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Developing Math Automaticity Using a Classwide Fluency Building Procedure for Students with Varying Processing Speeds

Philip K. Axtell
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Philip K. Axtell entitled "Developing Math Automaticity Using a Classwide Fluency Building Procedure for Students with Varying Processing Speeds." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

R. Steve McCallum, Major Professor

We have read this dissertation and recommend its acceptance:

Sherry Bell, Chris H. Skinner, Richard Saudargas

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Anne Mayhew
Vice Chancellor and
Dean of Graduate Studies

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Developing Math Automaticity Using a Classwide Fluency Building Procedure for Students of Varying Processing Speeds

A Dissertation Presented for the

Doctor of Philosophy Degree

The University of Tennessee, Knoxville

Philip K. Axtell

August 2006

Dedication

I'd like to dedicate this dissertation to my mother and father, Margaret and Kenneth Axtell who thought they would never be able to boast about my 1.8 high school GPA.

Acknowledgement

I’d like to thank everyone involved in helping me complete my doctoral in education and school psychology. I’d like to thank Dr. Chris Skinner who was instrumental in my training throughout my graduate career. I’d like Dr. R. Steve McCallum for his exceptional assistance that went beyond expectations in the completion of this dissertation. I’d like to thank Dr. Sherry Bell for giving me the opportunity to participate in the summer project that made this study and dissertation possible. Finally, I’d like to thank Dr. Saudargas for having the patience to sit through two rounds of dissertations.

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In the everlasting words of Nirbhay N. Singh: “You’ll be fine.”

Abstract

In order to investigate the influence of a with-in child variable (e.g., cognitive processes) and an external variable (e.g., particular intervention) on the acquisition of math fluency, or automaticity, a Detect, Prompt, Repair (DPR) treatment procedure was employed (external variable) for students with varying processing speed scores (internal variable). Forty-five students were randomly assigned to either the experimental group (DPR math intervention) or the control group (reading intervention) according to a true experimental design. After covarying pre-test scores, the DPR treatment produced a significantly higher (p = .016) adjusted mean math scores (M = 47.53, SD = 3.26) for the intervention group when compared to the control group (M = 33.31, SD = 4.39). To determine the possible effects of processing speed on gain scores the math group members were divided (using a median split) into relatively fast processors and slow processors. Although a repeated measure ANOVA indicated no processing speed and treatment interaction effect (p = .06), a minimally strong correlation between processing speed and math fluency was found (r = .19, p = .33). And, when each group was split into Fast, Average, and Slow processors, the DPR procedure produced gains in all three subgroups. Conversely, the control group did not show gains in math fluency, regardless of cognitive ability.

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CHAPTER 1

Introduction

Both external (e.g., intervention strategies) and internal (e.g., memory, processing speed) variables influence the development of math fluency and this study was designed to evaluate the effects of both. Specially, the capacity of a test-teach-test intervention (Detect-Prompt-Repair, DPR) to facilitate acquisition of basic math facts was investigated for students who exhibit both relatively slow and fast processing speed.

The National Council of Teachers in Mathematics (NCTM) emphasizes the importance of mathematics facility. In addition, a need for higher levels of math competence has increased in this technology-based world and a lack of knowledge, understanding, and skill development can close doors for students. Based on principles set forth by the NCTM, instructional programs in math for all students should enable them to understand numbers, number systems, ways of representing numbers, relationships among numbers, computational fluency, and the ability to make reasonable estimates. While these skills are an important aspect of overall learning and long-term achievement, one of the first steps in learning math as conceptualized by Haring and Eaton (1978) is accurate responding to basic mathematical facts, often referred to as basic math computation. This includes simple (basic) computations of single digit addition, subtraction, multiplication, and division (e. g., 5 + 5 =___, 5 – 5 =___, 5 x 5 =___, and 25/5 =___).

Many teachers have traditionally focused on providing students with ample instruction and practice, allowing them to successfully produce correct, accurate responses when tested. After students are able to produce correct answers, teachers will typically move on to the next skill. While striving for accuracy is desired by many teachers (Johnson & Laying, 1992) it may impair the development of fluency in basic skills. For example, two students who have achieved 100% accuracy may not have the same fluency level or expertise. If Student A takes five minutes to complete a worksheet accurately and it takes Student B ten minutes to complete the same worksheet with the same accuracy it is assumed that Student A is more skilled in the particular mathematical area (Miller & Heward, 1992). Thus, accurate responding should not be the sole criterion to measure the mastery of an acquired skill. A measure of fluency should also be used.

Fluency is conceptualized as responding both accurately and quickly to a selected stimulus. As the student learns a new skill, he/she will become increasingly fluent in that skill until it becomes automatic. Automaticity refers to the phenomenon that a skill can be performed with minimal awareness of its use (Howell & Larson-Howell, 1990; Hartnedy, Mozzoni, & Fahoum, 2005). Taking a cognitive processing perspective the ability of a student to automatically respond to a stimulus may free limited cognitive resources that can be applied to the more complex computations and concepts (LaBerge & Samuels, 1974; Skinner & Schock, 1995). For example, if a student has to actively think about the answer to 5 X 5, he/she has less cognitive resources to think about the next step in an algebraic algorithm. As such, this increases the time and effort it takes to complete complex math skills. Not only does this increased time and effort hamper more complex skill acquisition, it may produce an underestimate of a student's true ability, especially on time-limited tests or assessments. According to Gagné (1983), problem solving specifically occurs in working memory, which is limited to a few computations at any single moment in time. If each component of a complex, multi-step problem requires sustained attention, the completion of the problem will likely be impossible due to the limited capacity of working memory. As the student gains automaticity working memory is freed to address more complex operations of the selected problem (Gagné, 1983; LaBerge & Samuals, 1974).

Two lines of research are relevant for understanding the relationship between automaticity and math achievement. The first line of research focuses on building basic math skills to the point of fluent responding and focuses on interventions used to build fluency. The second line of research focuses on the underlying cognitive processes associated with math achievement and fluency, the presumed cognitive underpinnings of math.

Building Math Fluency

According to the Instructional Hierarchy model proposed by Haring and Eaton (1978) students learn a skill through the progression of four stages. The first stage is acquisition, which is the period when the desired behavior first occurs in accurate form. In this stage the emphasis is on accurate and repeated performance of the behavior involved in the particular skill. The second stage is the fluency building (proficiency) stage. After the skill has been acquired the student must perform it both quickly and accurately to ensure mastery.

Gagné, Yekovich, and Yekovich (1993) assert it is impossible to successfully—and effortlessly—complete a complex problem until the basic execution of the parts are mastered or automated. Group instruction to the mastery level is often the method employed in the classroom; while this may work well for most students, there may be a number of students who have not mastered the basic skills before the teacher moves on to new material. A student who is trying to learn new material, but at the same time attempting to master the prerequisite skills, has more difficulty (Gagné et al., 1993; Resnick, Siegel, & Kresh, 1971).

The third stage of the Instructional Hierarchy is generalization. The goal for this stage is for the student to take a previously learned skill or behavior and apply it to new set of stimuli that is similar to those used in the acquisition and fluency stages. For example, a student will be able to solve an addition problem when it is displayed either horizontally or vertically. Strategies to increase generalization include practice of a specific response to a variety of stimuli. The final stage of the model is application or adaptation. Here the student must modify, adapt, or apply a previously learned response or responses to a new and different stimuli. The ability to adapt and apply differing skills to novel situations is extremely important as one cannot teach the expected behaviors to every situation one encounters (Haring & Eaton, 1978).

As Haring and Eaton's (1978) model suggests, a student will move through each stage in sequence until he/she is able to adapt his/her knowledge as needed. Applied to math instruction, this model predicts that students who master the basic math skills (math computation) are better able to progress to more general and abstract skills such as math word problems that require math reasoning. In order to become proficient at more complex skills, the student will need to first master the basic skills before moving on.

Advantages to Automaticity

Several advantages are apparent for students who can respond accurately, quickly, and automatically. For example, students who display strong automatic basic math skills are able to complete more complex math tasks (Skinner, Fletcher, & Henington, 1996), score higher on achievement tests that measure higher level skill development (Skinba, Magneusson, Marston, & Ericson, 1986), and show higher maintenance levels of the learned skill over time relative to those students with weaker automaticity (Singer-Dudek & Greer, 2005). Additionally, students who are fluent in math skills show lower levels of math anxiety (Cates & Rhymer, 2003) and choose to engage in math activities more often than less fluent students (Billington, Skinner, & Cruchon, 2004; Skinner, Pappas, & Davis, 2005).

Students who are taught math skills beyond the mastery level (to the fluent level) show stronger maintenance after a two month period than students at the mastery level. Singer-Dudek and Greer (2005) taught composite math skills to four adolescents with developmental delays. These four students were randomly selected to participate in one of two groups, mastery instruction and fluency instruction. Prior to beginning instruction, each student was taught the prerequisite skills. Students in the “fluent” group were more accurate in both one and two month follow-up (maintenance) trials when compared to the “skill mastery only” group.

Not only do fluent responders show higher accuracy of retained skills over time, those students who are fluent in math also show less anxiety. Cates and Rhymer (2003) examined the fluency of college students in basic addition, subtraction, multiplication, division, and linear equations. Fifty-two students (40 female and 12 male) who came from a variety of majors were divided into a low anxiety and high anxiety group. All of the students were given one minute to complete a single skill probe sheet of addition, subtraction, multiplication, and division. The students were given four minutes to complete the linear equation probe sheet. The results were reported in digits correct per minute and the number of errors. The results show that students in the low math anxiety group completed significantly more digits correct per minute on all of the probes when compared to the high anxiety group. However, when the error rates were analyzed there was no significant difference between the two groups. While students in both groups were equally accurate, the students with low math anxiety were more fluent.

Increasing Math Fluency

Increasing response rates and academic responding are two important first steps to ensure that students will benefit from an intervention. Skinner, Fletcher, and Henington (1996) reviewed interventions that increase student learning rates and improve the efficacy of learning trials. The authors review several teacher led and independent seatwork interventions that increased student learning while not significantly decreasing learning time in the classroom. Some teacher-led instruction techniques that have shown increased learning rates include rapid pacing of instruction and the use of flexible wait time (i.e., the time between a teacher question and the students' response or the teachers' feedback), choral responding, and response cards.

