler et al., 2001; Swanson & Hoskyn, 2001). Failure and disengagement in school eventually drives some students with LD to abandon the idea of

a high school diploma and drop out of school (OSEP, 2001). According to the 24th annual report to congress (2001), during the 1999-2000 school years, 48,490 students with learning disabilities dropped out of high school; the second largest number of students to drop out were diagnosed with emotional disturbances (19,032). The academic needs of students with LD must be met, particularly in the area of mathematics. Without a strong understanding of basic mathematics, students with LD may fail to succeed in post secondary education and other aspects of their adult life (NCTM, 2007).

Computational Fluency and Secondary Students with Learning Disabilities

The needs of secondary students in mathematics have been well documented in the literature (Geary, 2004; Gagnon & Maccini, 2007; Jitendra, DiPipi, Perron-Jones, 2002; Maccini & Gagnon, 2000; Miller, Butler & Lee, 1998) and most agree that there is a need for math instruction which is effective for students with Learning Disabilities (Calhoone, Emerson, Flores, & Houchins, 2007; Greene, 1999; Maccini, Mulcahy, & Wilson, 2007; Miller, Butler, & Lee, 1998; Woodward & Montague, 2002). The research has supported the need for effective instruction in basic math skills. For students with disabilities who struggle in math, ineffective recall of basic facts, or computational fluency, is a commonly identified weakness (Fleishner, Garnett, & Shepard, 1982; Goldman, Pellegrino, & Mertz, 1988; Greene, 1999) and has been recognized as an urgent need for secondary students with LD (Calhoone et al., 2007). According to Whitehurst (2003), "Cognitive psychologists have discovered that humans have fixed limits on the attention and memory that can be used to solve problems. One way around these limits is to have certain components of a task become so routine and over-learned that they

become automatic.” Computational fluency is defined by NCTM (2000, p.152) as “having efficient and accurate methods for computing” (p.152). Students must be able to perform calculations correctly in order to be considered accurate. According to NCTM (2000), computational fluency is a skill that should be taught until eighth grade. After eighth grade, the assumption is that all students have mastered this skill. Unfortunately, research continues to demonstrate that this is not the case (Calhoone, et al., 2007).

Computational fluency is recognized as the building block for all higher level mathematics (Hasselbring, Lot, & Zidney, 2006), and the deficits found in secondary students with LD is alarming.

In the late 70's and 80's there was a surge of literature surrounding the question of whether or not students with LD could compute basic math facts at the same level as their peers (Cawley, Fitzmaurice, Shaw, Kahn, & Bates, 1979; Cawley & Miller, 1989; Warner, Schumaker, Alley, & Deshler, 1980). The results displayed great disparity between general education students and their peers with learning disabilities. A few of the researchers found that a large percentage of students with LD tend to lag behind their peers in computational fluency by at least one year for every two years that they attend school , and by the time they reach high school many students with LD may lag five, six, even seven years behind their non disabled peers (Hasselbring, Lot, & Zydney, 2006) (See Figure 1.).

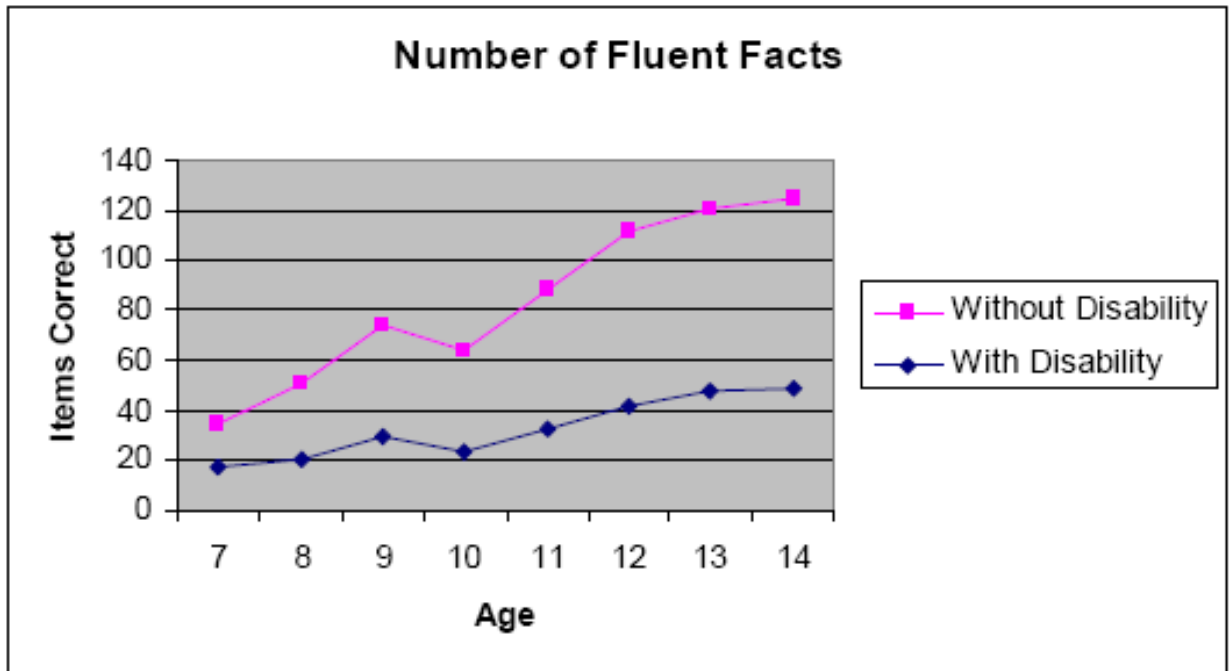


Figure 1: A comparison of the number of fluent addition facts by age for general and special education students (Hasselbring, Lot, & Zydney, 2006)

Math Fluency and Algebra

In recent years, the math research for students with LD has begun to focus on higher order thinking math such as algebra and problem solving (Witzel, Smith, & Brownell, 2001; Woodward & Montague, 2002). The expectation that all students will obtain math fluency by eighth grade leaves many struggling students with LD in a precarious position. The National Mathematics Advisory Council (2008) identified American students' lack of math fact fluency as an unacceptable gap in the curriculum which impedes the students' ability to learn algebra. The panel surveyed 743 Algebra 1 teachers nationally. They found that the teachers had some common concerns about incoming students. Teachers cited fluency in basic math skills as the biggest change they

want students to have prior to attending an algebra class. The expectation of algebra teachers is that students will be fluent in basic facts by the time they reach high school. One sample response from an algebra teacher was, “Students need to be better prepared in basic math skills and not be quite so calculator dependent”. According to McGlaughlin, Knoop, & Holliday (2005), for students struggling with algebra at the college level, fluency is identified as a leading contributor to student failure. So, even though the United States is striving to improve math instruction, computational fluency remains a salient issue for students with LD.

Kroesbergen & Luit (2003) conducted a meta-analysis of 58 current studies of math intervention strategies. After analyzing 58 studies on mathematics interventions, the authors discovered that most of the research focused on basic math skills, and the area of computational fluency (Kroesbergen & Luit, 2003). Calhoun, Emerson, Flores, & Houchins (2007) examined the computational fluency performance of 224 students with mild to moderate disabilities in grades 9-12. All students were diagnosed as having a math disability. The students were given the Mathematics Operations Test Revised (MOT-R), an assessment which requires the student to complete 50 problems ranging from grade levels one through six. The authors found that the computational fluency of the students in the study averaged at a second to third grade level, showing consistency with the studies conducted two decades earlier.

According to Woodward and Montague (2002), students with learning disabilities usually learn computational math through the use of rote memorization of traditional algorithms for each concept. Most of the algorithms do little to help the student learn the concept, rather they are expected to learn and follow the rule to solve each problem.

Solving mathematical problems using these historically-based algorithms, which were designed to make buying and selling easier in the markets of Europe, is not necessarily the best method for teaching students today, particularly those with learning disabilities (Woodward & Montague, 2002). Their needs vary, but research has shown that students with learning disabilities have difficulty retaining mathematical concepts and learn them in disjointed sequences, which slows their progression as they move into the secondary grades (Witzel, Smith, & Brownell, 2001). Well developed computational fluency skills have been associated with high scores on standardized math tests (Royer, Tronsky, Chan, Jackson, & Merchant, 1999), an important point considering the level of high stakes testing students are now exposed to. Once they reach the high school level, having an inability to compute basic calculations is a skill that everyone is assumed to be able to do. For teenagers who find themselves still using primitive computing techniques, the results can be embarrassing (Garnett, 1992). Researchers are beginning to examine the use of technology to increase mathematics ability (Maccini & Gagnon, 2005).

Technology

Adolescents and Technology

In order to increase computational fluency rates for today's students, sometimes referred to as digital natives (Prensky, 2001, 2006) the need to consider technology interventions is paramount. American adolescents of the 21st century have experienced an emersion in technology unlike any previous generations. According to Prensky (2001, 2006), the term Digital Native encompasses those students born after 1990. This group of students was born into a digital world, so they are preprogrammed by their

environment to gravitate toward technology. The U.S. Census Bureau (2000), reported that at a rate of 92.6%, American adolescents are the highest population subgroup to use computers (Russell, Bebell, O'Dwyer, & O'Conner, 2003). At a rate of 84%, teens admit that they are the owner of at least one personal media device, and 44% identified owning more than one device (Lenhart, Madden, and Hitlin, 2005). The significance of technology in the lives of adolescents, is difficult to dispute. Many teens broadly employ technology in virtually every aspect of their lives, with the exception of school (Lenhart, Madden, & Hitlin, 2005).

Technology use in Schools

The concept of incorporating technology into education is not new, but has recently been supported by and written into law. The Individuals with Disabilities Education Act of 1990 recognizes the importance of technology in the appropriate inclusion of students with disabilities by mandating that assistive technology be an annual consideration for all students with disabilities. According to the No Child Left Behind legislation (NCLB) of 2002, technology must be incorporated into public education. Technology implementation in education is a complicated task. In order for technology to be accepted as best practice, a number of issues will need to be addressed and clarified. In addition to its many possible educational uses, technology has also been specifically identified as a means for enhancing the lives of students with LD (Blackhurst, 2005; Johnson & Hegarty, 2003).

Technology use among Students with Learning Disabilities

The Education for the Handicapped Act (EHA, P.L. 94-142, 1975) ensured all children with disabilities between the ages of five and 21 would receive a free and appropriate public education (FAPE). Under the 1986 Amendments (P.L. 99-457), infants and toddlers were added to the children protected under the law. Two more amendments followed, 1990 (P.L. 101-476) and 1997 (P.L. 105-17). The amendments of 1990 defined assistive technology (AT) while the 1997 changes made it mandatory for individualized education program (IEP) teams to consider AT for all students with disabilities. IDEA has made it mandatory for assistive technology to be considered for every child receiving services and for teachers to acquire the competencies that would enable them to make appropriate decisions concerning assistive technology (IDEA, 1997). When considering students with LD, particularly those at the secondary levels, technology may play a significant part in their school success. In 2003, nearly 100% of public schools in the United States had access to the internet. This figure is compared to 35% in 1994 (National Center for Education Statistics, 2004).

The lives of students with LD may be significantly improved through the incorporation of technology (Blackhurst, 2005; Johnson & Hegarty, 2003). Many students with LD struggle with academic tasks while they excel at tasks involving the computer (Johnson & Hegarty, 2003). For them, the world is governed by technology and they see technology being implemented at most jobs and utilized daily to complete simple tasks like scanning their own purchases in stores (Edyburn, 2006). While in school, these tech savvy students are being taught by the same invariable methods used a century ago. For many students, particularly those with LD, the status quo in education is

not working for them, and the achievement gaps between them and their peers continues to grow (Edyburn, 2006). The benefits to including technology interventions in public schools have been documented (Edyburn, 2006; Hasselbring, 2001), yet there is a need for empirical studies describing specific benefits of software programs available to support instruction for students with disabilities (Hasselbring et al., 2006).

Technology Benefits for Secondary Students with Learning Disabilities

Many benefits to instructional technology have been mentioned in the literature (Maccini & Gagnon, 2005; Strangman & Dalton, 2005; Sitko, Laine, & Sitko, 2005). Some of these benefits include social improvement, achievement gains, and improved attitudes (Brown, 2005; Lewis, 2005). Most identified benefits come with the warning that more research is still needed (Brown, 2005; Boone & Higgins, 2005; Maccini & Gagnon, 2005; Strangman & Dalton, 2005; Sitko, Line, & Sitko, 2005). In spite of the warning of a shortage of research, some positive gains have been achieved mathematics. According to Maccini & Gagnon (2005), based on a review of technology programs in mathematics, the future of math education looks hopeful in terms of technology integration. They found that of the 11 studies examined, they all reported moderate to significant improvement for students with disabilities. They went on to say that some technologies yielded greater results than lessons taught by the teacher alone.

