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The University of Southern Mississippi

USING BRIEF EXPERIMENTAL ANALYSES TO IDENTIFY EFFECTIVE MATH INTERVENTIONS FOR EARLY ELEMENTARY STUDENTS

by

Chelsi Ronetta Clark

Abstract of a Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

August 2013

ABSTRACT

USING BRIEF EXPERIMENTAL ANALYSES TO IDENTIFY EFFECTIVE MATHEMATICS INTERVENTIONS FOR EARLY ELEMENTARY STUDENTS

by Chelsi Ronetta Clark

August 2013

Recognizing the need for early detection and intervention for children with mathematics difficulties, this study aimed to use a brief experimental analysis (BEA) to identify effective interventions within a response to intervention (RTI) framework. Participants included four lower elementary school students who exhibited marked problems in mathematics. The effects of mathematics interventions to increase mathematic computational fluency and accuracy were assessed during the BEA. The intervention that produced the greatest gains during the BEA was compared to the intervention that produced the least gains during an extended analysis phase. It was hypothesized that: (a) during a BEA of math interventions, students will demonstrate differential responding across interventions; (b) during a BEA of math interventions, students will make immediate gains in performance relative to baseline; and (c) the intervention identified as most effective during the BEA, when compared to the least effective intervention will produce stable, valid, and reliable data during the extended analysis phase. Visual analysis was used to compare the interventions during the BEA and extended analysis. Results indicated variability within and across participants with regard to which intervention was most effective. Moreover, results indicated that all students improved their math computation fluency.

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by

Chelsi Ronetta Clark

A Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
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CHAPTER I

INTRODUCTION

Educators have been placing increased attention on the early detection of mathematic difficulties in children (Bryant, Bryant, Gersten, Sammacca, & Chavez, 2008). Attention has also been drawn to the overall poor mathematics achievement of students in United States schools, indicating that schools are not focusing enough attention on preventing mathematics failure (Chard, Baker, Clarke, Jungjohann, & Smolkowski, 2008). The most recent findings by the National Assessment for Educational Progress (NAEP, 2009) indicate that 18% of all 4th grade students scored below basic level in math and that 41% of 4th grade students with disabilities scored below basic level in math. The more time that passes between the identification of academic difficulties and intervention, the more pronounced the problem becomes, and the more difficult remediation becomes (Chard et al., 2008). The findings of the NAEP support this statement in such that 27% of 8th grade students scored below basic level and, by the time students enter 12th grade, this number increases to 36% (NAEP, 2009).

Early intervention strategies are important in decreasing the amount of students who perform below expectations in mathematics as they progress throughout school. One strategy used to identify students with possible learning difficulties, to prevent learning difficulties, and to identify effective interventions for students with difficulties is Response-to Intervention (RTI; Fuchs, Mock, Morgan, & Young, 2003). Once a student has been identified as needing specialized intervention through the RTI process, the instructional hierarchy may be used to identify if that student is experiencing academic difficulties due to acquisition, fluency, generalization, or adaptation problems (Haring & Eaton, 1978). Commonly used strategies for mathematics interventions based on the instructional hierarchy are cover-copy-compare (CCC) for accuracy and constant time delay (CTD) for fluency (McCallum, Skinner, Turner, & Saeker, 2006; Poncy, Skinner, & Jaspers, 2007). Brief experimental analyses are conducted as an efficient means to quickly identify a likely effective intervention strategy for a particular student based on their intervention needs according to the instructional hierarchy (Codding et al., 2009).

Response-to-Intervention

RTI is a data-based assessment process used to identify the degree to which students respond to known highly effective academic interventions (Shapiro, 2004). The goal of RTI is to differentiate whether or not students are performing poorly due to insufficient instruction or disability (Fuchs, Fuchs, & Hollenbeck, 2007). The premise is that if a student does not respond beneficially to quality instruction and specialized intervention, then the student is performing poorly due to disability. According to Barnes and Harlacher (2008), there are five main principles of RTI: (a) proactive approach, (b) instructional match, (c) problem-solving orientation and data-based decisions, (d) effective practices, and (e) systems-level approach. Barnes and Harlacher (2008) also identified four main features of RTI: (a) multiple tiers, (b) assessment system, (c) protocol, and (d) evidence-based instruction/intervention.

RTI was developed to provide a continuum of supports based on a tiered process in which students pass through tiers of academic supports based on their response to different intensities of intervention (Barnes & Harlacher, 2008; Daly, Martens, Barnett, Witt, & Olson, 2007). The first Tier is referred to as the universal Tier in which all students are afforded the same level of quality instruction (Daly et al., 2007). During the first Tier students also undergo universal screening procedures to identify students who are performing below expected levels. When students do not respond to Tier I instruction or are identified as performing below expected levels, they move into Tier II. Tier II may consist of supplemental, small group instruction and regular progress monitoring to gauge their response to intervention (Daly et al., 2007). When students do not respond to Tier II instruction, they move into Tier III which consists of an individualized intervention based on their specific academic instruction needs and regular progress monitoring to gauge their response to intervention (Daly et al., 2007). Many students who struggle academically respond beneficially to the RTI Tier process which marks RTI as a problem solving process designed to identify problems and intervene effectively (Fuchs et al., 2007).