Other interventions have also contributed to successful outcomes. For example, increasing response rates, requiring timing procedures, reducing the time allotted for independent work, and reinforcing accurate, high rates of responding during independent seatwork can also increase the efficacy of a given intervention (Skinner et al., 1996). Response topography (the form or shape of the response) includes not only written responses, but also vocal responses, and subvocal responses. Using a Cover, Copy, and Compare (CCC) technique, Skinner, Ford, and Yunker (1991) and Skinner, Bamberg, Smith, and Powell (1993) found that responding vocally and subvocally resulted in more learning trials and greater increases in learning rates when compared to written responses (Skinner et al., 1991) and when using a with-in subjects, across-problems, multiple baseline design (skinner et al. 1993).

While the above interventions can be effective in increasing student learning rates, practitioners may continue to find students who either cannot or will not participate in the learning process regardless of the form it takes. Educators (e.g. Skinner, Papas, and Davis, 2005) have identified two rationales for nonparticipation in the learning process; children can't do the work or they won't. "Can't do" problems occur when a student does not understand the material, does not have enough time to accurately respond, or does not have the prerequisite skills. When these "can't do" problems are corrected there is an expectation that the child will be motivated to work. If the child can do the assigned material then academic engagement is a choice made by the student (Skinner, Wallace, & Neddenriep, 2002). A student who "won't do" the assigned material is not motivated. Motivation may be enhanced by addressing the nature of the task. Generally, when given a choice, a child will perform the task requiring the least amount of effort, either perceived or actual (Billington, Skinner, Hutchens, & Malone, 2004; Billington & Skinner, 2002).

Various methods have been developed to improve motivation. For example, Billington, Skinner, Hutchens, and Malone (2004) and Billington and Skinner (2002) demonstrated that given a choice of assignments, students chose to complete longer assignments and rated these assignments as less effortful, less difficult, and less time consuming than the shorter ones. While the two experimental assignments were longer than the control assignments, the students perceived the longer assignments to require less effort and chose these over the shorter assignments. By interspersing brief one-digit by one-digit multiplication problems within the experimental assignments consisting of three-digit by two-digit math problems, the students' perception of effort was altered. Thus, the students chose to complete the longer assignments. While this appears counterintuitive, the results support the hypothesis that assignments containing discrete tasks, the completion of each completed task is reinforcing (Logan & Skinner, 1998; Skinner, Hall-Johnson, Skinner, Cates, Weber, & Johns, 1999). By increasing fluency of basic math facts, the effort to complete basic problems is greatly reduced and more reinforcing. Students who perceive more complex problems as requiring less effort may begin to engage more frequently in the academic environment and presumably find completing assignments more reinforcing. In the section following, other interventions that specifically address and improve low achievement in math fluency (CCC and Detect, Prompt, Repair (DPR) will be addressed.

Cover, Copy, Compare. The Cover, Copy, and Compare (CCC) procedure has shown promise for producing increased fluency. First developed by Hansen in 1978, CCC was used to increase spelling accuracy in elementary school students. Students were taught to look at the selected word, copy the word while saying each syllable, cover the word, spell it from memory, and evaluate what they had written by comparing the two words. If the word were spelled correctly the student would move on to the next word. If spelled incorrectly, the student was required to rewrite the word. The results of this investigation showed that over 70% of the students improved their spelling accuracy. Similar CCC procedures have been used to increase accuracy in other subjects such as geography (Skinner, Belfiore, & Pierce, 1992), science (Smith, Dittmer, & Skinner, 2002), and math (Skinner, Turco, Beatty, & Rasavage, 1989). The CCC intervention strategy has shown to be most effective when three basic components are required; immediate feedback, accurate responding, and appropriate responding (e.g., written, vocal, or subvocal responses).

Increasing student accuracy depends on making and practicing accurate responses. A way to ensure correct student responding requires that they are given immediate feedback in the form of self-correction, thereby preventing the practice of inaccurate responses (Bennett & Cavanaugh, 1998; Skinner & Smith, 1992), which can be detrimental to correctly learning a new skill. In addition to providing accurate practice, immediate feedback leads to higher rates of academic responding often resulting in increased student performance (Skinner, Bamberg, Smith, & Powell, 1993; Skinner, Belfiore, Mace, Williams, & Johns, 1997).

Appropriate student responding can take many forms. Students can be taught to respond vocally in a class-wide intervention using CCC, respond in writing, or respond subvocally (e.g., repeating the problem and answer to themselves). While certain responses can be more efficient than other responses (e.g., verbal responses are more efficient than written responses), the advantage of the CCC intervention is that teachers can determine the response that is appropriate for their classroom and intervention. For example, a verbal response may be a more efficient way to respond than writing an answer, but a class full of students each responding verbally to individualized CCC interventions can interfere greatly with other students' learning.

A combination of two types of responding may also be helpful. A teacher who uses a class wide CCC intervention may teach the students to respond in writing and subvocally. For example, the copy portion may be written and students can respond subvocally, and then compare what they wrote to the answer. This would give each student many more opportunities to give accurate responses

Detect, Prompt, Repair. Detect, Prompt, Repair (DPR) developed by Poncy, Skinner, and O'Mara (2006) is a multi-component, classwide test-teach-test procedure that integrates brief response times, many opportunities to respond, immediate feedback, and a self-management component in the form of self-graphing. The DPR procedure consists of four components: (a) the tap-a-problem procedure, which inhibits ineffective counting procedures (e.g., students counting using their fingers) and indicates, which problem(s) the student have already mastered, (b) a CCC component designed to produce high rates of accurate, active academic responding by the student, (c) a timed assessment session (i.e., mad minute) to assess the effectiveness of the CCC portion, and (d) a self-graphing section designed to provide immediate feedback.

While several of the components of the DPR procedure have been used before, the tap-a-problem procedure is novel because it allows for the identification of target problems in which the student is not fluent. Because the DPR procedure is timed, students have a fixed interval to respond (to the entire worksheet). An additional timing procedure is introduced for each problem by using a metronome set at 40 beats a minute, giving only 1.5 seconds to respond to each problem. Following the click of the metronome, the student is to move on to the next problem, even if it is not completed. The problem(s) the child cannot complete in the allotted time (i.e., 1.5 seconds) indicate which problems require additional training to reach automaticity. This strategy provides feedback to the students, indicating specific skills to remediate, and encourages the building of automatic responding (through CCC). Thus, as they build automaticity students drop the slow inefficient counting strategies (such as finger counting) from their behavioral repertoire.

While building automaticity the DPR procedure also provides the student with efficient practice. One popular procedure to incorporate drill and practice is to use instructional ratios first proposed and developed by Gickling and colleagues (Gickling, 1977; Gickling & Havertape, 1981; Gickling & Armstrong, 1978; Gickling & Thompson, 1985). Ratios of known to unknown words are used to increase the learning rate of unknown words. These ratios range form 90% known to 10% unknown (90:10), 80:20, 70:30, 60:40, and 50:50. Roberts and Shapiro (1996) found that students acquired the most information when using a 50:50 ratio of known to unknown words. Roberts, Turco, and Shapiro (1991) performed a similar study and found the highest mean number of words learned was to use a ratio of 20 known to 80 unknown followed by a ratio of 50:50. The authors found the lowest number of words learned resulted from the use of a ratio of 80 known to 20 unknown. Even though these interventions provided practice, most of this practice was with words children already knew, wasting instructional time drilling material that was already known. The DPR procedure avoids this ineffective drill and practice by only having students practice information that is either not fluent and/or known.

Poncy et al. (2006) conducted a pilot study using the DPR procedure with 14 low achieving third grade students, three of whom were receiving special education services. Using a single subject design, the researchers were interested in increasing automaticity of subtraction problems. Each problem consisted of numbers that ranged from 0 to 19 with no correct answers less that zero. The results indicated students achieved a growth rate superior to that of district norms over a six-week period. The procedure produced an average growth rate of 3.2 correct digits (CD) per week while district norms showed an average weekly growth of 0.5 week (3 CD over six weeks). While this study showed promising results, the authors identified several limitations. First, the case-study (A-B) design did not control for certain threats to internal validity, such as previous achievement (history) and interaction effects (Campbell & Skinner, 2004). Additionally, treatment integrity measures were not collected. The current study was undertaken to control for limitations of previous studies and employs a true experimental design.

Importantly, not all students gain fluency equally from the DPR procedure, or from any intervention. There is some research linking within-the-child variables to math ability. Perhaps particular cognitive strengths and weaknesses influence the rate at which students benefit from interventions.

Cognitive Processes Related to Math Fluency

Much of the research focusing on the relationship between within-child variables and math achievement describes the cognitive abilities within the Cattell-Horn-Carroll (CHC) model. The CHC model is conceptualized according to three strata in a hierarchal model with the stratum III (general) ability at the top, followed by more specific stratum II abilities, and the most basic narrow stratum I abilities (Gustafsson & Undheim, 1996).

Many cognitive processes correlate with math achievement. Of the 10 stratum II abilities, McGrew and Hessler (1995) found five consistently appear to be related to math achievement. Comprehension Knowledge (Gc) is strongly related to math achievement (*r*s ranging from .33 to .66) in individuals aged six through late adulthood. A moderate to strong relationship was found between Fluid Reasoning (Gf) and achievement (*r*s ranging from .17 to .36) and a moderate to strong relationship was found between Processing Speed (Gs) and basic math skills (*r*s ranging from .14 to .39). Long-term Retrieval (Glr) and Short-term Memory (Gsm) were both found to be moderately related to basic math skills (*r*s ranging from .13 to .17) and (*r*s ranging from .11 to .15), respectively. Finally, Auditory Processing (Ga) was moderately correlated with math reasoning, but only within individuals in middle adulthood (*r*s ranging from .11 to .20). In addition to McGrew and Hessler (1995), other researchers have found moderate to strong relationships between Gf, Gc, and Gs and math achievement (Flanagan, Keith, & Vanderwood, 1997; Keith, 1999; Williams, McCallum, & Reed, 1996)

Floyd, Evans, and McGrew (2003) used Woodcock-Johnson III (WJ-III) Tests of Cognitive Abilities normative sample to examine the ability of Comprehension-Knowledge (Gc), Fluid Reasoning (Gf), Short-term Memory (Gsm), Processing Speed (Gs), Long-term Retrieval (Glr), Auditory Processing (Ga), Visual-Spatial Thinking (Gv), and Working Memory (WM) to predict math reasoning and math calculation skills. Regression coefficients from .10 to .29 were considered to represent moderate relations and coefficients at .30 and above were considered strong. Gc showed the strongest relationships with math reasoning and calculation skills although the strength of the relationship differed as a function of age. Gf demonstrated moderate relationships with basic math skills and moderate to strong relationships with math reasoning skills. Gsm showed moderate relations with both basic math skills and math reasoning skills. Gs showed a moderate relationship with math reasoning and Working Memory was moderately related to both math reasoning and math calculation skills.