Hasselbring and Goin (2005) created a technology intervention to increase computational fluency. After assessing the intervention with 400 students, the authors concluded that students became fluent in one of the four operations after 100 sessions at 10 minutes per session. Results like these are extremely promising for students with LD, but the costs may keep some interventions out of the classrooms. More research is still needed into affordable instructional technology to increase computational fluency. The

relationship between computational fluency and working memory (Bull & Johnston, 1997; Hitch & McAuley, 1991; Keeler & Swanson, 2001; Siegal & Ryan, 1989; Swanson, 1993) may need to be considered when developing technologies to improve fact recall for students with LD. With the rise in technology usage and availability in public schools, educators will have to begin considering the use of alternate technological devices such as handheld computers.

Handheld Computers

Technological devices are advancing at an astonishing rate, and some of the most tech savvy consumers of these products are under the age of 18. Hand held computers are well suited for educational purposes. They are compact with a high rate of mobility, therefore placing no restrictions on the time or place for student learning (Norris & Soloway, 2003). Research has shown handheld gaming to display positive effects on learning (Garris, Ahlers, & Driskell, 2002; McFarlane, Sparowhawk, & Heald, 2002; Pillay, Brownlee, & Wilss, 1999, Rosas et al., 2002), and studies supporting the use of these technologies in educational settings are on the rise (Dempsey et al., 2002), particularly in the area of mathematics. The positive effects of using handhelds in classrooms have been apparent at both the primary and the secondary level.

Using an experimental research design, Shin, Norris, and Soloway examined the effects of using handhelds in mathematics instruction with 50 second graders. The researchers chose to use a game entitled Skills Arena. The experimental group played the game on a Nintendo GameBoy™. The control group completed the same activities using a paper card game. The students were working on basic addition and subtraction facts. The study lasted four months. The students were evaluated using a 50 item instrument

before, during, and after the study. After analysis of the results, the researchers found that the students who used the handhelds outperformed the students using the paper card game. They also found that the low-ability students using the handhelds made significantly higher gains than the low achieving students using the paper card game.

(See Figure 2.)

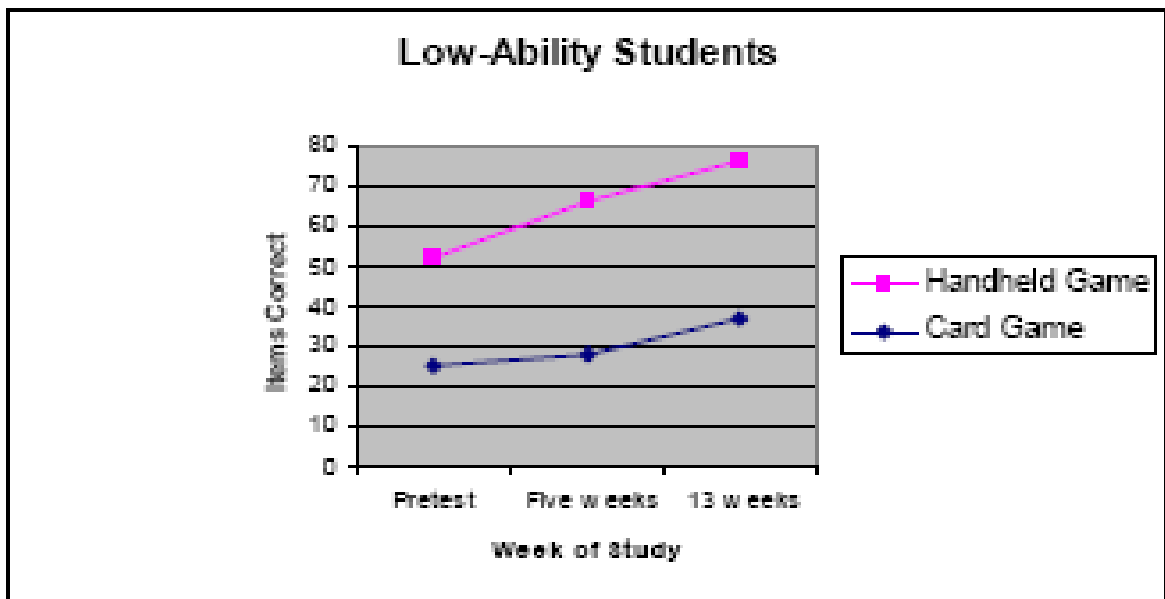


Figure 2: Gains for low performing students after using handhelds

In 2003 Vahey, Tater, & Roschelle conducted a study involving handhelds and mathematics instruction. The study included 25 eight grade math students and lasted for one month. The authors designed a curriculum called NetCalc which was based on a previous technology called SimCalc. SimCalc was designed to be used on a standard computer, while NetCalc was scaled down to be accessed on a small handheld computer. The students used the NetCalc software for one month. The topic of instruction was mathematics of change and variation, a topic typically taught in a Calculus course. The participants in the study completed a pre and post-assessment. On the pre-assessment, out

of a possible 33 points, the average score was 9.3. After the instruction using the handhelds, the average score was 22.7. The same students outscored high school students on the answers to questions from an Advanced Placement (AP) Calculus exam. Based on the positive results, and the need for more research into the effectiveness of handhelds, the current study utilized handheld technology to implement the brain training intervention.

The Nintendo Ds™ was chosen for use in the present study for a number of reasons. First, the Nintendo Ds™ is a technology product with which many adolescents have had considerable experience. For most of the participants, operating the Ds™ was comfortable and familiar to them. Because of the availability and popularity of the Ds™, it is a tool which students should enjoy using while at school as well as at home. The Ds™ was also chosen because the brain training activities selected for this research are not currently available for any other handheld device. Because of its portability, durability, and affordability, and with the right software, the Nintendo Ds™ has the potential to become a viable tool for teachers as they strive to meet the needs of 21st century students.

Braintraining Intervention

Neuroplasticity

“Neuroplasticity is the ability of the central nervous system (CNS) to change and adapt in response to environmental cues, experience, behavior, injury, or disease (Ludlow et al., 2008, p. 241)”. The human brain has shown the ability to change or reorganize

neural pathways as a result of learning (Cozolino, & Sprokay, 2006). Research has demonstrated that if a neural pathway remains inactive for a long period of time, that particular body function will fade (Ludlow, et al., 2008), for example, if a person learns a foreign language, but never uses it, they will lose the ability to speak the language. In contrast, research has also shown that if the pathway remains active, or is reengaged, abilities related to that substrate will increase (Nudo, Jenkins, & Merzenich, 1990). For this reason, retraining of the brain is extremely important for those with a brain injury, such as a stroke (Friel, Heddings, & Nudo, 2000). While retraining can occur throughout a person's life, the general belief has been that the brains of young children are most responsive to this change (Kramer, Bherer, Colcombe, Dong, & Greenough, 2004; Sawaki, Yaseen, Kopylev, & Cohen, 2003). Additionally, studies have shown that teenagers' brains may be highly susceptible to retraining in relation to algebra (Luna, 2004; Qin, et al., 2004). Unsurprisingly, the idea of retraining the brain is beginning to find its way into education (Ludlow, et al., 2008).

Principles of Brain Training

Brain training is based upon the premise of neuroplasticity. Research has demonstrated that completing short academic activities, such as reading aloud and solving arithmetic problems on a daily basis, will increase the blood flow to the prefrontal cortex, the area of the brain associated with memory and problem solving (Olsen, Westerberg, & Klingberg, 2004). The result of this training has shown improved memory function in both children and adults (Kawashima, 2005; Klingberg et al., 2005; Olsen, Westerberg, & Klingberg, 2004). Researchers have noted that in order for students

to be computationally fluent they must be able to retrieve math facts, and this retrieval process is where many students have difficulty (Hasselbring, Lot, & Zidney, 2006). One of the functions of working memory is to retrieve information from long term memory, as needed, to process information (Baddeley, 2000). If brain training can enhance working memory for students with LD, then it may help them to retrieve math facts from their own long term memory stores. The research on brain training is in its early stages, but the results appear promising.

After an extensive review of the literature on brain training, only one study was found which involved children under the age of 18. The research also included computerized brain training. In a randomized, controlled trial, Klingberg et al., (2005), examined the use of computerized brain training on 53 children with Attention Deficit Hyperactivity Disorder (ADHD) between the ages of nine and 12. During the study, the researchers took baseline data on the level of working memory (WM) for each child. The participants then completed computer-based working memory activities daily for 25 days. At the conclusion of the study, WM levels were again assessed for each child, with another follow up assessment 3 months later. The treatment group showed significant gains in working memory and maintained those gains at the follow up visit. While one additional study was located which was conducted with three young men, aged 20, 22, and 23, the remaining research on brain training has been conducted with adults. A large amount of this research has been with geriatric patients suffering from Alzheimer's disease.

Olsen, Westerberg & Klingberg (2004) confirmed earlier findings (Rainer & Miller, 2000) that brain training increases the activity in the prefrontal cortex. They

conducted two separate experiments, using fMRI. In both experiments they examined the brain activity of 11 subjects. All participants practiced daily brain training activities. In group one, the fMRI scans were done before and after the intervention. In group two, the scans were done five times during the five week study. Both experiments showed increases in the blood flow to the prefrontal cortex during the training activities. The results of fMRI studies have spawned research focusing on practical outcomes from brain training activities.

In a second study, Westerberg & Klingberg (2007) examined the effects of brain training on three male subjects. Results were examined after five weeks of daily training. The participants underwent fMRI scans prior to beginning the activities and after the completion of the study. The results showed that the training activities gradually increased the participant's performance and also generalized to tasks which were not part of the training activities. The fMRI scans also showed increased activity in the prefrontal cortex in all subjects, supporting the earlier findings (Olsen, Westerberg & Klingberg, 2004; Rainer & Miller, 2000).

Kawashima (2005) conducted an experimental study involving 16 Alzheimer patients and a control group. The study participants showed marked improvement after 6 months of daily brain training sessions. The participants improved their scores on both the Mini-Mental State Examination and the Frontal Assessment Battery; both assessments are used to measure dementia. The researchers also noted that some participants began to regain life skills which had been lost. One participant began to dress their self, while another regained toileting skills after the completion of the brain training activities. The members of the control group showed no improvement, and several

participants actually regressed. Kawashima has repeated the study twice with similar outcomes, but has not yet published these results.

There are still many questions about the extent to which working memory can be affected by brain training activities (Westerberg & Klingberg, 2007). The proposed brain training intervention has the potential to enhance the working memory functions of students with LD. This could have a profound affect on their ability to compute fluently, as well as completing other academic tasks.

Working Memory and Students with Learning Disabilities

Working memory contributes significantly to success in mathematics (Ashcraft, Krause, 2007; Keeler & Swanson, 2001; LeFevre, DeStefano, Coleman, and Shanahan, 2005) and the retention of basic facts has, at times, been attributed to memory function in students with LD (Geary & Brown, 1991; Jordan & Hanich, 2000). The most widely accepted model of working memory was proposed by Baddeley and Hitch (1974). The model expanded on the previous model of short term memory. The earlier model of short term memory believed that information was stored for a brief time in short term memory and then passed into long term memory (Atkinson & Shiffron, 1968) (See Figure 3)..

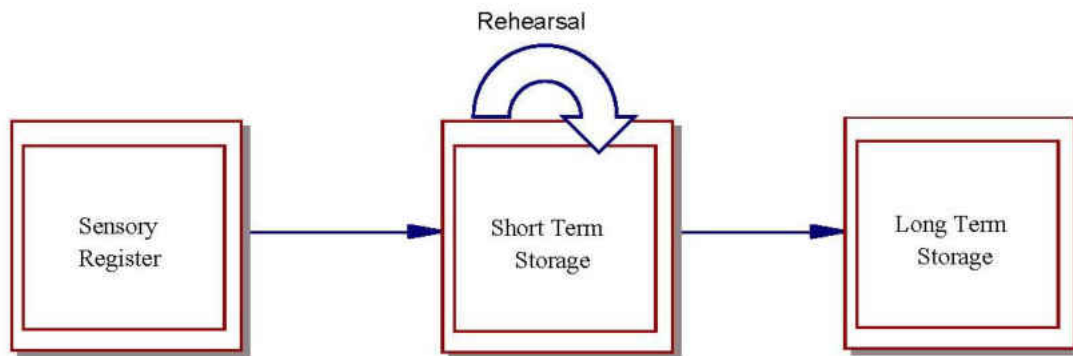


Figure 3: Baddeley's model of working memory

The model proposed by Baddeley and Hitch (1974) (Figure 3) is most commonly referred to as the Baddeley model of working memory. Within the original Baddeley model, working memory is controlled by a Central Executive Function, which makes a person aware of information in their working memory. Information is then processed by one of two subsystems. The first of these subsystems is the Phonological Loop. The Phonological Loop is in control of all verbal information or stimuli, such as a song, lecture, or written article. The second subset is referred to as the Visuospatial Sketchpad. The Visuospatial Sketchpad is responsible for processing all visual images (Baddeley & Hitch, 1974; Baddeley, 2002). In 2000, Baddeley added a fourth subsystem to his model, the Episodic Buffer. The purpose of the Eposodic Buffer is to link the episodes from each of the other subsets to create an episodic memory, such as a scene from a movie (Baddeley, 2000). Baddeley also notes that while the Central Executive Function coordinates the subordinate sections, it also pulls information from long term memory, when necessary (See Figure 4.). Regardless of the proposed model of working memory, both are in agreement that information must be rehearsed to make it into long term

memory (Atkinson & Shiffron, 1968; Baddley & Hitch, 1974). Rehearsal has become an important component of effective instruction, and is extremely important for students with LD who may struggle with working memory problems (Burns, 2004, 2005; Cooke & Reichard, 1996; Roberts & Shapiro, 1996).