Researchers have looked at the beneficial use of RTI in early elementary school students with mathematics difficulties. Bryant et al. (2008) examined the effects of Tier II interventions with 126 first and 140 second grade students with difficulties in early mathematics skills and concepts. A regression-discontinuity design was used to measure the pre- and post-intervention intervention effects on scores on the *Texas Early Mathematics Inventory—Progress Monitoring (TEMI-PM).* Students who scored below the 25th percentile on the pre-test were selected to receive interventions in this study. The students received small group 15 minute booster sessions over a period of 18 weeks. Bryant et al. (2008) found that whereas the booster sessions did not produce significant improvements for the first grade students, they did produce significant improvements for the second grade students. The authors attributed this difference to the possibility that first grade students may need more intervention time to learn number-sense tasks and numerical combinations.

Fuchs et al. (2007) examined the effects of RTI for first and third grade students with mathematics difficulties. First grade students from 41 classrooms and 10 elementary schools who scored lower than the 20th percentile on standardized measures were randomly assigned to treatment and control groups. In their multiyear study of third grade students, 120 classrooms were randomly assigned to treatment and no treatment conditions. Within those classrooms, one-third of the 144 lowest scoring children were randomly assigned to intervention or no intervention regardless of their classroom treatment condition. The first grade students received intervention through a program designed to target automaticity of math facts and the third grade students received intervention through a program designed to target problem-solving skills. They found that students who received Tier II and Tier III interventions made substantial improvements compared to control group students or students who only received Tier I intervention. They concluded that RTI is effective for promoting growth among early elementary school students at risk of academic failure (Fuchs et al., 2007).

Instructional Hierarchy

First introduced by Haring and Eaton (1978), the instructional hierarchy is a developmental approach to assessment designed to attend to student response-to-intervention and how responding changes as the skill is strengthened (Ardoin & Daly, 2007; Haring & Eaton, 1978). The instructional hierarchy is comprised of four stages of academic skill development that are directly linked to appropriate instructional techniques (Daly & Martens, 1994). The four stages include (a) acquisition, (b) fluency, (c) generalization, and (d) adaptation (Haring & Eaton, 1978). According to the instructional hierarchy, appropriate intervention first depends on accurate assessment of a person's skill level as they advance through stages of a learning hierarchy (Daly, Lentz, & Boyer, 1996).

As a skill is introduced, a person must successfully master each stage in the instructional hierarchy before they are able to progress to the next stage on the hierarchical ladder. The first stage in the instructional hierarchy is the acquisition stage. At this stage, a new skill is introduced, and the ability to accurately produce the skill regardless of a set time period is measured (Cates & Rhymer, 2003). Instructional techniques directly linked to this stage include modeling and prompting (Daly & Martens, 1994; Daly et al., 1996). The second stage in the instructional hierarchy is the fluency stage. The fluency stage includes a more sensitive method of measurement in which the newly acquired skill is expected to be produced rapidly as well as accurately (Cates & Rhymer, 2003). Instructional techniques directly linked to this stage include drill and reinforcement (Daly & Martens, 1994; Daly et al., 1996). The third stage in the instructional hierarchy is the generalization stage. In this stage, the student is able to perform the acquired skill under various settings and situations, including conditions that are different from those experienced during training (Cates & Rhymer, 2003). Training in the natural context is used for intervention in the generalization stage (Daly & Martens, 1994). The final stage of the instructional hierarchy is the adaptation stage. In this stage the student is able to adapt the acquired skill to appropriately fit the unique needs of various settings and situations (Cates & Rhymer, 2003). Solving novel problems is used for intervention in the adaptation stage (Daly & Martens, 1994).

Brief Experimental Analysis

Linking assessment to intervention is a critical component of effectively remediating academic problems (Fuchs et al., 2003; Martens & Gertz, 2009). A brief experimental analysis is an assessment tool that allows practitioners to make valid, accurate judgments about what type of intervention is best suited for a particular academic problem in a relatively brief period of time (Martens, Eckert, Bradley, & Ardoin, 1999; McComas et al., 2009). With regard to the instructional hierarchy, a brief experimental analysis allows the practitioner to assess the stage at which a student is performing based on the assessment results. Determining whether a student is performing poorly due to skill or performance deficits based on results from a brief experimental analysis is necessary to develop interventions that will accurately target the individualized needs of that particular student (Burns, Ganuza, & London, 2009; Codding, Baglici et al., 2009; Duhon et al., 2004). Martens and Gertz (2009) note that there are three critical features of interpreting BEAs: "(a) identifying meaningful indicators of academic performance; (b) choosing an experimental design, and (c) relating outcomes to a theoretical model of individualized instruction" (p. 96).