Proctor, Floyd, and Shaver (2005) used the WJ-III standardization sample to examine the relation between cognitive abilities (WJ-III Test of Cognitive Abilities) and math achievement (WJ-III Tests of Achievement) for low math achievers and their average achieving peers. The results of this study indicate that when average scores of the two low achieving groups were compared to the average peer group, children in the math calculation group did not show significantly different cognitive profiles when compared to their average peers. However, children in the Math Reasoning group did show significantly lower Processing Speed cluster scores than the average peer comparison group. This group also scored significantly lower on the cognitive clusters of Fluid Reasoning and Comprehension-Knowledge.

Proctor, Floyd, and Shaver (2005) emphasize two interesting findings from their studies. First, the group mean scores of the calculation weakness group did not show significant CHC ability weaknesses when compared to the average achievement group, which is counter to other CHC studies discussed in this section. However, when intragroup individual scores were examined only, 50% of the children displayed one or more CHC normative weakness. Therefore, in this sample one in two children (in both groups) did not display a cognitive weakness even though they had significantly lower achievement in either math calculation or reasoning skills.

Second, while previous research (as discussed above) has shown a relationship with math reasoning skills and processing speed, no such relationship was found in this study. The authors offer a tentative rationale—perhaps Processing Speed is related to average or above average skills in math reasoning and may be unrelated to below average reasoning. Also, children with low achievement in reading were not included in any group, thus excluding students with a double weakness. Such a group may include children with significantly lower processing speed abilities than was revealed in this study.

Given these findings, a child with low achievement in a math skill or skill area(s) may not necessarily exhibit a cognitive deficit. This hypothesis has two further important implications for practice. One relates to the current definition of a learning disability (LD) used in most states. Does a child with a learning disability in math (or any achievement area) necessarily show cognitive deficit one or two areas? Many states require a processing deficit for LD eligibility. Apparently many children would be ruled out if this requirement exists. Also if the cause of the underachievement is not within the child then other causes external to the child (i.e. adverse academic environment, poor instruction or intervention strategies, and poor materials) must be investigated. In summary, it is important to consider both internal (e.g. cognitive abilities) and external variables (e.g. instructional quality) factors associated with math skill development.

Problem Statement

Both within child characteristics (i.e. processing speed) and external (e.g. intervention) can influence acquisition of a particular skill. Poncy et al (2006) investigated the capacity of one intervention (DPR) to facilitate acquisition of math fluency in elementary students; however, there were methodical limitations inherent in the study that introduce threats to internal validity, such as history, testing effects, and the integrity of the DRP procedures. One purpose of the current study was to investigate the DPR method in the context of a true experimental design, which controls for various possible threats to internal validity. In addition, there is no evidence available yet to support the use of the DPR procedure for middle school students. In fact, with few exceptions (e.g. Lee & Tingstrom, 1994; Singer-Douglas, & Greer, 2005; Skinner, Turco, Beatty, & Rasavage, 1989; Smith, Dittmer, & Skinner, 2002; Zental, 1990), there have been few studies examining fluency building in children beyond the elementary school level (and none employed the DPR procedure). Consequently, the primary purpose of the current study is to examine the ability of middle school students to build their fluency with basic math facts in division using DPR.

An additional purpose of this study is to evaluate the relationship between an internal, within-the-child variable (i.e. processing speed) and fluency building. Previous research has yielded equivocal results regarding the impact of processing speed on math fluency, and the existing research used only children who were part of the standardization sample of the WJ-III (McGrew & Hessler, 1995; McGrew, Flanagan, Keith, & Vanderwood, 1997; Keith, 1999). In this study I evaluate an independent sample of children to determine if a relationship exists between processing speed and (increasing) fluency in basic division skills of middle school children.

Research Questions

The following general research questions were addressed. Does the DPR procedure increase fluency relative to a control condition in a true experimental design context for middle school students? Does a within-child factor (processing speed) influence pre- and post-test math fluency scores? Is there a relationship between processing speed and efficiently building math fluency? Specific questions include:

1. Does the DPR procedure produce a significantly higher math fluency mean score than a reading-based control condition when students are randomly assigned and the pretest is used as a co-variant?
2. Does the treatment condition interact significantly with processing speed to produce differential gains for the students with faster processing speed?
3. Is there a significant positive correlation between processing speed scores and math fluency gain scores?

CHAPTER 2

Methods

Participants and Setting

Participants were middle school students with an age range of 12 to 15 years (*M* =13.8, *SD* = 0.84), were enrolled in a four-week summer school program for academically at-risk students. Participants came from one of three middle schools in a rural county in the southeast. Socioeconomic status of the county is relatively low, with an average of about 50% of the school population receiving free or reduced lunch based on federal guidelines. Participants were referred by their teachers for participation based on a failing grade in one or more academic subjects. In addition, some of the participants had been court-ordered to attend due to truancy or behavior infractions during the school year. Eleven students had been identified as eligible for special education services, but none had been identified as having mental retardation and none of the students received special education or academic modifications while in the summer program.

A total of 97 participants were enrolled in the summer school program. Each student was randomly assigned to either the control (reading intervention) group or the DRP treatment group before the program began. Forty-nine participants were initially assigned to the control group and 48 were assigned to the DPR treatment group. Forty-five of the 97 participants completed the CBM pretest assessment, 18 in the control group and 27 in the math group. To determine the equivalence of groups, an independent samples *t* test was completed with the 45 students who completed the pre-test. The results indicate no significant difference between the two groups' mean math pretest scores, $t(43) = -1.02$, $p = .311$. Due to attrition of participants in both groups, five in the control group and four in the treatment group, the following analyses were completed with the final 36 students (13 in the control and 21 in the treatment group) who completed both the pre- and post-test CBM assessments (only 34 of the 36 students completed the processing speed assessments). It is unclear as to why there was such an attrition rate. These children were in a summer school program that was not mandatory and they had a history of nonattendance. The curriculum for the two groups was no different except for the two interventions conducted during the first 45 minutes of each instructional day.

Teachers were participants in a teacher education course and field experience and enrolled in a special education teaching certification program. All of the participants had some prior teaching experience in general education classrooms as teachers.

Materials

A stopwatch and audible hand held metronome were used throughout the experimental sessions. Pre- and post-test data were collected using division fact probes that I constructed. Processing Speed data were collected by a graduate student in school psychology using the Visual Matching subtest of the Woodcock-Johnson Tests of Cognitive Abilities, 3rd Edition (Woodcock, McGrew, & Mather, 2001).

The pre- and post-test data collection probes consisted of 144 division problems leading to an answer between 2 and 9 (See Appendix A and B). All of the problems were either two-digit divided by one-digit or one-digit divided by one-digit. The division problems were inverses of single-digit by single-digit multiplication facts between two and nine. The probes consisted of a total of 3 pages with 48 problems on each page. Each page consisted of 48 problems arranged in 8 rows of 6 problems in each row. The post-test consisted of the same problems in a random order. Students were given 2 minutes to complete as many problems as possible.

Intervention packets consisted of four pages and one student progress page (See Appendix C). The four pages of each intervention packet were stapled together face up and remained in an office folder for each child. Each folder contained two intervention packets labeled “1” and “2”. The first page of the packet was a cover page with the student’s name and either a “1” or “2” written on the front to indicate either the first or second intervention run. The second page contained 48 problems in eight rows with six problems in each row. This amounted to a full page of division problems. The third page was the CCC sheet consisting of five rows with six blank boxes. The fourth and final page of the daily packet consisted of a mad minute page with the same 48 problems as the second page, but in random order. A student progress chart was stapled to the left side of each student’s folder and allowed students to track their progress. This page consisted of a grid for the students to enter the number of correct digits achieved on the mad minute page. The examiner developed an answer board with the answers to each of the problems and placed it in view of the children after the tap-a-problem section was finished. After all the children completed the CCC worksheet, the answer board was removed.

Study Design.

Dependent Variable. A true experimental design was used to evaluate the effects of DPR on math (division) fluency. The experimental group received the math intervention and a control group received a reading comprehension intervention. The dependent variable (DV) was division fluency represented by the number of correct digits per 2 minutes on pre-and post test CBM probes. These probes were developed by me and included basic division facts consisting of the inverse of one-digit by one-digit multiplication problems. All of the answers were one digit and did not include zero, one, or ten. Accuracy (percent number correct) was not calculated for the intervention packets.

The procedures outlined by Deno and Mirkin (1977) were used to score the correct digits per minute for the mad minute and digits correct per 2 minutes for the pre/post tests. Each division problem was set in a horizontal orientation and only one digit correct per problem was possible. The total number of correct digits correct for one minute was calculated for the intervention probes and digits correct per two minutes for the pre- and post-tests. Problems that were left blank were not counted and problems with the wrong answer were also not counted in the determination of the digits correct per two minutes.

Procedure

Pre-and Post-Test Procedures. The math CBM probe pre-test along with a battery of other achievement and cognitive assessments were administered on the first day of the summer program. The cognitive assessment (e.g., processing speed) was administered by a school psychology student. This student also administered the processing speed subtest of the WJ-III. I administered four classrooms (two intervention classrooms and two control classrooms) identical CBM probes as a pre-test. Students in each of the four classrooms were assessed separately and the students were given two minutes to complete as many problems as they were able.