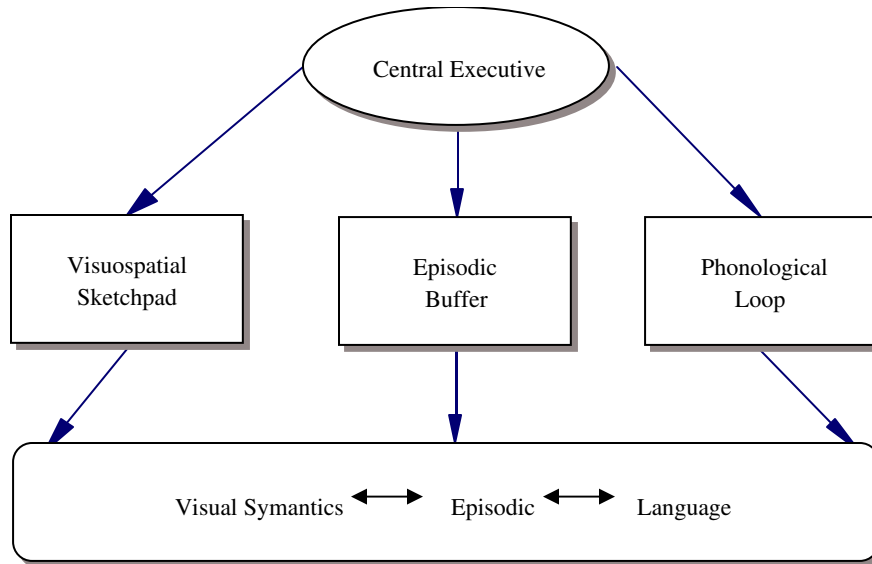


Figure 4: Baddeley's revised model of working memory

For students with LD to effectively retrieve strategies needed to solve various math problems, they rely on both the Visuospatial Sketchpad and the Phonological Loop (Keeler & Swanson, 2001). The problem for students with LD may be in the storage of information, not the way their brain processes it. Therefore the investigation of technology tools to enhance each student's ability to store and retain information is necessary. Feedback is important in any type of instructional intervention, but it is a crucial part of virtually all technology interventions (Clariana & Koul, 2006; Melis & Andres, 2005; Mishra, 2006; Soloman & Perez, 2002).

Instructional Feedback for Students with Learning Disabilities

With the invention of the computer, a whole new way of providing feedback emerged. Computers have the ability to evaluate student performance and provide instructional feedback (Mory, 2004). The present study intends to incorporate software equipped with an instructive feedback component. Webster's Dictionary defines feedback as "the transmission of evaluative or corrective information about an action, event, or process to the original or controlling source" (Webster's, 2008). Feedback is listed as part of Gagne's nine events of learning, and is slated as an important part of a student's instructional experience (Gange, Briggs, & Wagner, 1992). The term instructive feedback varies widely in the literature, but typically refers to two types of feedback; immediate and delayed. Immediate feedback (IF) refers to that which is provided directly following each item of an academic task, while delayed feedback (DF) occurs at the end of the whole task when all items have been completed (Bennett & Cavanaugh, 1998; Dihoff, Brosvic, & Epstein, 2003; Mory, 2004). Immediate feedback is generally believed to be more effective for the learner (Baechle & Lian, 2001; Bennett & Cavanaugh, 1998; Brosvic, Dihoff, Epstein & Cook, 2006; & Perkins, 1988), but delayed feedback is still better than no feedback. For the purposes of the present study, immediate feedback will be considered both with respect to students with learning disabilities and computer assisted instruction (CAI).

Immediate feedback has been repeatedly shown to increase academic performance for students with LD (Baechle & Lian, 2001; Bennett & Cavanaugh, 1998; Brosvic, Dihoff, Epstein & Cook, 2006; Pany, McCoy, 1988; Perkins, 1988). Results of

studies involving immediate feedback have remained positive across academic tasks as well as age groups. Baechle & Lian (2001) explored the use of immediate feedback on the learning of metaphors for 52 students with LD between the ages of eight and 13. The results of the study showed significant increases in the metaphor performances of the participants. In 1988, Perkins examined the effects of different types of feedback on 48 male students in grades first through fourth. While she concluded that immediate corrective feedback, where the student is immediately shown the correct answer, yielded the best results, any type of feedback was better than no feedback.

Bennett and Cavanaugh (1998), were interested in the effects of various types of feedback on the math performance of a single 9 year old girl while learning multiplication tables. The researchers examined the number of facts answered correctly per minute while the student self corrected under 3 conditions; no correction, immediate correction, and delayed correction. The results showed that the items correct per minute were highest when she was immediately given feedback and allowed to self correct.

Similar gains were reported by Brosvic, Dihoff, Epstein & Cook, (2006) in a series of 3 studies examining the effects of immediate vs. delayed feedback on retention of math fact series for 77 male and 43 female students with math LD. The results demonstrated that the provision of immediate feedback increased the participant's attainment of math facts across all four arithmetic operations. In light of the success of instructional feedback, the incorporation into CAI was a natural progression.

Feedback and CAI

Most researchers will agree that IF is a central component to any effective CAI program (Clariana & Koul, 2006; Melis & Andres, 2005; Mishra, 2006; Sloman & Perez, 2002). While the need for feedback in CAI is clear, the most effective type of feedback is not. Numerous studies have been completed to determine the most appropriate form of feedback to use in CAI. Two common types of feedback which are proposed as effective are multiple try feedback (MTF), which offers the learner multiple chances to come up with the right answer and knowledge of response (KR) feedback which simply cues the learner when their answer is right or wrong (Clariana & Koul, 2006; Melis & Andres, 2005; Mishra, 2006; Sloman & Perez, 2002).

In a meta-analysis of MTF, Clariana and Koul (2003) examined 20 studies which evaluated the use of MTF in CAI. Of the studies evaluated, they examined 35 effect sizes to determine efficacy of MTF. Of the 35 effect sizes, 12 indicated that MTF was less effective than KR during CAI, but 23 effect sizes indicated that MTF was slightly more effective than KR. While there were more studies indicating that MTF is more effective, the differences were slight. KR has been identified to be most effective when used with lower level thinking tasks such as memorization of math facts (Morrison, Ross, Gopolakrishnan, & Casey, 1995). While the current feedback research is varied, there still remain many questions to be answered. In Mory's (2004) review of feedback research, she offers several recommendations for future research:

1. Examine how feedback functions within a wider variety of learning domains. Higher-order learning such as concept acquisition, rule use, problem solving, and the use of cognitive strategies offers a rich source for researchers to explore.
2. Analyze individual learner motivations and attitudes and prescribe feedback based on factors such as tenacity, self-efficacy, attributions, expectancy, and goal structure.
3. Identify measurable variables that can reflect internal cognitive and affective processes of learners that might potentially affect how feedback is perceived and utilized.
4. Examine how feedback functions within constructivist learning environments and test new feedback strategies within these environments.
5. Examine the role of monitoring and how both external and internal feedback generation affects the learning from a viewpoint of self-regulation.
6. As technologies continue to advance, design feedback that utilizes the improved capabilities for instruction.
7. Continue to identify and test interactive patterns among the learner, the environment, individual internal knowledge construction, and varying types of feedback (p. 777).

In light of the current recommendations to complete the gaps in feedback research, the studies conducted to date all send a similar message. When instructional feedback is concerned, any feedback is better than no feedback (Baechle & Lian, 2001; Bennett & Cavanaugh, 1998; Brosvic, Dihoff, Epstein & Cook, 2006; Dihoff, Brosvic, & Epstein, 2003; Mory, 2004; Perkins, 1988). The brain training intervention being

examined is equipped with immediate feedback throughout the program. This component will keep students engaged and has the potential to maintain their willingness to participate in the required exercises. During the study, timed math probes were evaluated to determine the effects of the intervention.

CHAPTER 3: METHODOLOGY

Introduction

The purpose of this study was to determine the efficacy of using handheld computer activities to increase computational fluency by enhancing working memory for students with learning disabilities, who were identified as being below grade level in mathematics. The study examined how the identified activities affected the students' computational fluency speed and accuracy. Appropriate measures were taken to obtain informed consent. The following consent documents are included in the appendixes: Approval letter from the Institutional Review Board of The University of Central Florida (Appendix A), the Volusia County research approval document (Appendix B), the Parental Consent form (Appendix C), the Student Assent form (Appendix D), the Principal Letter of Support (Appendix E), and the Teacher Letter of Support (Appendix F).

Research Question

Is computational fluency speed and accuracy increased for secondary students with learning disabilities, after completing brain training activities on a handheld computer?

Research Design

The research design is an experimental single subject design, using the ABAB design method (Kazdin, 1982). According to Kazdin (1982), repeated observations of performance over time, is the most important component of single case experimental research. The single subject methodology was selected because it is designed to measure the effects of an intervention on the same person over time (Kazdin, 1982). The ABAB design was chosen because of the reversal component in the design. The researcher was not trying to determine the long term effects of the brain training activities, but rather the immediate daily effects of the activities. By utilizing the reversal design where the intervention is implemented and then removed before being implemented again, the researcher was able to more clearly determine the intervention effects. The effects of the computerized brain training were analyzed by taking baseline data on participant's computational fluency prior to the intervention, continuing to collect data during the intervention, and then once more when the intervention was withdrawn. A final sample was taken when the intervention was reinstated for the second time.

Design Review

Single-subject research has become important when examining educational interventions for the individual student, and many of the current interventions being practiced in school evolved through the single subject design (Horner, et al., 2005). The ABAB design is the most basic experimental design in single-subject research (Kazdin, 1982). The A phase of the design determines a baseline by observing the participants behavior or performance consistently for several days until their performance becomes

stable. At this point the intervention is introduced (B Phase). Phase A and Phase B are alternated two times. If the performance of the students advances during the intervention phase and then regresses to baseline levels when the intervention is removed, then the intervention is assumed effective (Kazdin, 1982)

Description of Participants

Participants were selected from a large suburban high school on the East Coast of Florida. A random sample was chosen from all students participating in three mathematics resource classrooms. Of the 45 students, 25 agreed to participate in the study by returning parental consent forms and completing Student Assent forms. All students were assigned a number from 1-25. The numbers were entered into an online randomizer and five numbers were chosen. Those five participants were re-labeled as participants one through five for anonymity purposes. The five participants were all male and ranged in age from 15-16 years old. The participating teacher identified possible participants based on their Individual Education Plans (IEP) (See Table 1).

. Table 1: Participant Demographics

Participant	Grade level	FCAT Level	Disability	Race	Age	Gender
1	9	1	LD	W	16	M
2	9	1	LD	W	16	M
3	9	1	LD	H	16	M
4	9	1	LD	H	15	M
5	9	1	LD	H	16	M

All possible participants were identified as having a learning disability and were also identified as struggling in mathematics based on scores from the Florida Comprehensive Assessment Test (FCAT). Students scoring a level one or low level two were considered for the study, but all participants in the final sample had scored a level 1 on the 2006-2007 FCAT exam. Students scoring a level one or two on the FCAT are considered below grade level in mathematics, but this level can range from slightly below grade level to significantly below level. For students scoring a level one, their scale score may range from 1238-1781, a difference of 543 points. When a student scores a level 2 their scale score ranges from 1782 – 1900, exhibiting a difference of 118 points. So, students scoring a level 1 are considered well below grade level. For this reason it is important to note that while the students participating in the study were taking a high school algebra class, their basic math skills were still significantly below grade level. If a student scores on the low end of a level 1, they will fall notably short of their peers in math (See Figure 5). Based on the knowledge of the students’ math scores, and because the researcher was

interested in measuring computational fluency, it was important to create a math probe which would not be overtly difficult for the participating students.