For the math probes the teacher(s) and/or I gave all students a pre-test packet and asked them to keep it face down on their desks. The students were told to put their first and last name on the back page of the packet as it lay upside down on their desks. After each of the students received a packet and put their name on it, the following directions were read aloud: "When I say 'please begin' start answering the problems. Begin with the first problem and work across the page (demonstrate by pointing). Then go to the next row. If you cannot answer a problem, mark an 'X' through it and go to the next one. If you finish the page, turn the page and continue working. Are there any questions? (pause) Please begin." A stop watch was used to time the students for two minutes. When time expired the students were told to stop, put their pencils down, and hold up their packet to be collected. The post-test was given following the same procedure on the second to the last day of the program.

Teacher Training. Three sessions were allotted for teacher training. Two weeks prior to the beginning the summer program a fellow researcher and I met with the student teachers in their university classroom. This session consisted of explaining general instructional strategies that are typically used for children having difficulties in math and reading comprehension as part of the lecture series of the professor. The next session took place two days prior to the start of the summer program. I gave each teacher a training packet (See Appendix D) and discussed all of the procedures. During this session the teachers were allowed to ask questions and were instructed to review the training materials prior to the next training session.

The next day I held the final training session with the teachers before the program began the following day. The procedures were reviewed again and the teachers were given a stop watch and metronome during the session that would be used in the intervention procedure. Each of the teachers was allowed to practice this procedure until he/she accurately completed each step and read each set of directions correctly. While each teacher completed the practice intervention, I completed the integrity checklist (See Appendix E), followed by praise and corrective feedback.

DPR Intervention Procedures. The DPR procedure took place in the students' classrooms each morning. The classroom teachers, students, and researcher (to conduct interobserver agreement) were present during the intervention. The intervention was 18 school days in duration and began at 8:30, lasting approximately 45 minutes. The intervention occurred in a group format for each of the math intervention groups. At the same time the control group received a reading comprehension intervention. During the first day of the intervention, I modeled the intervention for the teachers while training the students on intervention procedures.

I developed a student training packet with single digit addition problems in the same format the children would experience in the actual DPR procedure. The procedure was explained to the students and questions were answered as they arose. The directions were read aloud and explained. Finally the children were allowed to hear the metronome and get accustomed to the rate and tone of the "ticks".

Following the explanation of the procedures, I led the children through the sample packet precisely the way it would be used on the intervention days. After procedures and directions were demonstrated the children were allowed to ask questions. This procedure was repeated for the second math intervention group. The control group was also trained this day, but on the reading comprehension intervention by another experimenter.

Each day the intervention was provided twice to each student. Each of the two teachers in the classroom administered one of the two intervention trials each day. Two DPR packets labeled “1” and “2” (one for each intervention trial) were made for each student prior to the next school day. Following the first administration, the students were asked to take the second packet from their folders.

On the first day of the intervention (after the training day), I gave the teachers of both groups the math folders of each student. I then went into each of the math group classrooms before the intervention began to refresh the memories of the students, briefly review the procedures and directions, answer any questions, and ensure the students knew the procedures and expectations. At 8:30 the intervention began and the teachers presented the student folders, asked the students to retrieve the packet labeled number one, and place it upside down on their desks. After students had their materials ready, the teacher set the metronome to 40 beats per minute, held it up in front of the class and read the following directions: “The sheets on your desk are math facts. All the problems are division facts. When I say ‘please begin’ start answering the problems. Begin with the first problem and work across the page (demonstrate by pointing). Then go to the next row. If you cannot answer a problem, mark an ‘X’ through it and go to the next one. If you finish the page, stop and put your pencil down and sit quietly. Remember, you have to go on to the next problem when you hear the metronome click even if you are not finished. Are there any questions? (pause) Please begin.”

The students were given one minute and 20 seconds to complete the first page of math problems. This amount of time was selected because 40 beats a minute gives the student approximately 1.5 seconds to answer each of the 48 problems. This amount of time (1:20”) allowed each student to have a chance to answer each question and complete the entire page of 48 problems.

After the students finished the second page, the teachers instructed the students to circle the first five problems that were either wrong or not answered. The teachers circulated the room to answer any of the students’ questions and ensure everyone was following the instructions. The students were then asked to copy the five circled problems with the correct answers on the next page with the CCC matrix. The students completed the CCC worksheet following the procedures used in Skinner, Turco, Beatty, and Rasavage (1999). The students copied the first problem and answer into block number one. The students began by looking at the first problem and answer and repeated it to themselves five times. Next, the students covered the problem with their hand, wrote the problem and answer in the next box, and repeated it again to themselves five times. Finally, the students uncovered the problem and solution to compare their response. This procedure gave the students 25 opportunities to respond (i.e. practice) in each row for each problem and 125 opportunities to respond for each CCC sheet. Thus, for both intervention trials the children were provided with 250 opportunities to respond each day. Both teachers circulated the classroom to answer any questions and ensure the students were completing the procedures correctly.

Once the children had completed the CCC sheet the teacher moved to the front of the classroom, got the students’ attention, and told them to listen to the next step. The teacher informed the students that the mad minute would be next and read the following directions: “When I say ‘please begin’ start answering the problems. Begin with the first problem and work across the page (demonstrate by pointing). Then go to the next row. If you cannot answer a problem, mark an ‘X’ through it and go to the next one. If you finish the page, put your pencil down and sit quietly. Are there any questions? (pause) Please begin.” The teacher then started the stop watch and timed the children for one minute. At the end of one minute the teacher instructed the students to stop and count the number of digits the student got correct. The students graphed their scores after each intervention trial on their grid sheets stapled to the left cover of their folders.

While the first teacher led the students through the first trial, the second teacher completed the treatment integrity checklist. Following the first intervention trial the teachers switched and the second teacher led the students through the second intervention trial and the first teacher completed the treatment integrity sheet. The teacher that was not administering the intervention was either completing the integrity sheet or circulating around the classroom ensuring the students were participating in the intervention.

The DPR procedure was completed each day and supplemented the regular math instruction, which both groups experienced. While there were no formal contingencies embedded in the procedure, the teachers were encouraged to give praise and corrective feedback. The students were also encouraged to ask questions and show the teachers their progress. The teachers were encouraged to liberally praise the students while checking their progress following the intervention. Following the implementation of the intervention, I retrieved the student folders and integrity checklists each day.

Treatment Integrity and Interobserver Agreement. Each of the teachers completed an integrity sheet each day of the intervention when they were not directly performing the intervention. I also sat in four of the 17 class days for each of the two intervention classrooms. This equated to 24% of the sessions for each classroom. The results showed 100% integrity and suggest strong treatment integrity.

A second experimenter also independently scored digits correct per minute for 20% of the pre- and post-test probes. Interscorer agreement was calculated by dividing the number of agreements on digits correct by the number of agreements plus disagreements and multiplying by 100. Interscorer agreement for digits correct was 98%.

CHAPTER 3

Results

A "true" experimental design was used to determine if the DPR procedure increased the math automaticity skills of middle school children with varying levels of processing speed.

DPR Intervention vs. Control Group

To determine if the math intervention produced higher adjusted mean post-test scores (relative to the control condition), an analysis of covariance (ANCOVA) was conducted to control for any pre-test differences between the groups. According to the ANCOVA results, the DPR procedure produced a significantly higher mean post-test score (M = 52.13, SD = 31.56) for the intervention group when compared to the control group (M = 25.15, SD = 13.44), F (1, 34) = 6.49, p = .016, with an effect size of 2.00 (see Tables 1 & 2 for actual means and standard deviations)[1]. The math intervention did produce significantly higher post-test automaticity scores when compared to the control group.

Interaction of Processing Speed and Gain Scores

To determine the possible effects of processing speed on division fluency, pre-test to post-test scores were analyzed using a repeated measures ANOVA. First, the intervention group processing speed scores were divided using a median split into high and low processing groups. Importantly, the fast and slow processors were only fast and slow relative to this group; their processing speed scores did not reflect the accepted fast and slow range common to typical classifications. The group was rank ordered according

[1] All tables and figures are located in the appendix

to processing speed. The overall processing group consisted of 21 participants (all of whom completed the processing speed assessment), with the 10 slowest processors grouped in the slow group and the 11 quickest processors in the fast group. The slow processing group had a mean WJ-III Visual Matching score of 82.60 with a standard deviation of 8.98. The high processing group had a mean Visual Matching score of 107.73 with a standard deviation of 9.47.

The effects of processing speed were analyzed using a repeated measures ANOVA. The fast processing group had a mean DC/2M pre-test score of 26.00 (SD = 10.46) and a post-test score of 55.81 (SD = 29.15). The slow processing group had a mean pre-test DC/2M score of 30.50 (SD = 28.73) and a post-test mean score of 50.50 (SD = 37.90). The results of the ANOVA suggest a nonsignificant interaction effect of processing speed across pre-and post-test scores, $F(1,19) = 1.29$, $p = 0.271$ (Table 3 & Figure 1). However, there was a slight trend for fast processors to benefit the most from the DRP procedure as can be seen in Figure 1. A modest correlation between gain scores and processing speed was found for this sample of students ($r = .19$, $p = .331$).

Ability and Gain

In a further attempt to clarify the relationship between processing speed and gain scores, both groups were categorized into thirds based on relative processing speed; Fast, Average Ability, and Slow for both the math intervention and control groups. The Math Slow group yielded processing scores ranging from 63 to 87 with an average score of 79 and a gain score range of -12 to 42 DC/2M (average of 16). The Average group had processing scores ranging from 91 to 104 with an average score of 94 and a gain score range of 3 to 71 DC/2M (average of 27). The Fast group had a processing scores ranging from 112 to 116 with an average of 114 and a gain score of 3 to 60 DC/2M (average of 32). As can be seen in Figure 2, overall gain scores for each ability group increased from pre-test to post-test and it appears that students gain about equally from this intervention across all ability levels.

The control group was also split into three ability levels. The Control Slow group had processing scores ranging from 77 to 88 with an average score of 85 and a gain score range of 2 to10 DC/2M (average of 7). The Average group had processing scores ranging from 88 to 93 with an average score of 91 and a gain score range of -7 to 26 DC/2M (average of 10). The Fast group had processing scores ranging from 93 to 110 with an average of 99 and a gain score of 1 to 11 DC/2M (average of 5). As can be seen in Figure 2, overall gain scores for each ability group largely remained flat from pre-test to post-test. As can been seen in Graph 3.2, it appears students in the control group achieved little gain regardless of their ability level. The average growth rates for the intervention and control groups were calculated. On average the treatment group had a growth rate of 6.28 DC/2M per week and the control group achieved a growth rate of 1.84 DC/2M per week.

To determine whether a statistically significant effect of processing speed and gain scores existed in the math group, I split the group into thirds according to processing speed. I placed the bottom third in the Slow Processing group (7 students) and the top third in the Fast Processing group (7 students). The Slow Processing group had a mean gain of 19 correct digits (SD = 19.35) and the Fast Processing group had a mean gain of 29 correct digits (SD = 18.92). The results of an independent samples t test indicate no significant difference between the two groups' mean gain scores, $t(12) = .978$, $p = .348$ (Figure 3).

CHAPTER 4

Discussion

The current study was designed to investigate the effectiveness of the Detect, Prompt, Repair (DPR) procedure for middle school students who have relative slow and fast processing speeds. Although the DPR procedure has been proven effective for elementary aged children, the effectiveness of the procedure has not been determined for middle school children. Nor has the effectiveness been investigated for those who vary in processing speed, though the DPR procedure is designed to build automaticity, which requires mental quickness.

Results show that the DPR procedure was effective in increasing the automaticity of division math facts in middle school children when their mean scores were compared to a control, reading intervention group mean in a true experimental format. These results are consistent with the findings obtained by Poncy, Skinner and O'Mara (2006) based on the application of the intervention with elementary school students. This procedure can be used to augment traditional classroom instruction; it allows each student the opportunity to practice building math automaticity in a large group setting (e.g. an entire classroom).

Application of the DPR procedure provides several instructional advantages compared to more traditional fluency building techniques. In addition to providing an individualized intervention procedure, DPR allows the practice of skills that benefit from remediation. While other procedures (e.g. instructional ratio) provide practice of unlearned skills, they also require practice with a ratio of known material to unknown material. Consequently, students are forced to practice material already mastered, leading to inefficiency.   The tap-a-problem portion of the DPR procedure allows students to target only those skills that are not yet automatic. They practice (using the CCC sheet) only those skills in need of improvement without unnecessary practice on items already known. For example, in this study, the CCC portion provided the students 30 opportunities to give a written response and 125 opportunities to respond subvocally, producing 155 opportunities to respond quickly and to automatize basic skills. In addition, the DPR procedure may also discourage inefficient counting strategies (e.g., finger counting) by allowing a limited amount of time to respond to each item.

As previously noted, results of this study are consistent with previous studies using the DPR procedure (Poncy, Skinner, & O'Mara, 2006). The consistency in findings is significant because of the student differences (i.e., elementary vs. middle school children). Also, the design of this study relative to the earlier investigation by Poncy et al. (2006) allowed other limitations to be addressed. First, Poncy et al. did not employ a true experimental design, with random assignment. Second, they did not provide students with the problems and answers before they began their CCC worksheet, ensuring students did not practice incorrect problems and answers. Apparently, the DPR procedure is effective for both elementary and middle school students, even though specific features can be varied slightly, as demonstrated across these two studies.

Processing Speed and Automaticity

Because DPR is an automaticity building activity, and because previous research shows a relationship between cognitive abilities (particularly processing speed) and math skill building it is important to further explore the extent to which processing speed may be related to math automaticity building. The results of this study reveal no significant effect of processing speed and automaticity, though a trend does exist. That is, there is a moderately weak correlation between automaticity and processing speed and the gain in math fluency appears to be slightly more robust in those who show faster processing speed. This is congruent with previous research showing positive correlations in processing speed and math achievement (Flanagan, Keith, & Vanderwood, 1997; Keith, 1999; McGrew and Hessler, 1995; Williams, McCallum, & Reed, 1996).

Current results also show the DPR procedure to be equally effective for students across three processing speed levels. Thus, this procedure can be effective not only for the slow processing speed students, but also for these with average and fast processing speeds. As Figure 2 shows, students of all levels increase in automaticity about equally. Additionally, Figure 2 show gains were also obtained in the control group. This may have occurred because of practice effects, the effects of the other math instruction that was given to both groups, or spillover effects in the form of students talking to one another about the math intervention strategies.

Limitations

This study is limited in a number of ways. First, fast and slow processors showed only relative differences in their speed, not true norm based differences. Consequently, caution should be exercised in drawing conclusions of “no difference” findings between fast and slow processors. Also, the sample size was small, which reduces the power of this processing speed analysis. Another limitation is related to the error associated with the post-test scores. Students were administered three pre-tests and the median score was obtained for data analysis. On the other hand, only one post-test was administered at the conclusion of the intervention procedure, precluding the use of a median score for the post-test analysis. Taking the median score of the three measures would likely have produced a more valid measure of student performance. Nonetheless, gains are impressive given the short duration (18 school days) of the intervention.

Finally, these results were obtained from only one area of the country (south) and from middle to low SES school's. Also, the students were court ordered to attend the program and the teachers were considered student teachers. Thus, the results may not generalize to other regions, settings, or grades.

Future Directions

The DPR procedure has shown promise in building automaticity in both elementary and middle school, nondisabled students both in the current study and in previous research (Poncy, et al. 2006). Results suggest that the procedure works regardless of the students' level of processing speed, but performance may be better among those with faster processing speed. A larger sample with greater differentiation on the processing speed variable will be necessary to investigate this question. Also, investigation of the effect of the DPR procedure with children with significant educational disabilities will be helpful. Finally, a component analysis would also be useful in determining which elements of the procedure are producing the greatest influence on student's ability to achieve automaticity. This may be particularly useful combined with a design including students who have normative as well as relative processing speed differences.

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Appendices

Table 1
Pre- and Post-Test Mean and Standard Deviations for Digits Correct (per 2 Minute) From Math (Treatment) and Reading (Control) Groups.

		Pretest Scores		Posttest Scores	
Group	*n*	*M*	*SD*	*M*	*SD*
Treatment	23	27.56	19.90	52.13	31.56
Control	13	17.76	8.33	25.15	13.44

Table 2

One-Way Analysis of Covariance for Pre- and Post-Test Math Fluency Scores (Treatment) and Reading (Control) Groups.

	SS	Df	MS	F
Treatment	1547.11	1	1547.11	6.49*
Error	7862.63	33	238.26	
Total	94818.00	36		

*p = .016

Note. Effect size = 2.00.

Table 3

Pre- and Post-test Math Scores for Fast and Slow Processors.

		Pretest Scores		Posttest Scores			
Group	*n*	*M*	*SD*	*M*	*SD*	*F**	*p*
Slow Processors	10	30.50	28.73	50.50	37.90	1.29	.271
Fast Processors	11	26.00	10.46	55.81	29.15		

*Interaction effect, processing speed and treatment

.