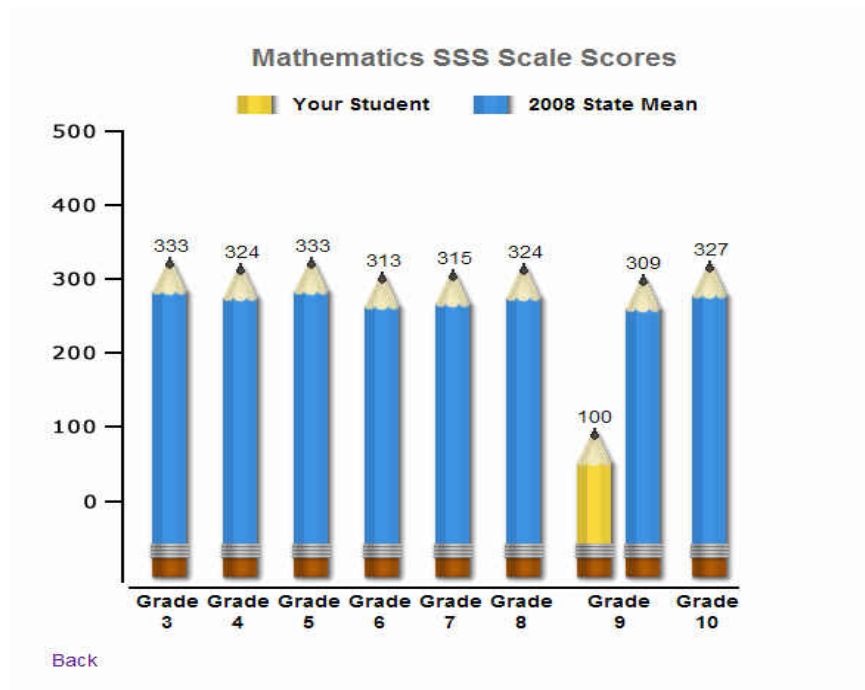


Figure 5: Example of a grade nine student scoring a low level 1 on FCAT (Florida Department of Education, 2008)

All students in the identified classroom were invited to participate in the research activities, but data were only collected on those students meeting the research criteria who have provided both Parental Consent and Student Assent forms. Demographics were collected and identified for all participants (Table 1). The students were being taught by a teacher certified in exceptional student education as well as mathematics.

Setting

The research was conducted in three mathematics resource classrooms of the participating teacher. All three classes were Algebra 1a courses, with the exception of one class in which there were 5 students working on the Algebra 1b curriculum. All

students participating in the Algebra 1a curriculum were repeating this course. The participating school operates on a block schedule, and the students had attempted the Algebra 1a course during the first half of the year. During the four weeks that the researcher spent in the classroom, the students were learning to graph linear equations. The timed math probes were interjected as an addition to, but not a substitute for the Algebra curriculum being taught. The brain training and timed math activities were set up in the back of the classroom behind a partition. Students came to the research table in groups of four. They completed only the timed math probes (See Appendix E) during the baseline weeks. During the intervention weeks, the students completed the brain training activities and then completed the timed math probe. During the baseline weeks, the activities took approximately three to four minutes per group. During the intervention phases, the activities took about 10 minutes per group. The activities were supervised by the researcher, the teacher, and her paraprofessional. The researcher was involved in both the supervision and the data collection.

Research Team

The research was conducted by a doctoral candidate at the University of Central Florida in the Department of Child, Family, and Community Resources. The researcher holds a graduate degree in the area of exceptional student education and has experience teaching secondary students with learning disabilities. The research was facilitated by the participating teacher and her paraprofessional. The fourth team member completed a fidelity checklist to ensure fidelity. The fourth team member holds a doctorate degree in exceptional student education and has extensive experience with students with learning disabilities and educational research.

The research team was trained in all intervention procedures. All members learned to program and manipulate the hand held activities, as well as specific protocols for conducting the timed math activities. The researcher met with the teacher prior to implementing the study and provided her with a DS and the braintraining software to allow her time to become acquainted with the program. The braintraining software guides the participant through the program step by step. The directions are written at approximately a fifth grade reading level. The researcher guided the students through the initial steps to accommodate for any struggling readers within the groups. The paraprofessional was also exposed to the software and the researcher implemented all groups during the introduction phase of the research. The teacher and paraprofessional assisted, but did not conduct the groups independently until they were comfortable with both the protocol and the software. The researcher collected and analyzed all data at the end of each session.

Dependent Measure

Rate of fluency gains on timed math probes was examined daily for each student. After careful discussion with the participating teacher on the content she was teaching and the math levels of her students, specific probes were created (See Appendix E). Each probe contained a random mixture of single digit addition, subtraction, and multiplication problems. Division was excluded because the teacher felt that some students would become very frustrated when asked to complete division problems in a timed setting. Each probe was timed daily for one minute. Both items correct and incorrect were counted and recorded on a standard chart for each student.

Independent Measure

Brain Age is a computer program designed for the Nintendo Ds™ hand held computer system. The Ds™ is a handheld gaming computer which serves as a host to numerous games produced by the Nintendo company. The Ds™ has two screens, and includes 3D graphics as well as touch screen technology. Players are often required to read one screen and write answers on the other. The Ds™ also has voice recognition technology and players are sometimes asked to complete activities where they speak. Because of the voice recognition software and a writing pad, the type of response vacillates between written and spoken responses. The Brain Age™ activities are based on the principles of brain training and instructional feedback. The activities are a series of mental exercises which the participant completed daily. The exercises took approximately 5-10 minutes to complete. Constant feedback is built into the activities, allowing the participant to know immediately if they had an answer correct or incorrect. The program began by taking the student through a series of brief activities to determine a beginning performance level. A Stroop Test, which measures a person's ability to focus attention, is included in the initial activities. Each day, the computer remembered the participant and displayed appropriate activities to engage the learner's prefrontal cortex and working memory. The activities varied, but always included timed math calculations. The timed math calculations were a series of twenty problems which include single digit addition, subtraction, and multiplication. With the dual screen technology, the problems appears on one screen and the participant is required to write the answer on the second

screen. The problems are scrolling and the current problem has a box around it. If they write the correct answer, the computer places a green check on the problem and a new problem appears (See figure 6). If the answer is wrong, the computer places a red x on the problem and the words "try again" appear. The participant gets three opportunities to write the correct answer before the computer moves on to the next problem. For the purposes of this study the students only completed the math activities with written responses.

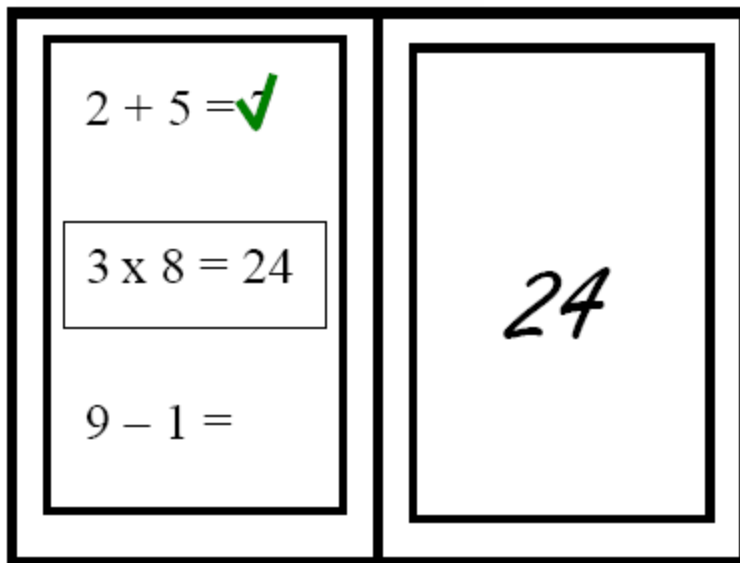


Figure 6: Sample of DS screen

Nintendo Ds™ is a popular gaming system among adolescents, and there is a strong likelihood that many of the participating students had a game system at home. Most of the participants admitted to having had exposure to the Ds™ gaming system, and some mentioned having played Brain Age outside of school. If the study was seeking to determine long-term effects of brain training, this would be considered a limitation of the current study. However, this research sought only to understand the immediate effects of

brain training on mathematical fluency, by having students complete the timed math probes immediately following the brain training activities. Because of this, outside use of the Ds™ or brain training activities was not considered to have affected the results of the study.

Procedures and Data Collection

Students in a resource mathematics class were invited to participate, with Informed Consent being collected from both the students and their parents. All students had the opportunity to participate, but data were only collected on those five students chosen randomly, and identified with a learning disability and a math deficit. The researcher first worked with the teacher to identify students with an identified learning disability based on their IEP. From this group, all students who had scored a level one or two on Florida Comprehensive Assessment Test (FCAT) were considered for participation in the study. The procedures were completed over a four week period (see Figure 7). All students completed a timed math probe daily for 1 week to determine a baseline (Kazdin, 1982), with data being recorded for the study participants. Because the math probes were timed, the researcher was looking for an average gain for each student. At the end of week one, students were introduced to Brain Age, a brain training program based on the work of Dr. Ryuta Kawashima. The researcher explained all activities to the students and allowed each student the opportunity to complete the trial activities. At this time the researcher created profiles for each student in the software program. During week two, students completed the Brain Age activities daily, prior to completing the timed math probe. Average gains for each student continued to be recorded. During week three, the Brain Age activities were withdrawn and students continued to complete the

timed math probes. During week four, the Brain Age activities were reinstated and data collection continued as the students completed the math probes.

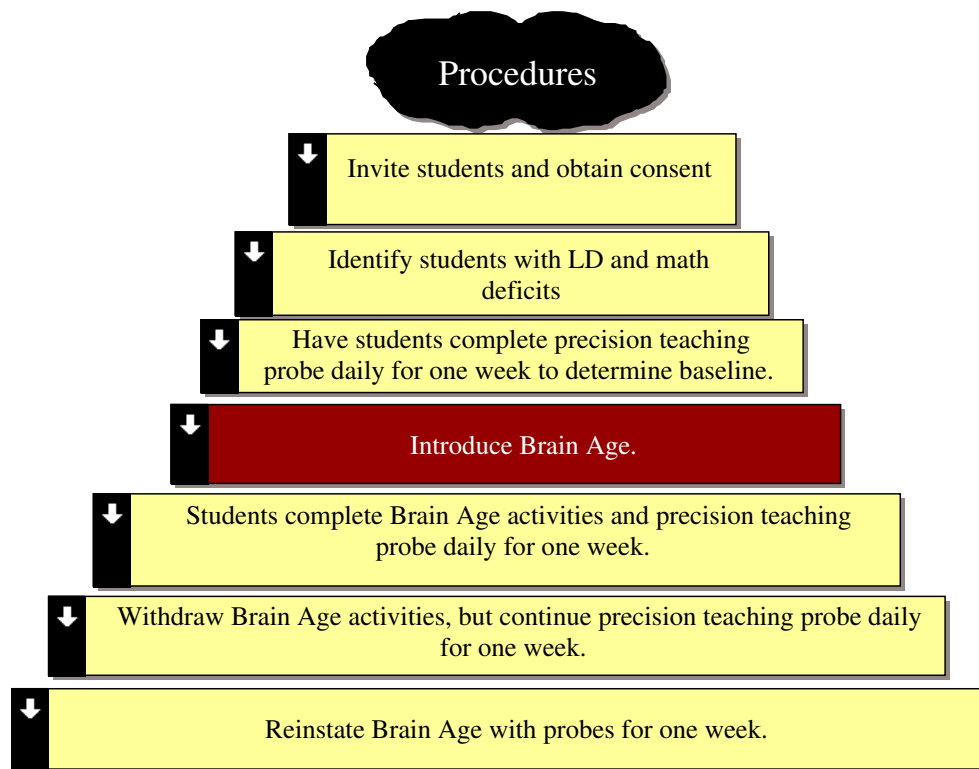


Figure 7: Research procedures

Fidelity of Treatment

During all phases of the treatment, the researcher, the participating teacher and paraprofessional completed a ten-item fidelity checklist (see Figure I). daily to determine efficacy of the treatment. The checklist was also completed at random intervals during the treatment by an unbiased member of the research team who was trained to understand the procedures being implemented. The researcher ensured that all team members had a

fluent understanding of the procedures, and they had ample time to practice the procedures prior to implementation.

Data Analysis

Timed math probes were completed and the results were recorded daily. The data were represented graphically using a simple line graph to show the participants level of performance over time (Kazdin, 1982), and average scores were stated for each week. Statistical analysis was also completed to determine if there was significant change from one phase to the next. The Pearson's correlation coefficient was conducted to determine if serial dependency existed. After finding that dependency did exist, the researcher had planned to conduct a time series analysis. The computation of a time series analysis was not possible due to the small number of data points available per week. Therefore the split-middle technique was used to determine the projected slope of the data during the intervention phase, The split-middle technique (White, 1974) has been advocated as a supplement to visual inspection (Ottenbacher, 1990). The split-middle technique is used to find the median of the data and determine a trend line. To determine the split middle, the data is split vertically, and the each section is split again. A trend line is then drawn through the highest and lowest points within the sections. The trend line is then continued through the intervention phase to predict the possible results if the intervention were not implemented (White & Harding, 1980). Using the split-middle technique has shown an increase in inter-rater agreement when visually analyzing graphs (Baily, 1984). After determining the trend lines, a binomial test was computed to determine if the number of data points in the intervention phase, falling on or above the projected slope, were enough

to be considered statistically significant. All results have been displayed independently for each participant in Chapter 4.

Social Validity

The present study sought to improve the lives of secondary students with learning disabilities by introducing them to an affordable tool which has the potential to improve their ability to compute fluently. Prior to beginning the study, the researcher met with the participating teacher who expressed concerns for her students with LD. The teacher reported that her students experience high levels of frustration and embarrassment when attempting to recall basic math facts. The proposed intervention had the potential to advance the academic ability and self concept of students with LD.

Threats to Validity

Internal threats to validity included history and maturation. History as a threat to validity was a distinct possibility, but difficult to predict prior to treatment. Until the study was underway the researcher had no way of knowing what event could possibly occur at the same time of treatment. The researcher's goal was to acquire a large enough sample size to account for any specific events for one or two participants. The goal was achieved with 25 possible participants. Six were lost to high levels of absenteeism, which left the researcher with a possible 19 participants. Because the data were analyzed using timed math probes, the possibility existed that the student's achievement may increase due to classroom instruction and not the intervention. This was not an issue because the

participants did not make consistent gains across all four phases. Instead, they displayed regression during the second baseline phase.

CHAPTER 4: RESULTS

The purpose of the current study was to examine the effects of computer based brain training on the mathematical fluency of secondary students with learning disabilities. One research question was analyzed, and focused specifically on the student's rate of fluency after completing the brain training activities. Research question examined: Is computational speed of math facts increased for secondary students with learning disabilities, after completing brain training activities on a handheld computer?

The study was designed to measure the fluency gains of secondary students who were struggling in mathematics. Because the researcher was interested in specifically measuring fluency gains, the math probes consisted of basic math facts. The curriculum being taught in the class was algebra, but many students were still struggling to compute even basic facts fluently.

The data were analyzed using a single subject ABAB design. All students completed a one minute timed math probe at the same time each day during both baseline and intervention phases. All problems answered correctly were included in the data. Data for all participants are represented visually utilizing a simple line graph for each participant. Baseline data was first taken to determine a rate of performance for each participant. Due to the nature of repeated timed math probes, some gains were expected during the baseline phase. The data were analyzed by visual inspection (Kazdin, 1982), and also evaluated using the split-middle technique (White, 1974). Data were analyzed and represented separately for each participant.

Participant 1

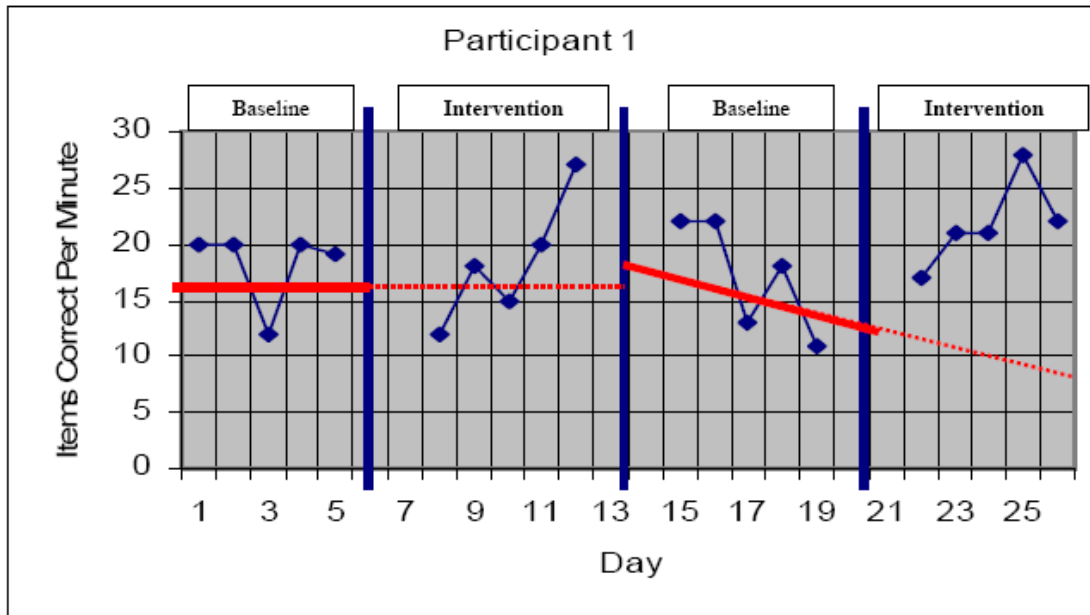


Figure 8: Fluency progress participant 1

Figure 8 represents the correct number of math problems solved per minute daily during both the baseline and the intervention phases for participant one. The solid red line during the baseline phases represents the line of slope determined through the split middle technique. The dashed red line extending into the intervention phase represents the predicted slope of the data if the intervention were not used. These lines are present on all five charts. Participant one maintained a stable baseline during week one, and started the intervention phase with a sharp decline in items correct. On the ninth day of the study the data displayed an increase, followed by a slight decrease before a sharp increase in items correct which continued through the first intervention phase. During the second baseline phase, the items correct per minute started out higher than the first

baseline phase, but continued to decrease each day. However day 18 of the study exhibited an increase followed by a significant decrease. During the final intervention phase, participant one maintained a steady increase, and ended with a significant decline on the last day. Participant 1 displayed a mean number of 18.2 items correct per minute during the first baseline and intervention phases, a mean of 16.4 during the second baseline phase and a mean number correct of 21.8 during the final intervention phase.

Binomial Test

	Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Part1phase1and2	Group 1	above	3	.60	.50 1.000
	Group 2	below	2	.40	
	Total		5	1.00	
Part1phase3and4	Group 1	above	5	1.00	.50 .063
	Total		5	1.00	

Figure 9: Binomial Test P1

The split-middle technique was used to determine the projected slope of the data during the intervention phase and a binomial test was computed to determine if the number of points falling on or above the projected slope were statistically significant (Figure 9). The split middle celeration lines have been represented in red on the fluency progress chart for participant one (Figure 8). The celeration line extended from each baseline phase into each intervention phase to display the projected celeration line. Null hypothesis = There is no change in performance across phases. For participant one, during the initial baseline and intervention phases, at a value of $p > .05$, the null hypothesis was accepted. The data of the intervention phase were not significantly different from the baseline phase. However, at $p < .05$, the null hypothesis was rejected

for the second baseline and intervention phase. There was a statistically significant difference between the phases.

Participant 2

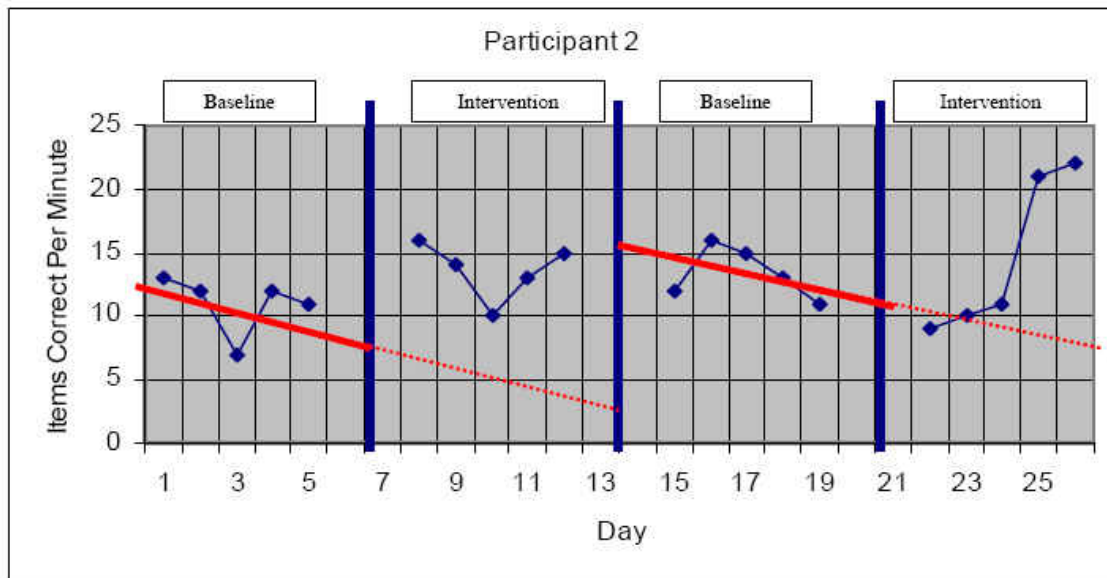


Figure 10: Fluency progress participant 2

Figure 10 represents the correct number of math problems solved per minute daily during both the baseline and the intervention phases for participant two. Participant two maintained a stable baseline during week one. They started the intervention phase with an increase in items correct over the last day of the baseline phase. After the initial increase, participant two displayed a steady decline before increasing on days 11 and 12. The second baseline phase started out with an increase, and then consistently decreased during days 17, 18, and 19. During the final intervention phase, participant two's problems correct started out low but maintained a steady increase for the entire phase. Participant two displayed a mean number of 11 items correct per minute during the first

baseline, 13.6 items correct during the first intervention phase, and a mean of 13.4 during the second baseline phase with a mean number correct of 15.2 during the final intervention phase.

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Part2phase1and2	Group 1	above	5	1.00	.50	.063
	Total		5	1.00		
Part2phase3and4	Group 1	above	4	.80	.50	.375
	Group 2	below	1	.20		
	Total		5	1.00		

Figure 11: Binomial Test P2

The split-middle technique was used to determine the projected slope of the data during the intervention phase and a binomial test was computed to determine if the number of points falling on or above the projected slope were statistically significant (Figure 11). The split middle celeration lines have been represented in red on the fluency progress chart for participant two (Figure 10). The celeration line extended from each baseline phase into each intervention phase to display the projected celeration line. Null hypothesis = There is no change in performance across phases. For participant two, during the initial baseline and intervention phases, at a value of $p < .05$, the null hypothesis was rejected. There is a statistical difference between the phases. However, at a $p > .05$, the null hypothesis is accepted for the second baseline and intervention phase. The data of the intervention phase were not statistically significantly different from the baseline phase.

Participant 3

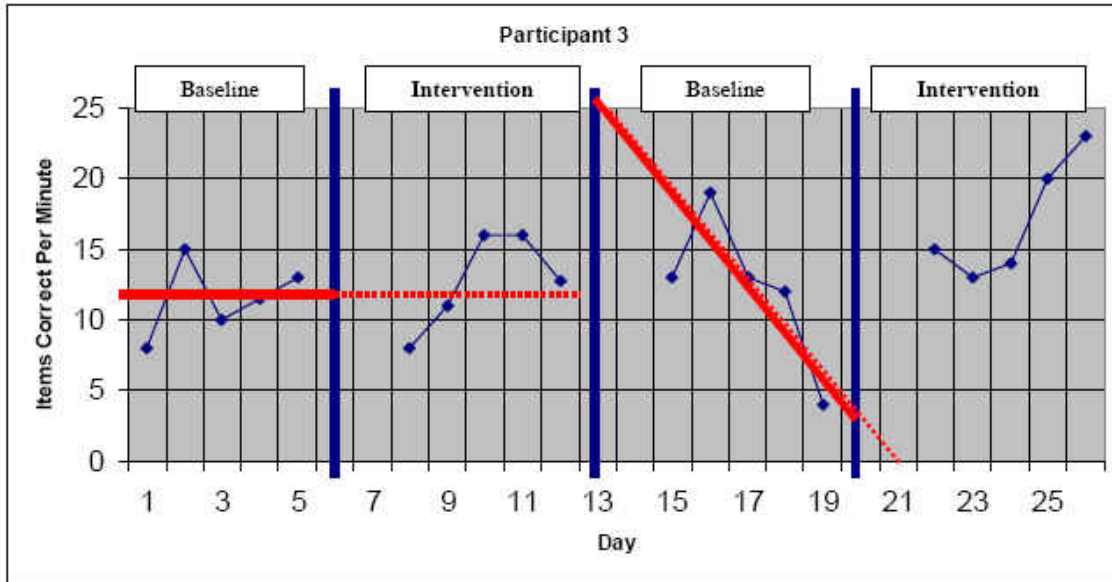


Figure 12: Fluency Progress participant 3

The correct number of math problems solved per minute daily during both the baseline and the intervention phases for participant three is represented in Figure 12. Participant three maintained a stable baseline during week one and began the first intervention phase with the same number of items correct as on day one. During the first intervention phase, the data showed a steady increase, before leveling out and decreasing on day 12. During the second baseline phase, the items correct per minute started out at the same level as on the last day of the intervention phase, but then continued on a sharp decline for the remainder of the week. During the final intervention phase, participant two maintained a steady increase, with only a slight decline on day 23. Participant three displayed a mean number of 11.6 items correct per minute during the first baseline phase, and 12.8 during the intervention phase, with a mean of 12.2 during the second baseline phase and a mean number correct of 17 during the final intervention phase.