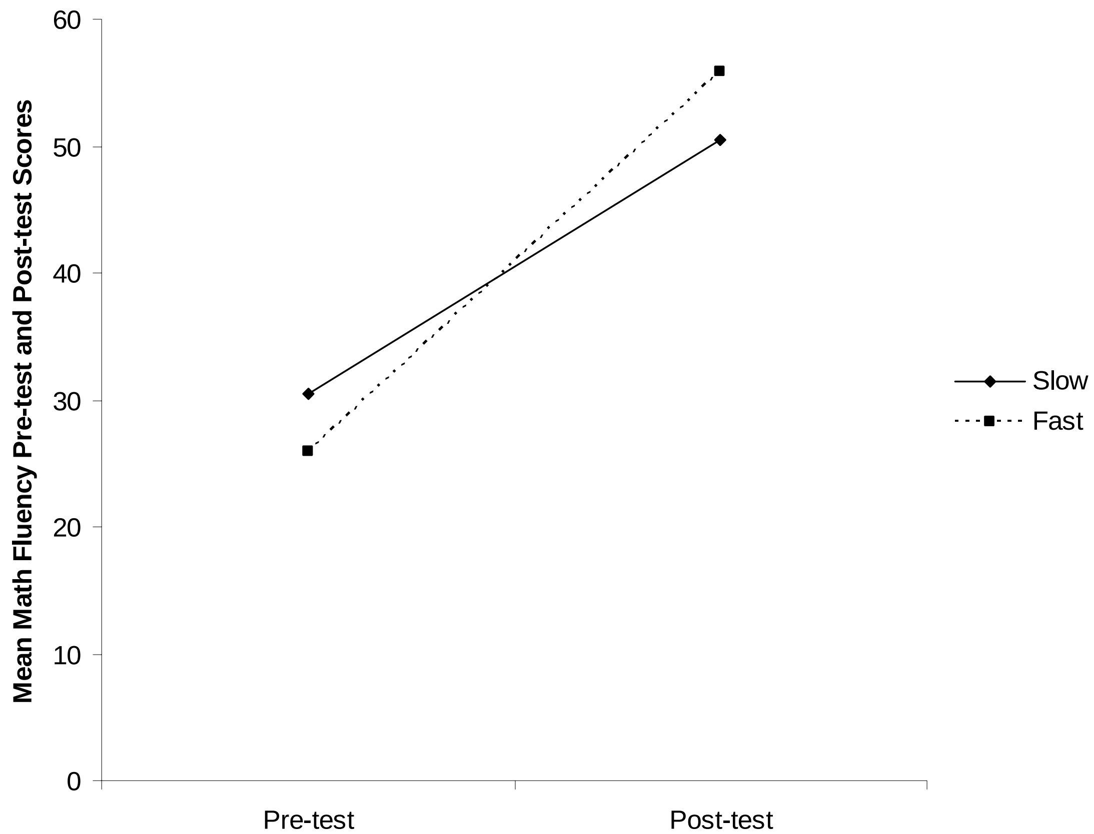


Figure 1. Math Fluency Gain Scores for Fast and Slow Processors

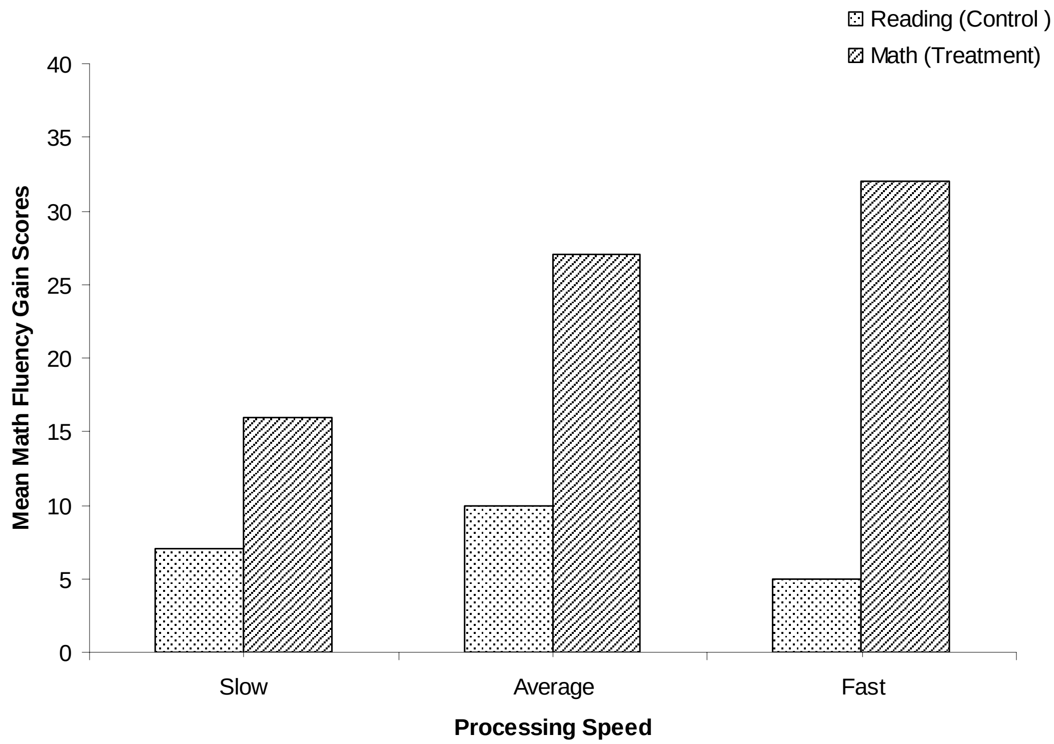


Figure 2. Math Fluency Gain Scores for Three Levels of Processing Speed

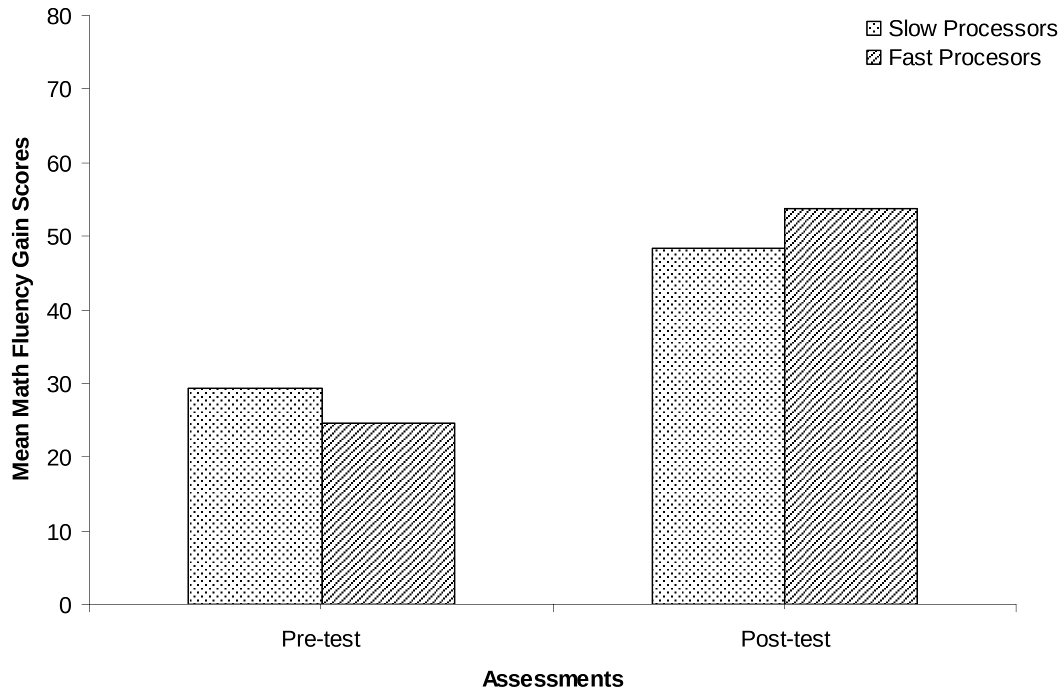


Figure 3. Math Fluency Gain Scores for Slow and Fast Processors

Appendix A

Sample Division Pre-Test

Pre-One Name:______________________________ Date: ____________

64 ÷ 8 =	20 ÷ 5 =	35÷ 7 =	63 ÷ 7 =	14 ÷ 7 =	12 ÷ 3 =
36 ÷ 6 =	27 ÷ 3 =	18 ÷ 6 =	32 ÷ 4 =	45 ÷ 5 =	4 ÷ 2 =
12 ÷ 2 =	25 ÷ 5 =	81÷ 9 =	28 ÷ 7 =	8 ÷ 4 =	6 ÷ 3 =
21 ÷ 7 =	24 ÷ 4 =	18 ÷ 9	56 ÷ 8 =	40 ÷ 8 =	48 ÷ 6 =
16 ÷ 4 =	42 ÷ 7 =	16 ÷ 8 =	72 ÷ 9 =	10 ÷ 2 =	36 ÷ 9 =
15 ÷ 3 =	54 ÷ 6 =	24 ÷ 8 =	9 ÷ 3 =	30 ÷ 5 =	49 ÷ 7 =
14 ÷ 7 =	36 ÷ 6 =	27 ÷ 3 =	35÷ 7 =	18 ÷ 6 =	64 ÷ 8 =
63 ÷ 7 =	20 ÷ 5 =	12 ÷ 3 =	45 ÷ 5 =	32 ÷ 4 =	4 ÷ 2 =

72 ÷ 9 =	9 ÷ 3 =	10 ÷ 2 =	49 ÷ 7 =	54 ÷ 6 =	16 ÷ 8 =
15 ÷ 3 =	42 ÷ 7 =	30 ÷ 5 =	24 ÷ 8 =	16 ÷ 4 =	36 ÷ 9 =
4 ÷ 2 =	32 ÷ 4 =	12 ÷ 3 =	35÷ 7 =	27 ÷ 3 =	64 ÷ 8 =
45 ÷ 5 =	63 ÷ 7 =	20 ÷ 5 =	14 ÷ 7 =	36 ÷ 6 =	18 ÷ 6 =
8 ÷ 4 =	56 ÷ 8 =	24 ÷ 4 =	18 ÷ 9	28 ÷ 7 =	21 ÷ 7 =
12 ÷ 2 =	25 ÷ 5 =	6 ÷ 3 =	40 ÷ 8 =	48 ÷ 6 =	81÷ 9 =
9 ÷ 3 =	54 ÷ 6 =	15 ÷ 3 =	49 ÷ 7 =	24 ÷ 8 =	10 ÷ 2 =
30 ÷ 5 =	72 ÷ 9 =	42 ÷ 7 =	16 ÷ 4 =	16 ÷ 8 =	36 ÷ 9 =

12 ÷ 2 =	56 ÷ 8 =	28 ÷ 7 =	8 ÷ 4 =	25 ÷ 5 =	18 ÷ 9
24 ÷ 4 =	6 ÷ 3 =	48 ÷ 6 =	40 ÷ 8 =	21 ÷ 7 =	81÷ 9 =
16 ÷ 4 =	10 ÷ 2 =	15 ÷ 3 =	54 ÷ 6 =	16 ÷ 8 =	36 ÷ 9 =
30 ÷ 5 =	42 ÷ 7 =	9 ÷ 3 =	24 ÷ 8 =	49 ÷ 7 =	72 ÷ 9 =
14 ÷ 7 =	18 ÷ 6 =	27 ÷ 3 =	35÷ 7 =	4 ÷ 2 =	63 ÷ 7 =
20 ÷ 5 =	45 ÷ 5 =	32 ÷ 4 =	64 ÷ 8 =	36 ÷ 6 =	12 ÷ 3 =
18 ÷ 9 =	40 ÷ 8 =	12 ÷ 2 =	8 ÷ 4 =	25 ÷ 5 =	24 ÷ 4 =
81 ÷ 9 =	56 ÷ 8 =	21÷ 7 =	48 ÷ 6 =	6 ÷ 3 =	28 ÷ 7 =

Appendix B

Sample of Post-test

Post-Test One Name:______________________________ Date: _____________

49 ÷ 7 =	54 ÷ 6 =	15 ÷ 3 =	9 ÷ 3 =	16 ÷ 4 =	72 ÷ 9 =
24 ÷ 8 =	10 ÷ 2 =	36 ÷ 9 =	42 ÷ 7 =	30 ÷ 5 =	16 ÷ 8 =
14 ÷ 7 =	36 ÷ 6 =	27 ÷ 3 =	35÷ 7 =	18 ÷ 6 =	64 ÷ 8 =
63 ÷ 7 =	20 ÷ 5 =	12 ÷ 3 =	45 ÷ 5 =	32 ÷ 4 =	4 ÷ 2 =
8 ÷ 4 =	12 ÷ 2 =	18 ÷ 9	24 ÷ 4 =	48 ÷ 6 =	28 ÷ 7 =
25 ÷ 5 =	81÷ 9 =	6 ÷ 3 =	40 ÷ 8 =	56 ÷ 8 =	21 ÷ 7 =
10 ÷ 2 =	42 ÷ 7 =	54 ÷ 6 =	16 ÷ 8 =	9 ÷ 3 =	36 ÷ 9 =
24 ÷ 8 =	49 ÷ 7 =	16 ÷ 4 =	72 ÷ 9 =	15 ÷ 3 =	30 ÷ 5 =

32 ÷ 4 =	64 ÷ 8 =	63 ÷ 7 =	4 ÷ 2 =	14 ÷ 7 =	12 ÷ 3 =
20 ÷ 5 =	27 ÷ 3 =	36 ÷ 6 =	35÷ 7 =	45 ÷ 5 =	18 ÷ 6 =
12 ÷ 2 =	21 ÷ 7 =	25 ÷ 5 =	40 ÷ 8 =	24 ÷ 4 =	48 ÷ 6 =
81÷ 9 =	6 ÷ 3 =	56 ÷ 8 =	8 ÷ 4 =	28 ÷ 7 =	18 ÷ 9
30 ÷ 5 =	36 ÷ 9 =	15 ÷ 3 =	16 ÷ 4 =	10 ÷ 2 =	16 ÷ 8 =
54 ÷ 6 =	9 ÷ 3 =	72 ÷ 9 =	49 ÷ 7 =	24 ÷ 8 =	42 ÷ 7 =
4 ÷ 2 =	14 ÷ 7 =	12 ÷ 3 =	36 ÷ 6 =	27 ÷ 3 =	45 ÷ 5 =
64 ÷ 8 =	35÷ 7 =	32 ÷ 4 =	20 ÷ 5 =	18 ÷ 6 =	63 ÷ 7 =

24 ÷ 4 =	18 ÷ 9	8 ÷ 4 =	56 ÷ 8 =	12 ÷ 2 =	28 ÷ 7 =
48 ÷ 6 =	25 ÷ 5 =	81÷ 9 =	21 ÷ 7 =	40 ÷ 8 =	6 ÷ 3 =
42 ÷ 7 =	10 ÷ 2 =	24 ÷ 8 =	30 ÷ 5 =	16 ÷ 4 =	36 ÷ 9 =
54 ÷ 6 =	72 ÷ 9 =	49 ÷ 7 =	15 ÷ 3 =	9 ÷ 3 =	16 ÷ 8 =
64 ÷ 8 =	27 ÷ 3 =	20 ÷ 5 =	12 ÷ 3 =	32 ÷ 4 =	14 ÷ 7 =
20 ÷ 5 =	63 ÷ 7 =	18 ÷ 6 =	36 ÷ 6 =	4 ÷ 2 =	32 ÷ 4 =
40 ÷ 8 =	18 ÷ 9	48 ÷ 6 =	21 ÷ 7 =	56 ÷ 8 =	6 ÷ 3 =
24 ÷ 4 =	81÷ 9 =	8 ÷ 4 =	12 ÷ 2 =	25 ÷ 5 =	28 ÷ 7 =

Appendix C

Sample Procedure Packet

Summer Program 2005 **#1**
Math

Student Name:_________________________

Form 1A (Int) Name:________(Tap-A-Problem)______________________

24 ÷ 8 =	9 ÷ 3 =	15 ÷ 3 =	42 ÷ 7 =	54 ÷ 6 =	16 ÷ 8 =
10 ÷ 2 =	49 ÷ 7 =	30 ÷ 5 =	72 ÷ 9 =	36 ÷ 9 =	16 ÷ 4 =
42 ÷ 7 =	15 ÷ 3 =	16 ÷ 4 =	9 ÷ 3 =	10 ÷ 2 =	72 ÷ 9 =
24 ÷ 8 =	36 ÷ 9 =	30 ÷ 5 =	49 ÷ 7 =	54 ÷ 6 =	16 ÷ 8 =
72 ÷ 9 =	54 ÷ 6 =	42 ÷ 7 =	9 ÷ 3 =	10 ÷ 2 =	49 ÷ 7 =
15 ÷ 3 =	16 ÷ 8 =	30 ÷ 5 =	24 ÷ 8 =	16 ÷ 4 =	36 ÷ 9 =
9 ÷ 3 =	54 ÷ 6 =	15 ÷ 3 =	42 ÷ 7 =	72 ÷ 9 =	10 ÷ 2 =
30 ÷ 5 =	16 ÷ 8 =	49 ÷ 7 =	16 ÷ 4 =	24 ÷ 8 =	36 ÷ 9 =

The CCC Sheet

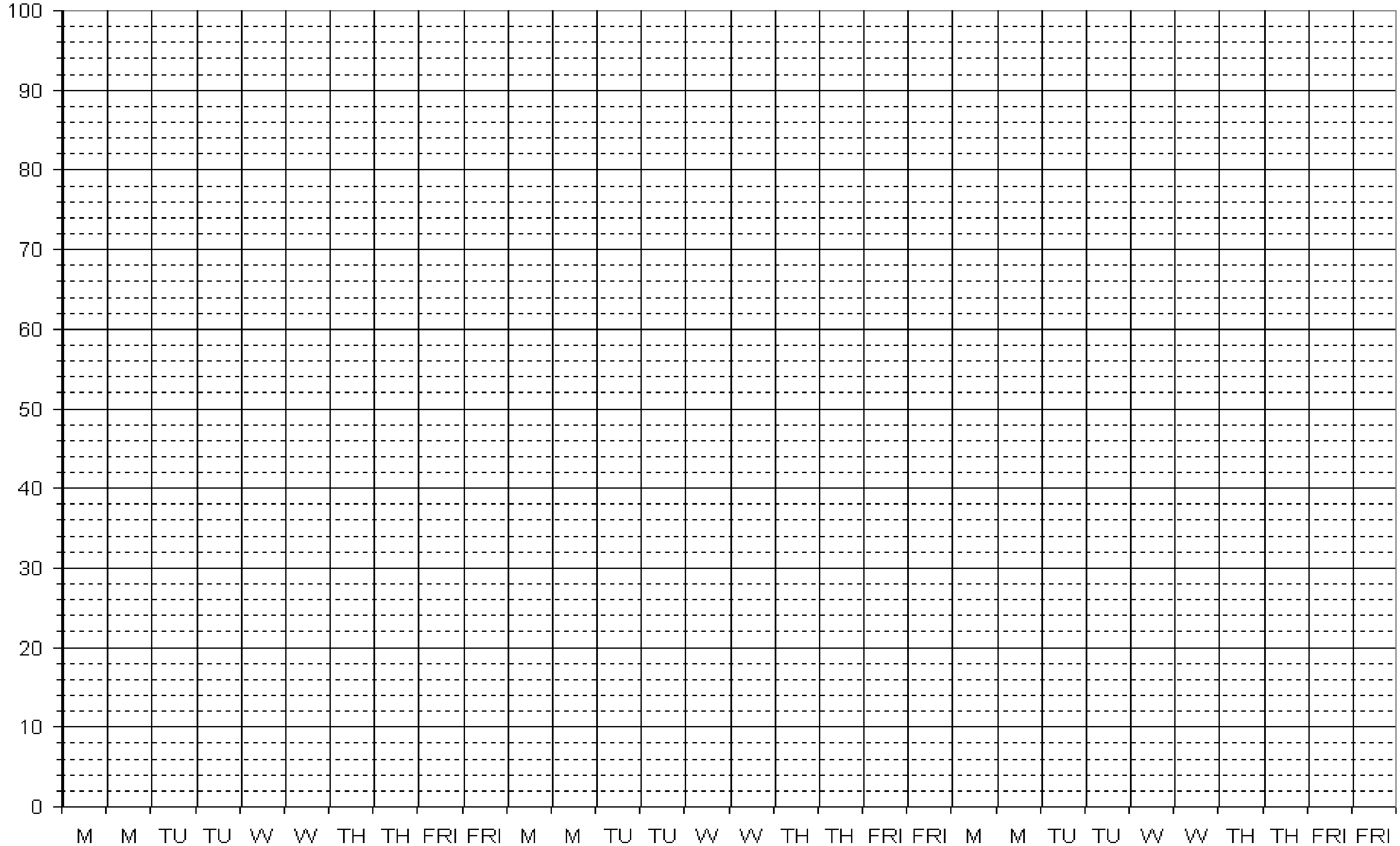
PROBLEM & ANSWER	#1	#2	#3	#4	#5
1.					
2.					
3.					
4.					
5.					

Form 2A (Inr) Name:____(Mad Minute)________________________

72 ÷ 9 =	49 ÷ 7 =	9 ÷ 3 =	54 ÷ 6 =	16 ÷ 4 =	15 ÷ 3 =
42 ÷ 7 =	10 ÷ 2 =	30 ÷ 5 =	36 ÷ 9 =	16 ÷ 8 =	24 ÷ 8 =
49 ÷ 7 =	16 ÷ 4 =	15 ÷ 3 =	9 ÷ 3 =	54 ÷ 6 =	72 ÷ 9 =
16 ÷ 8 =	10 ÷ 2 =	36 ÷ 9 =	30 ÷ 5 =	42 ÷ 7 =	24 ÷ 8 =
15 ÷ 3 =	42 ÷ 7 =	54 ÷ 6 =	16 ÷ 8 =	9 ÷ 3 =	16 ÷ 4 =
24 ÷ 8 =	49 ÷ 7 =	36 ÷ 9 =	72 ÷ 9 =	10 ÷ 2 =	30 ÷ 5 =
16 ÷ 4 =	36 ÷ 9 =	54 ÷ 6 =	16 ÷ 8 =	42 ÷ 7 =	49 ÷ 7 =
10 ÷ 2 =	72 ÷ 9 =	30 ÷ 5 =	9 ÷ 3 =	24 ÷ 8 =	15 ÷ 3 =

Name:___________________________________ Student Daily Progress Graph

Summer 2005



Appendix D

Teacher Training Packet

The Tap-A-Problem

1. When the teacher says begin, do a problem every tick. (Ticks will sound every 1-2 seconds).
2. If problem is not finished by the next tick you must go on.
3. When teacher says stop, put your pencils down.
4. Write down the problems you did not do in the numbered boxes on the CCC sheet (5 problems).
5. Begin the CCC.