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Part3phase1and2	Group 1	above	3	.60	.50	1.000
	Group 2	below	2	.40		
	Total		5	1.00		
Part3phase3and4	Group 1	above	5	1.00	.50	.063
	Total		5	1.00		

Figure 13: Binomial Test P3

The split-middle technique was used to determine the projected slope of the data during the intervention phase and a binomial test was computed to determine if the number of points falling on or above the projected slope were statistically significant (Figure 13). The split middle celeration lines have been represented in red on the fluency progress chart for participant three (Figure 12). The celeration line extended from each baseline phase into each intervention phase to display the projected celeration line. Null hypothesis = There is no change in performance across phases. For participant three, during the initial baseline and intervention phases, at a value of $p > .05$, the null hypothesis was accepted. The data of the intervention phase were not significantly different from the baseline phase. However, at a $p < .05$, the null hypothesis was rejected for the second baseline and intervention phase. There was a statistically significant difference between the phases.

Participant 4

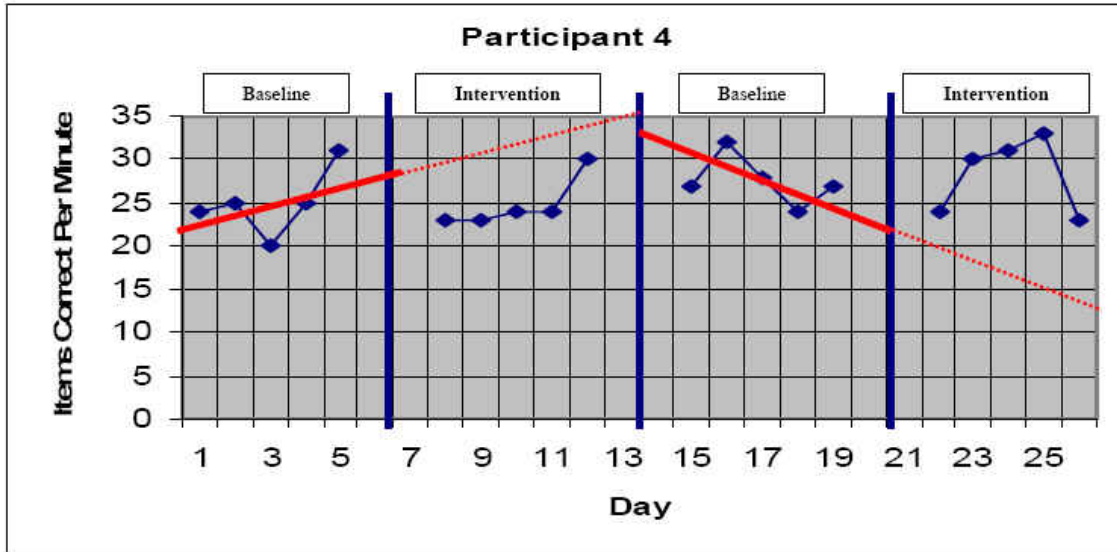


Figure 14: Fluency progress participant 4

Represented in Figure 14 is the correct number of math problems solved per minute daily during both the baseline and the intervention phases for participant four. Participant four maintained a stable baseline during week one. The student started the intervention phase with a consistent number of items correct and showed an increase on day 12. The second baseline phase started out with an increase and then consistently decreased during days 17 and 18 before a slight increase on day 19. During the final intervention phase, participant four's problems correct started out low but maintained a steady increase for most of the phase, before a sharp decrease on the last day. Participant four displayed a mean number of 25 items correct per minute during the first baseline and 24.8 items correct during the first intervention phase, with a mean of 27.6 during the second baseline phase and a mean number correct of 28.2 during the final intervention phase.

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Part4phase1and2	Group 1	below	5	1.00	.50	.063
	Total		5	1.00		
Part4phase3and4	Group 1	above	5	1.00	.50	.063
	Total		5	1.00		

Figure 15: Binomial Test P4

The split-middle technique was used to determine the projected slope of the data during the intervention phase and a binomial test was computed to determine if the number of points falling on or above the projected slope were statistically significant (Figure 15). The split middle celeration lines were represented in red on the fluency progress chart for participant four (Figure 14). The celeration line extended from each baseline phase into each intervention phase to display the projected celeration line. Null hypothesis = There is no change in performance across phases. For participant four, during both the initial baseline and intervention phases, and the second baseline and intervention phases, at a value of $p < .05$, the null hypothesis was rejected four all four phases. For all phases there was a statistically significant difference from the baseline phase.

Participant 5

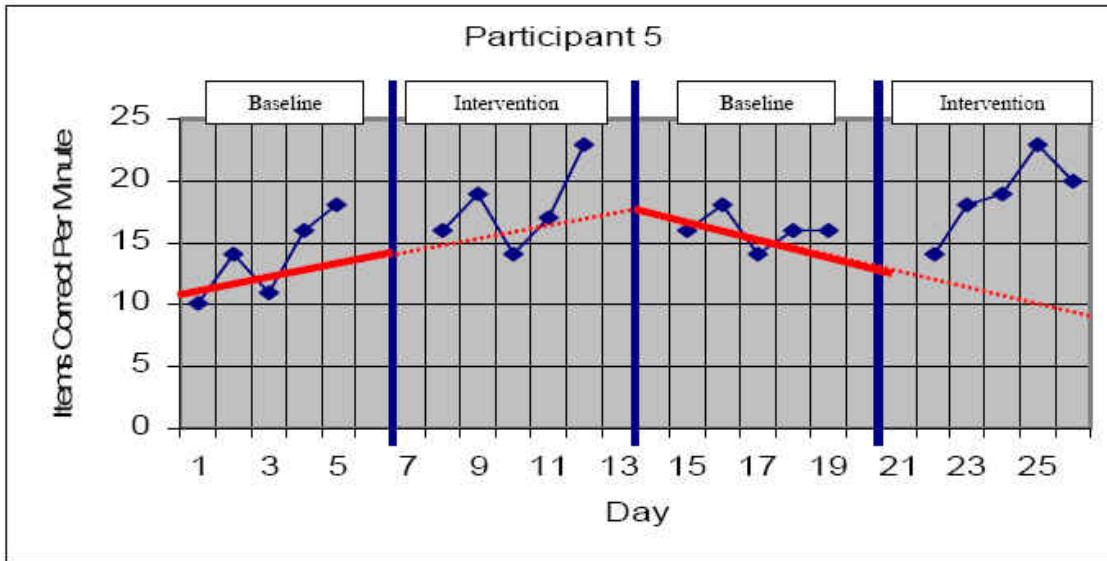


Figure 16: Fluency progress participant 5

The correct number of math problems solved per minute daily during both the baseline and the intervention phases for participant five has been represented in Figure 16. Participant five maintained a stable baseline during week one, with a steady increase on days 3, 5, and 7. Participant five's data from the first intervention phase began with an increase in items correct, before decreasing on day 10. The data showed a sharp increase on days 11 and 12. During the second baseline phase, the data showed only a slight increase and small decrease. During the final intervention phase, participant five showed a steady increase in the items correct, but decreased on the last day. Participant five displayed a mean number of 13.8 items correct per minute during the first baseline and 17.8 items correct during the first intervention phase with a mean of 15.8 during the second baseline phase and a mean number correct of 18.8 during the final intervention phase.

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Part5phase1and2	Group 1	above	4	.80	.50	.375
	Group 2	below	1	.20		
	Total		5	1.00		
Part5phase3and4	Group 1	above	5	1.00	.50	.063
	Total		5	1.00		

Figure 17: Binomial Test P5

The split-middle technique was used to determine the projected slope of the data during the intervention phase and a binomial test was computed to determine if the number of points falling on or above the projected slope were statistically significant (Figure 17). The split middle celeration lines were represented in red on the fluency progress chart for participant five (Figure 16). The celeration line extended from each baseline phase into each intervention phase to display the projected celeration line. Null hypothesis = There is no change in performance across phases. For participant five, during the initial baseline and intervention phases, at a value of $p > .05$, the null hypothesis was accepted. There was no statistical difference between the phases. However, at a $p < .05$, the null hypothesis is rejected for the second baseline and intervention phase. The data of the intervention phase exhibited a statistically significant difference from the baseline phase.

The mean number of items correct per participant across phases has been displayed (See Table 2).

Table 2: Mean Number of Items Correct per Participant Across Phases

Participant	Baseline 1	Intervention 1	Baseline 2	Intervention 2
1	18.2	18.2	16.4	21.8
2	11	13.4	13.6	15.2
3	11.6	12.8	12.2	17
4	25	24.8	27.6	28.2
5	13.8	17.8	15.8	18.8

Overall Summary of Findings

The evaluation of computerized brain training and number of math problems correct per minute produced mixed results. Participants one, two, and three demonstrated gains or maintenance across all four phases, and ended with a 2-5 point gain in the final intervention phase. For participants one, three, and five, mean items correct per minute increased at the first intervention phase, but regressed during the second baseline phase before increasing again during the last intervention phase. Continuous gains across phases were expected due to the repeated timed math probes, so the regression during the second baseline is important to note. Participant four demonstrated a statistically significant change in the number of items correct across both intervention phases. Participant two's data demonstrated a statistically significant change during the first

intervention phase only, while data for participants one, three, and five demonstrated statistically significant change for the second intervention phase, but not the first.

CHAPTER 5: SUMMARY

Conclusions

The results of the current research have demonstrated that while computerized brain training may be effective for some students, the results are varied. Though this research was not designed to directly measure working memory, the research on WM has shown that brain training may enhance the WM of adolescents and adults (Kawashima, 2005; Klingberg et al., 2005; Olsen, Westerberg, & Klingberg, 2004). The present study sought to determine if the computerized brain training might enhance WM enough to increase computational speed and accuracy for the identified population. While some gains in computational speed and accuracy were noted for all participants, statistically significant differences were only observed for one participant across all four phases. Specific attention should be given to the noted regression during the second baseline phase for three of the five participants.

Visual Inspection

Visual inspection of the data for all five participants showed some disparity in results for the five participants. Data for participants one, two, three, and five did however display improved performance during the first intervention phase. This was followed by a negative slope during the second baseline phase and improved performance during the final intervention phase. Participant four's data demonstrated no gains in the first intervention phase, but a decline during the second baseline phase and gains during

the last intervention phase. The initial purpose of this research was to examine the data and determine if the students were making more significant gains during the intervention phases. The assumption was that students would make continuous gains due to the use of timed math probes, and the research would examine whether or not the use of computerized brain training would lead to more significant gains. Continuous gains were not visible in the data, and instead a more traditional ABAB design pattern emerged. According to Kazdin (1982), intervention effects may be considered valid if the performance improves during the first intervention phase, regresses during the second baseline phase, and improves again during the last intervention phase.

Statistical Analysis

The statistical analysis applied to the data was a binomial test. After conducting a split-middle analysis, the researcher ran the binomial test to determine if the number of data points falling on or above the projected celeration line was significantly different from the baseline phase. For participant four, the data were statistically different during both intervention phases. For participant two, the data were statistically different during the first intervention phase only, while for participants one, three and five, the difference was only noted as statistically significant during the final intervention phase.

Effectiveness of Computerized Brain Training

The results of the present study have indicated a few positive effects on timed math probes while completing the brain training activities. The math probes appeared to be at an appropriate level for the students. Even though the participants were enrolled in

an algebra class, they appeared to be appropriately challenged by the math probes. While the probes consisted of only single-digit addition, subtraction, and multiplication, the researcher observed the majority of students using finger counting and table tapping techniques to solve many of the problems. While there were variations in the data, all five participants demonstrated visible gains during one or both of the intervention phases. The participants displayed a high level of interest in the software, which may have attributed to the regression in the second baseline.

The level of regression during the second baseline was unexpected and should be considered when interpreting the results of this research. While the students completed the timed math probes during all four phases, the researcher observed a more obvious level of engagement during the intervention phases. During the intervention stages, the students would count the number of problems they answered and then look back in their folder to compare the results with the items correct on the previous day. This additional motivation may have contributed to the higher scores during the intervention phases.