Cover, Copy, and Compare (CCC)

1. Look at the problem and its answer.
2. Repeat the problem and answer in your head 5 times (say it to yourself softly).
3. Cover problem with your hand and write the problem and answer in the 5 boxes to the right.
4. Uncover problem and solution.
5. Evaluate your response.

Mad-Minutes

1. Keep paper face down.
2. Listen to directions. When teacher says begin, turn paper over and start.
3. Complete the problems starting at the top and go across, X any problems your can not do.
4. When teacher says stop, put your pencil down.
5. Score your probe by counting the number of written digits and chart the amount on the last page.

CBM administration directions:

1. Place the passage in front of the student.
2. Place your copy in front of you but shielded so the student cannot see what you record. Also keep the stopwatch out of the sight of the student.
3. Say these directions verbatim to the student:

Tap-A-Problem Instructions

The sheets on your desk are math facts. All the problems are (addition, subtraction, multiplication, division) facts. When I say 'please begin' start answering the problems. Begin with the first problem and work across the page

*(demonstrate by pointing)**. Then go to the next row. If you cannot answer a problem, mark an 'X' through it and go to the next one. If you finish the page, stop and put your pencil down and sit quietly. Remember, you have to go on to the next problem when you hear the metronome click even if you are not finished. Are there any questions?*** *(pause)* ***Please begin.***

(Time the children for 1 min. 20 seconds)

<u>Mad Minute Instructions</u>

When I say 'please begin' start answering the problems. Begin with the first problem and work across the page (demonstrate by pointing)**. Then go to the next row. If you cannot answer a problem, mark an 'X' through it and go to the next one. If you finish the page, put your pencil down and sit quietly. Are there any questions?** (pause) **Please begin.**

(Time the children for 1 min.)

1. Monitor student performance so that students work the problems in rows and do not skip around or answer only the easy problems (This is difficult during group administration).
2. At the end of 2-minutes, tell or instruct the students to stop and place a bracket (]) after the last completed problem.

<u>Scoring Procedures</u>: Count the number of correctly written digits in the problems. For a digit to be counted as correct it must be in the correct place value.

<u>Instructions for Teachers:</u>

<u>Teacher giving the Intervention</u>

The student's will be given their folders at the beginning of the class time in the intervention room. Two teachers will be in the room. One teacher will take the children through the intervention and the other teacher will complete the "Treatment Integrity Checklist" for each intervention. The teachers will run through the intervention twice. There will be two packets in each of the student's folders. One for each intervention run. Ask the students to take out the first packet and put their name on the cover sheet. Remind the students to leave the packet closed until told to begin. Read the instructions entitled "Tap-A-Problem" for the first probe set, start the metronome to 40 beats per minute, and give the children **1:20 minutes** to complete the first page. Make sure the students are moving on to the next problem at click of the metronome. When you say stop, ensure that all of the students have put their pencils down. Once the children have completed the first page of the packet go on to the CCC sheet. Display the poster with the problems and correct answers so each child can see it.

CCC Sheet

Ask each student to circle the first five incorrect problems on the first sheet. Ask each student to copy the first problem of the sheet they just completed to the CCC worksheet.
Instruct the student to:
1. Look at the problem and its answer.
2. Repeat the problem and answer in your head five times (say it to yourself).
3. Cover the problem with your hand and write the problem and answer in the next box, and say it five times to yourself.
4. Uncover problem and solution and evaluate your response.
5. Repeat this procedure until you reach the last box in that row.

Have the students repeat this procedure for all of the five incorrect problems. Both teachers should circulate around the room to ensure the children are completing the worksheet as instructed. Once all of the children have completed the CCC worksheet, put the poster away, and instruct the students to turn to the last page and keep it turned over.

Mad-Minute

Ensure the students keep the paper face down until told to begin. Read the instructions entitled "Mad Minute" and give the children **1 minute** to complete as many problems as they can. Ensure the students are completing the problems starting at the top and going across and placing an X in any of the problems they can not do. When you say stop instruct the students to put their pencils down. Instruct the students to score their probe by counting the number of correct digits and chart the amount on the last page.

Charting Progress for each student

After the mad minute, each student will count the number of digits correct on the mad minute worksheet and graph the results. On the inside cover of each folder there will be a graph sheet for each child to chart their progress for each intervention each day. The teachers should circulate around the room to give assistance if necessary and ensure each child is charting their work. After the students have completed the first chart the teachers will repeat the intervention using the second packet.

Instructions for completing the "Treatment Integrity Checklist"

While one teacher is giving the intervention to the children the other teacher in the room is completing the checklist to ensure that the intervention is being given accurately. Place a check mark on the line after the intervention teacher completes the step. If the step is not completed do not check it. After completing the Checklist place the date at the bottom of the page.

All of the folders with the completed work should be given to Greg, Phil, or Brian to be scored and committed to a database.

Probe Instructions

For each of the probe set given you must read the instructions verbatim to the students before they begin.

Tap-A-Problem Instructions

The sheets on your desk are math facts. All the problems are (addition, subtraction, multiplication, division) facts. When I say 'please begin' start answering the problems. Begin with the first problem and work across the page *(demonstrate by pointing)****. Then go to the next row. If you cannot answer a problem, mark an 'X' through it and go to the next one. If you finish the page, stop and put your pencil down and sit quietly. Remember, you have to go on to the next problem when you hear the metronome click even if you are not finished. Are there any questions?*** *(pause)* ***Please begin.***

(Time the children for 1 min. 20 seconds)

Mad Minute Instructions

When I say 'please begin' start answering the problems. Begin with the first problem and work across the page *(demonstrate by pointing)****. Then go to the next row. If you cannot answer a problem, mark an 'X' through it and go to the next one. If you finish the page, put your pencil down and sit quietly. Are there any questions?*** *(pause)* ***Please begin.***

(Time the children for 1 min.)

Form 1A (Int) Name:_(Tap-A-Problem)____________________

24 ÷ 8 =	9 ÷ 3 =	15 ÷ 3 =	42 ÷ 7 =	54 ÷ 6 =	16 ÷ 8 =
10 ÷ 2 =	49 ÷ 7 =	30 ÷ 5 =	72 ÷ 9 =	36 ÷ 9 =	16 ÷ 4 =
42 ÷ 7 =	15 ÷ 3 =	16 ÷ 4 =	9 ÷ 3 =	10 ÷ 2 =	72 ÷ 9 =
24 ÷ 8 =	36 ÷ 9 =	30 ÷ 5 =	49 ÷ 7 =	54 ÷ 6 =	16 ÷ 8 =
72 ÷ 9 =	54 ÷ 6 =	42 ÷ 7 =	9 ÷ 3 =	10 ÷ 2 =	49 ÷ 7 =
15 ÷ 3 =	16 ÷ 8 =	30 ÷ 5 =	24 ÷ 8 =	16 ÷ 4 =	36 ÷ 9 =
9 ÷ 3 =	54 ÷ 6 =	15 ÷ 3 =	42 ÷ 7 =	72 ÷ 9 =	10 ÷ 2 =
30 ÷ 5 =	16 ÷ 8 =	49 ÷ 7 =	16 ÷ 4 =	24 ÷ 8 =	36 ÷ 9 =

The CCC Sheet

PROBLEM & ANSWER	#1	#2	#3	#4	#5
1.					
2.					
3.					
4.					
5.					

Form 2A (Inr) Name:____(Mad Minute)_________________________

72 ÷ 9 =	49 ÷ 7 =	9 ÷ 3 =	54 ÷ 6 =	16 ÷ 4 =	15 ÷ 3 =
42 ÷ 7 =	10 ÷ 2 =	30 ÷ 5 =	36 ÷ 9 =	16 ÷ 8 =	24 ÷ 8 =
49 ÷ 7 =	16 ÷ 4 =	15 ÷ 3 =	9 ÷ 3 =	54 ÷ 6 =	72 ÷ 9 =
16 ÷ 8 =	10 ÷ 2 =	36 ÷ 9 =	30 ÷ 5 =	42 ÷ 7 =	24 ÷ 8 =
15 ÷ 3 =	42 ÷ 7 =	54 ÷ 6 =	16 ÷ 8 =	9 ÷ 3 =	16 ÷ 4 =
24 ÷ 8 =	49 ÷ 7 =	36 ÷ 9 =	72 ÷ 9 =	10 ÷ 2 =	30 ÷ 5 =
16 ÷ 4 =	36 ÷ 9 =	54 ÷ 6 =	16 ÷ 8 =	42 ÷ 7 =	49 ÷ 7 =
10 ÷ 2 =	72 ÷ 9 =	30 ÷ 5 =	9 ÷ 3 =	24 ÷ 8 =	15 ÷ 3 =

Appendix E

Treatment Integrity Sheet

Treatment Integrity Checklist for the Math Intervention
Summer 2005

One teacher will mark off the appropriate items as the other teacher takes the children through the intervention.

____: The students were told to get their folders or the folders were passed to all students.

____: The students were told to take out the first packet of materials and told to write their name on the cover sheet.

____: The teacher read the instructions entitled “Tap-A-Problem”.

____: The metronome was set at 40 beats per minute.

____: The teacher gave the students **1:20 minutes** to complete the first page and told the students to put their pencils down when the 1:20 minutes expired.

____: Students circled 5 problems on the 1^{st} intervention page.

____: Students completed the correct problems on the CCC worksheet.

____: The teacher told the children to turn to the last page in the packet and instructed them to keep the page turned over.

____: The teacher read the instructions entitled “Mad Minute”.

____: The teacher started the stopwatch and gave the students **1 minute** to complete the final sheet.

____: The teacher instructed the students to graph their progress.

Date:____________________

Vita

Philip K. Axtell was born in Danville, Virginia and grew up in Williamsburg, Virginia. He graduated from Lafayette High School in 1987 and served 4 years of active duty in the United States Air Force. After discharge from active duty, he attended Virginia Commonwealth University and graduated with a Bachelor of Science degree in Psychology in May of 1996.

Philip is currently a doctoral intern with Knox County Schools and completing his doctoral degree in education with an emphasis on school psychology at the University of Tennessee, Knoxville. He will be graduating in August of 2006.