The participants were eager to participate with the computer activities and the teacher commented on their willingness to complete class assignments in order to be ready when it was their turn with the computers. The researcher noticed an increased interest in the activities during the intervention phases. The students appeared to be far less interested in completing the timed math probe when the computers were not part of the activities sequence. During the intervention phase, the students would count their answers and compare the score with the previous days activities. After comparing the scores they would become visibly happy or disappointed based on their results. During the intervention weeks the time on task was very high. All participants remained actively

engaged in the activities and did not require any type of reinforcement to complete all activities in a timely manner. Even the students which the paraprofessional had cautioned may exhibit some undesirable behaviors, were focused and engaged during all activities. The teacher agreed with the researchers observation that the students were very focused while completing the computer activities and disappointed during the baseline phase when they were only completing the timed math probes. The students took exceptional care with the Ds™ systems, and after four weeks of use by 45 students, all pieces of equipment were in perfect condition. Throughout the study, the students were consistently respectful of the researcher and the research proceedings.

An interesting observation was the interest that the present study generated from the faculty at the participating high school. During the intervention phase, the research proceedings were observed by the school principal, the assistant principal in charge of exceptional student education, and the department chair for the exceptional education department. All three visitors stayed to observe the students, as well as trying the brain training activities. They all expressed excitement about the technology, and genuine interest in the results. The assistant principal discussed the possibility of purchasing the brain training activities for the following school year, pending the results of the research. They also articulated an interest in being considered as a research site, should the researcher conduct a follow up study.

Overall, the computerized brain training activities seem to have a positive effect on math fluency. The activities also appeared to have a motivating effect on the student's enthusiasm towards completing the timed math probes. They were anxious to be called for their turn and hesitated to leave when they were through. The teacher expressed her

interest in participating in any further research with the computerized brain training. While the results appeared encouraging, they should be utilized with caution until further replication studies are completed.

Implications for Practice

Math fluency is a continued concern for students at all levels, but particularly for secondary students who struggle with mathematics (Fleishner, Garnett, & Shepard, 1982; Goldman, Pellegrino, & Mertz, 1988; Greene, 1999). The preliminary results of using computerized brain training to increase computational fluency appear positive. While more research is needed on the effects of the brain training, it appeared to have the potential to be a practical resource for secondary teachers.

The students appeared to be very comfortable with the computer technology employed in this study. The computerized brain training activities were performed on a Nintendo Ds™, a platform which all students mentioned having some experience with. After receiving instructions the first day, most students were able to turn on the equipment and complete their activities with little or no assistance from the teacher or researcher. By the third day, all students were independently completing the brain training activities. The feedback component present in the braintraining activities had a motivating effect on the participants. While answering math problems on the Ds™, students have to write their answer on the screen. At times the Ds™ does not recognize handwriting and may say the answer is wrong, when in fact it is correct. When this occurs the participant must keep writing the answer until it is recognized. The researcher expected that this component could be frustrating for students, but found it to have the opposite effect. The students appeared extremely motivated by the immediate feedback

and would continue to write the answer until it was recognized by the Ds™ . They would verbally express a small amount of frustration, but continued to persevere and never gave up. This could serve as a tremendous benefit to teachers who wish to employ this technology in their classrooms, because they could trust that the students would continue to try, even if they have the wrong answer. Once the students have been instructed on how to use the Ds™, completion of the activities will take little to no time from their regular teaching activities. Also important to note is that in two weeks of using the Ds™s with 45 students, every piece of equipment was in tact at the end of the study. The students were extremely careful with the equipment. Also of interest is the equal level of engagement found among both male and female participants. The researcher expected the male students to find the technology engaging, but was unprepared for the high interest level of the female students. Both groups were equally engaged with the software, and one of the female students purchased the software to use at home.

The computerized brain training activities possess the potential of being a practical way for teachers to help students with learning disabilities increase their computational fluency speed. The activities were performed using technology which is not only non- threatening to secondary students, but popular with them as a recreational activity. High school students could carry around these activities without the fear of peer rejection, which could be associated with other technology interventions. The Ds™ would potentially be well accepted by their peers, considering its popularity among adolescents.

Limitations

Limitations are important to consider within the context of the results of the current study. Single subject research lends itself to a small sample size. According to Kazdin (1982) generalizability is only a concern if single subject research is done in isolation, with no replication. This particular study included five students. The use of a small sample size does not make generalizability impossible, but the small sample increases the need for replication (Kazdin, 1982). The study included a clear description of the methodology used, which will lend itself to replication.

Another limitation to consider was the absenteeism rate for high school students, particularly towards the end of the school year. When selecting participants, the researcher had to eliminate 6 possible students because their rate of absenteeism was so high that they missed half of the days in which data were taken. This would be important to consider during replication. Perhaps beginning the study during the first half of the school year would yield better participation results. The end of the school year also appeared to have a slight effect on the students' ability to focus. The researcher noticed the students becoming more and more restless as the study progressed. They were always anxious to participate, but during the last intervention phase some of the students had to be reminded to focus and not disturb the person closest to them. The teacher and paraprofessional commented on the restlessness of the students towards the end of the study as well. Considering the results of the current study, it is likely that if the study were conducted earlier in the school year, better results may be found.

Recommendations for Future Research

Replication of the current study will be necessary in order to interpret the results as reliable. When replicating the study, longer phases may be considered. While the current phases were adequate, longer baseline and intervention phases may yield a different statistical result. When running the binomial test with five data points, when four out of five fell above the projected celeration line, significance was not found, but if the same data were run and eight out of ten fell above the line, the results would be considered significant.

The time of the year is another important consideration before replicating the current study. Because the data collection took place towards the latter half of the school year, several participants were lost to maturation issues. The students who were seniors left school two weeks early. There was also a high level of absenteeism and a certain amount of restlessness among the students. The teacher attributed this to the time of year, and stated that attendance and focus is much higher during the first half of the year.

Research into the use brain training activities with school aged children is still new. More research is needed into the actual effects of brain training on working memory for students with learning disabilities. The research should directly measure working memory. If brain training does, in fact, enhance working memory for students with learning disabilities, the effects could be life altering for many students.

Conclusion

Math fluency remains a salient issue for secondary students with learning disabilities. While many teachers struggle to teach higher level math to these students, the students are still using very primitive methods to solve the most basic math problems. In order for struggling math students to grasp higher level math concepts, they need to increase their fluency with basic facts. Currently, drill and practice, or the use of calculators, are the most common solutions to these problems. New tools need to be examined as potential solutions to increasing the level of computational fluency for secondary students with LD.

The computerized brain training activities appear to have some effect on the participant's ability to compute math facts quickly. All participants displayed an increased number of items correct per minute during at least one of the intervention phases. While the results may not be conclusive, they do warrant further investigation into computerized brain training as a possible tool for secondary students with LD.

APPENDIX A:
INSTITUTIONAL REVIEW BOARD



University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Notice of Expedited Initial Review and Approval

From : UCF Institutional Review Board
FWA00000351, Exp. 5/07/10, IRB00001138

To : Marcey A. Kinney

Date : May 06, 2008

IRB Number: SBE-08-05641

Study Title: AN INVESTIGATION OF THE EFFECTS OF USING HANDHELDS TO INCREASE COMPUTATIONAL SPEED BY ENHANCING WORKING MEMORY FOR SECONDARY STUDENTS WITH LEARNING DISABILITIES

Dear Researcher:

Your research protocol noted above was approved by **expedited** review by the UCF IRB Vice-chair on 5/6/2008. **The expiration date is 5/5/2009.** Your study was determined to be minimal risk for human subjects and expeditable per federal regulations, 45 CFR 46.110. The category for which this study qualifies as expeditable research is as follows:

7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The IRB has approved a **consent procedure which requires participants to sign consent forms.** Use of the approved, stamped consent document(s) is required. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Subjects or their representatives must receive a copy of the consent form(s).

All data, which may include signed consent form documents, must be retained in a locked file cabinet for a minimum of three years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained on a password-protected computer if electronic information is used. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

To continue this research beyond the expiration date, a Continuing Review Form must be submitted 2 – 4 weeks prior to the expiration date. Advise the IRB if you receive a subpoena for the release of this information, or if a breach of confidentiality occurs. Also report any unanticipated problems or serious adverse events (within 5 working days). Do not make changes to the protocol methodology or consent form before obtaining IRB approval. Changes can be submitted for IRB review using the Addendum/Modification Request Form. An Addendum/Modification Request Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at <http://iris.research.ucf.edu>.

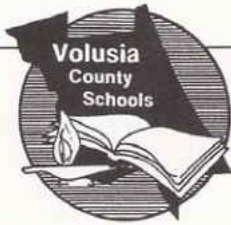
Failure to provide a continuing review report could lead to study suspension, a loss of funding and/or publication possibilities, or reporting of noncompliance to sponsors or funding agencies. The IRB maintains the authority under 45 CFR 46.110(e) to observe or have a third party observe the consent process and the research.

On behalf of Tracy Dietz, Ph.D., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 05/06/2008 01:44:13 PM EDT

IRB Coordinator

APPENDIX: B
VOLUSIA COUNTY PUBLIC SCHOOLS RESEARCH APPROVAL



Dr. Margaret A. Smith
Superintendent of Schools

P.O. Box 2410
Daytona Beach, Florida 32115-2410

DeLand
(386) 734-7190

Daytona Beach
(386) 255-6475

729 Loomis Avenue
Daytona Beach, Florida 32114

New Smyrna Beach
(386) 427-5223

Osteen
(386) 860-3322

School Board of Volusia County

Ms. Judy Conte, Chairman
Mrs. Diane Smith, Vice-Chairman
Dr. Al Williams
Ms. Candace Lankford
Mr. Stan Schmidt

April 16, 2008

Ms. Marcey A. Kinney
408 Lafayette Street
Port Orange, FL 32127

Dear Ms. Kinney:

I have received your request to conduct research with Volusia County Schools. I understand you will be conducting research on "An investigation of the effects of using handhelds to increase computational speed by enhancing working memory for secondary students with learning disabilities." I am approving your request to conduct your research with students and math resources teachers at Pine Ridge High School. As with all request to do research; participation is at the sole discretion of the principal, teachers, parents and students involved.

By copy of this letter, you may contact Mr. Russell, the principal. We request that you conduct your survey with as little disruption to the instruction day as possible.

I would appreciate receiving a copy of your survey results at the completion of your study.

Sincerely,

Chris J. Colwell, Deputy Superintendent
Instructional Services

CJC/mf

cc: Mr. Thomas Russell, Principal - Pine Ridge High School

APPENDIX C:
PARENTAL CONSENT



Parental Consent

Researchers at the University of Central Florida (UCF) study many topics. To do this we need the help of people who agree to take part in a research study. You are being asked to allow your child to take part in a research study. You can ask questions about the research. You can read this form and agree right now for your child to take part, or take the form home with you to study before you decide. You will be told if any new information is learned which may affect your willingness to allow your child to continue taking part in this study. Your child is being invited to take part in this research study because he or she is in a special education class at Pine Ridge High School. You must be an adult 18 years of age or older to be able to give this permission and sign this form for your child to take part in this research study.

The person doing this research is Marcey A. Kinney, a doctoral candidate of UCF, department of children and family services.

Study title: An Investigation of the Effects of Using Handhelds to increase Computational Speed by Enhancing Working Memory for Secondary Students with Learning Disabilities.

Purpose of the research study: The purpose of this study is to determine the effectiveness of using a handheld computer game to increase computational speed of math facts for secondary students.

What your child will be asked to do in the study: Your child will be asked to complete daily timed math probes for one week. The probes will be worksheets on math facts such as addition, subtraction, multiplication or division. Your child will have one minute to complete as many facts as possible. After one week, your child will be introduced to Brain Age, a research based brain training activity by Nintendo. Each day your child will complete the Brain Age activities, followed by completion of the timed math probe. The whole process will take approximately 7-10 minutes. Your child will complete math probes with the Brain Age game every other week for a total of four weeks.

Voluntary participation: You should allow your child to take part in this study only because you want to. There is no penalty for you or your child for not taking part. Your child's teacher has agreed to allow the research to be conducted in your child's classroom, but participation is completely voluntary. Your child will not be penalized for not participating, and an alternate assignment will be provided if they do not participate. You have the right to stop your child from taking part at any time. Just tell the researcher or your child's teacher that you want your child to stop. You will be told if any new information is learned which may affect your willingness to allow your child to continue taking part in this study.

Location:

The activities will take place in your child's math class as part of their educational activities.

Time required:

The activities will take approximately 7-10 minutes each day for four weeks.

Audio or video taping:

Your child will not be audio or video taped in this study.

Risks:

There are no expected risks for taking part in this study. Your child does not have to answer every question or complete every task. Your child will not lose any credit if they skip questions or tasks.

Benefits:

Participation in the study may benefit your child by increasing their math fluency through repeated timed math probes.

Compensation or payment:



University of Central Florida IRB
IRB NUMBER: SBE-08-05641
IRB APPROVAL DATE: 5/6/2008
IRB EXPIRATION DATE: 5/5/2009

There is no compensation, payment or extra credit for your child's part in this study. Participation in the study will not affect your child's grade in the class.

Confidentiality: Your child's identity will be kept confidential. The researcher will make every effort to prevent anyone who is not on the research team from knowing that your child gave us information, or what that information is. For example, your child's name will be kept separate from the information he or she gives, and these two things will be stored in different places.

Your child's information will be assigned a code number. The list connecting your child's name to this number will be kept in a password protected computer. When the study is done and the data have been analyzed, the list will be destroyed. Your child's information will be combined with information from other children who took part in this study. When the researcher writes about this study to share what was learned with other researchers, she will write about this combined information. Your child's name will not be used in any report, so people will not know how he or she answered or what he or she did.

There are times when the researcher may have to show your child's information to other people. For example, the researcher may have to show your child's identity to people who check to be sure the research was done right. These may be people from the University of Central Florida or state, federal or local agencies or others who pay to have the research done.

Study contact for questions about the study or to report a problem:

Marcey A. Kinney, Doctoral Candidate, Exceptional Student Education Program, College of Education, (386) 760-3829, mkinney@mail.ucf.edu, or Dr. Rebecca A. Hines, Faculty Supervisor, Department of Child, Family, and Community Sciences (386) 506-4083 or by email at rhines@mail.ucf.edu.

IRB contact about you and your child's rights in the study or to report a complaint:


Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901.

How to return this consent form to the researcher:

Please sign and return this consent form to your child's teacher. By signing this letter, you give me permission to report your responses anonymously in the final manuscript to be submitted to my faculty supervisor as part of my course work.

- I have read the procedure described above
- I voluntarily agree for my child to take part in the research
- I am at least 18 years of age

_____ Signature of parent	_____ Printed name of parent	_____ Date
_____ Signature of parent	_____ Printed name of parent	_____ Date

 University of Central Florida IRB
IRB NUMBER: SBE-08-05641
IRB APPROVAL DATE: 5/6/2008
IRB EXPIRATION DATE: 5/5/2009

APPENDIX D:
STUDENT ASSENT



Hello, My name is Marcey Kinney. I am a doctoral student at the University of Central Florida. I am doing a research project on high school students. The purpose of this study is to determine the effectiveness of using a handheld computer game to increase computational speed of math facts for secondary students. I am interested in understanding if completing certain activities on a Nintendo DS computer will increase a students ability to remember math facts. I am conducting this research as part of my studies at the University of Central Florida.

As a way to study this, I would like to have you complete activities on a Nintendo game boy and then complete a one minute timed math probe. You would do this each day for four weeks. Every other week you will complete the math probe without playing the game.

Only Dr. Hines, my professor at UCF, and I will see your scores on the math probes. I will destroy the probes at the end of the study. All names will be changed so that nobody will know it was you in my study. It will not affect your grade if you decide you don't want to do this. You can stop participating at any time. You will not be paid for doing this.

If you would like to take part in my study, please check and sign the bottom portion of this letter.

____ I want to take part in Ms. Kinney's research project.

Student's Signature

Date

Student's Printed Name



University of Central Florida IRB
IRB NUMBER: SBE-08-05641
IRB APPROVAL DATE: 5/6/2008
IRB EXPIRATION DATE: 5/5/2009

APPENDIX E:
PRINCIPAL LETTER OF SUPPORT



PINE RIDGE HIGH SCHOOL

926 Howland Boulevard
Deltona, Florida 32738
Phone: (407) 688-9500
Fax: (407) 328-6862



Tom Russell
Principal

John Devito Craig Pender
Kathryn Dyer Dr. Thomas Robare
Steve Foglio Jennifer Williams
Assistant Principals

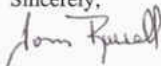
February 26, 2008

Marcey A. Kinney
PhD. Candidate
Exceptional Education Program
Dept. of Child, Family, & Community Service
College of Education
University of Central Florida
Orlando, FL 32816-1250

Dear Ms. Kinney,

Thank you for the opportunity to participate in your investigation of the effectiveness of handheld computers to increase working memory for students with learning disabilities. At Pine Ridge High School we are always looking for innovative ways to help our students succeed. We would be happy to participate in this investigation after obtaining parental consent.

Sincerely,


Tom Russell
Principal

APPENDIX F:
TEACHER LETTER OF SUPPORT



PINE RIDGE HIGH SCHOOL

926 Howland Boulevard
Deltona, Florida 32738
Phone: (407) 688-9500
Fax: (407) 328-6862



Tom Russell
Principal

John Devito **Craig Pender**
Kathryn Dyer **Dr. Thomas Robare**
Steve Foglio **Jennifer Williams**
Assistant Principals

February 24, 2008

Marcey A. Kinney
PhD. Candidate
Exceptional Education Program
Dept. of Child, Family, & Community Service
College of Education
University of Central Florida
Orlando, FL 32816-1250

Ms. Kinney,

Thank you for the opportunity to participate in your investigation of the effectiveness of handheld computers to increase working memory for students with learning disabilities. At Pine Ridge High School. I am always looking for innovative ways to help my students succeed. I would be happy to have my students participate in this investigation after obtaining parental consent.

Sincerely,

Theresa Brazee
ESE Dept
Algebra I
CLAW Sponsor

APPENDIX G:
MATH PROBE SAMPLE

Name _____ Date _____

$$\begin{array}{r} 3 \\ \times 7 \\ \hline \end{array}$$

$$\begin{array}{r} 9 \\ - 6 \\ \hline \end{array}$$

$$\begin{array}{r} 3 \\ \times 2 \\ \hline \end{array}$$

$$\begin{array}{r} 8 \\ + 3 \\ \hline \end{array}$$

$$\begin{array}{r} 4 \\ + 8 \\ \hline \end{array}$$

$$\begin{array}{r} 3 \\ - 1 \\ \hline \end{array}$$

$$\begin{array}{r} 2 \\ \times 3 \\ \hline \end{array}$$

$$\begin{array}{r} 4 \\ \times 3 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ \times 9 \\ \hline \end{array}$$

$$\begin{array}{r} 9 \\ - 4 \\ \hline \end{array}$$

$$\begin{array}{r} 6 \\ \times 7 \\ \hline \end{array}$$

$$\begin{array}{r} 1 \\ \times 2 \\ \hline \end{array}$$

$$\begin{array}{r} 13 \\ - 9 \\ \hline \end{array}$$

$$\begin{array}{r} 8 \\ \times 8 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ \times 8 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ - 1 \\ \hline \end{array}$$

$$\begin{array}{r} 1 \\ + 1 \\ \hline \end{array}$$

$$\begin{array}{r} 13 \\ - 4 \\ \hline \end{array}$$

$$\begin{array}{r} 9 \\ \times 2 \\ \hline \end{array}$$

$$\begin{array}{r} 4 \\ \times 8 \\ \hline \end{array}$$

$$\begin{array}{r} 7 \\ + 6 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ + 9 \\ \hline \end{array}$$

$$\begin{array}{r} 3 \\ + 5 \\ \hline \end{array}$$

$$\begin{array}{r} 2 \\ - 1 \\ \hline \end{array}$$

$$\begin{array}{r} 13 \\ - 7 \\ \hline \end{array}$$

$$\begin{array}{r} 4 \\ \times 1 \\ \hline \end{array}$$

$$\begin{array}{r} 6 \\ + 6 \\ \hline \end{array}$$

$$\begin{array}{r} 10 \\ - 9 \\ \hline \end{array}$$

$$\begin{array}{r} 2 \\ \times 9 \\ \hline \end{array}$$

$$\begin{array}{r} 8 \\ - 5 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ \times 4 \\ \hline \end{array}$$

$$\begin{array}{r} 6 \\ + 1 \\ \hline \end{array}$$

$$\begin{array}{r} 1 \\ \times 9 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ + 6 \\ \hline \end{array}$$

$$\begin{array}{r} 3 \\ + 4 \\ \hline \end{array}$$

$$\begin{array}{r} 7 \\ \times 5 \\ \hline \end{array}$$

$$\begin{array}{r} 7 \\ - 6 \\ \hline \end{array}$$

$$\begin{array}{r} 17 \\ - 9 \\ \hline \end{array}$$

$$\begin{array}{r} 7 \\ - 4 \\ \hline \end{array}$$

$$\begin{array}{r} 10 \\ - 3 \\ \hline \end{array}$$

$$\begin{array}{r} 7 \\ - 1 \\ \hline \end{array}$$

$$\begin{array}{r} 1 \\ + 4 \\ \hline \end{array}$$

$$\begin{array}{r} 12 \\ - 7 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ - 4 \\ \hline \end{array}$$

$$\begin{array}{r} 14 \\ - 6 \\ \hline \end{array}$$

$$\begin{array}{r} 7 \\ + 7 \\ \hline \end{array}$$

$$\begin{array}{r} 8 \\ + 4 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ + 7 \\ \hline \end{array}$$

$$\begin{array}{r} 8 \\ - 4 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ \times 5 \\ \hline \end{array}$$

$$\begin{array}{r} 2 \\ + 5 \\ \hline \end{array}$$

$$\begin{array}{r} 3 \\ + 9 \\ \hline \end{array}$$

$$\begin{array}{r} 3 \\ \times 8 \\ \hline \end{array}$$

$$\begin{array}{r} 10 \\ - 6 \\ \hline \end{array}$$

$$\begin{array}{r} 8 \\ \times 6 \\ \hline \end{array}$$

$$\begin{array}{r} 1 \\ + 3 \\ \hline \end{array}$$

$$\begin{array}{r} 2 \\ + 2 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ \times 1 \\ \hline \end{array}$$

$$\begin{array}{r} 9 \\ - 3 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ + 1 \\ \hline \end{array}$$

$$\begin{array}{r} 4 \\ \times 2 \\ \hline \end{array}$$

$$\begin{array}{r} 7 \\ + 8 \\ \hline \end{array}$$

$$\begin{array}{r} 10 \\ - 1 \\ \hline \end{array}$$

$$\begin{array}{r} 6 \\ \times 2 \\ \hline \end{array}$$

APPENDIX H:
RESEARCH PROTOCOL

Protocol

Creating Groups

1. Each Brain Age cartridge will hold four profiles.
2. For this research four Nintendo DS™ systems were used.
3. The researcher created groups of four and used a coded system with a chart to keep track of groups.
4. For example, cartridge one contained information for students one, two, three, and four, cartridge two contained information for students five, six, seven, and eight.
5. Group one would consist of the first student on each cartridge. For example, group one was students one, five, nine, and 13. Group two was students two, six, 10, and 14.

Baseline Weeks 1 and 3

1. Call group one to the research table.
2. Give each student a pencil.
3. Pass out the math probe, face down.
4. Have the students write the date and their number on the back of the probe.
5. Press the reset button on the electric timer.
6. Tell students "we will begin in 10 seconds".
7. Tell the students "you may begin".
8. Press the start button on the electric timer.
9. The timer will buzz when time is up say, "stop, pencils down"
10. Have students place the paper in their designated folder.
11. Repeat with remaining groups.

Intervention Weeks 2 and 4

1. Call group one to the research table.
2. Pass out the Nintendo DS™ systems with the correct cartridge for each student
3. Have students open their profile and follow any directions given. At times the students will be asked to complete various activities prior to having access to their daily training.
4. When the students get to the screen containing daily training activities, the students will pick calculations X 20.
5. They will complete the activity.
6. They will follow any directions in the activities until they have received a date stamp for the ~~days~~ activities.
7. When all students have finished (they should all finish within a minute or two of one another), collect the DS™ systems.
8. Complete protocol for baseline weeks (see above).
9. Repeat with remaining groups.

APPENDIX I:
FIDELITY CHECKLIST

Fidelity Checklist

Baseline Weeks 1 and 3

- Group one is called to the research table.
- Each student is given a pencil.
- Math probe is passed out, face down.
- Students write the date and their number on the back of the probe.
- Tell students "we will begin in 10 seconds".
- Tell the students "you may begin".
- Press the start button on the electric timer.
- The timer will buzz when time is up say, "stop, pencils down"
- Have students place the paper in their designated folder.
- Repeat with remaining groups.

Intervention Weeks 2 and 4

- Group one is called to the research table.
- Nintendo DS™ systems are passed out with the correct cartridge for each student
- Students open their profile and follow any directions given.
- The students pick calculations X 20.
- The students complete the activity.
- The students follow all directions in the activities until they have received a date stamp for the ~~days~~ activities.
- After the students complete the activities, the teacher collects the DS™ systems.
- Complete protocol for baseline weeks (see above).
- Repeat with remaining groups

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