A major component of a brief experimental analysis is the usefulness for students who do not respond to regular classroom instruction (Burns et al., 2009; Martens & Gertz, 2009). Students who do not respond to regular instruction and do not get specialized intervention services tend to remain further behind their classmates as they move through their academic career. By conducting a brief experimental analysis, practitioners are better able to intervene with these students, potentially close the achievement gap, and allow these students to catch up with their classmates (Martens et al., 1999; McComas et al., 2009).

Helping students remediate academic problems as quickly as possible is necessary to ensure that they do not fall further behind as course work becomes more intensive. The nature of a brief experimental analysis is that interventions can be implemented fairly quickly because the assessment procedures allow for multiple interventions to be rapidly changed over a brief period of time prior to full implementation (Martens &

Gertz, 2009). The rapid changing of interventions also allows control for environmental confounds that may be present during all BEA conditions (Martens et al., 1999).

An extended analysis is longer-term implementation of a BEA that allows practitioners to compare the interventions to baseline or other interventions (Daly, Murdoch, Lillenstein, Webber, & Lentz, 2002). Using an extended analysis phase after a BEA allows practitioners to become more confident in their assessment results as the results of the extended analysis help to confirm the superior intervention as indicated by the BEA (Baraneck, Fineup, & Pace, 2011; Codding, Baglici et al., 2009; Daly et al., 2002; Duhon et al., 2004; Wilber & Cushman, 2006). An extended analysis allows practitioners to look at the stability of the intervention effects over time before full implementation (Codding, Baglici et al., 2009). An extended analysis phase also allows practitioners to assess information about the effectiveness and efficiency of a particular intervention before full implementation (Baraneck et al., 2011).

Several studies have noted the utility of using BEAs to develop effective interventions for academic problems across various subject areas. Baraneck et al. (2011) used a BEA to find effective interventions to teach sight word recognition. The authors compared the effectiveness of nine interventions during the BEA, and two interventions during an extended analysis phase. Although the results of their extended analysis were undifferentiated, two of the interventions were still much more effective than baseline and eight others. In another literacy study, Dufrene and Warzak (2007) used a BEA to identify effective interventions to increase both English and Spanish reading for a dual language learner. Aside from literacy, researchers also use BEAs to develop effective interventions in mathematics. Gilberston, Witt, Duhon, and Dufrene (2008) used a BEA to compare a reward and an instruction condition for four regular education elementary students and evaluated impact of the intervention conditions on math fluency and on-task behavior. Results indicated that the BEA identified the most effective condition for each of the students. Mong and Mong (2012) used a BEA with an extended intervention analysis phase to examine the effects of CCC, taped problems, and math to mastery on the mathematical fluency of three elementary school students. They found that the BEA accurately predicted the most effective intervention for each student as evidenced by the extended analysis phase.

Duhon et al. (2004) also used a BEA and an extended analysis to identify skill versus performance deficits in four elementary school students from general education classrooms who had deficits in multiple skill areas including mathematics. They found that that BEA accurately differentiated between skill and performance deficits and that the extended analysis phase supported the BEA. Codding, Baglici et al. (2009) found similar results using a BEA and an extended analysis phase to identify effective mathematic interventions for four elementary school students.

One study in particular conducted a BEA of math interventions based on the instructional hierarchy to identify effective mathematics interventions for four elementary and middle school students. Reisener (2009) conducted a BEA and extended analysis of CCC, reward, CTD, and control (i.e., no intervention). BEA results clearly identified a superior intervention for two of the four students, and additional iterations of interventions were necessary to identify a more effective intervention for the final two students. During extended analyses, the most effective intervention was compared to the least effective condition, which included the control condition for three of the four participants. Results of extended analyses indicated that the initially identified intervention was more effective than the comparison intervention for all four participants.

Mathematics Interventions for Accuracy and Fluency

Linking intervention to assessment is an essential feature of the RTI process. BEAs allow practitioners to quickly identify interventions that may be effective during full implementation. The instructional hierarchy may be used as the conceptual framework for identifying interventions that are tested during the BEA. However, the utility of this approach to assessment and intervention hinges on the availability of research-based intervention procedures that are likely to improve student performance. Whereas the math intervention literature is limited relative to the literacy intervention literature, there are some intervention procedures that have been demonstrated as effective for improving students' math performance.

Contingent Reward

The use of contingent rewards is a method for interventionists to determine whether or not a child can improve their accuracy and fluency based on motivation alone, or whether instructionally-based supplemental or intensive instruction is needed (Daly, Persampieri, McCurdy, & Gortmaker, 2005). Additionally, the use of rewards can assist in determining whether or not a student's academic problems are skill or performance based (Duhon et al., 2004). Skill deficits include poor performance due to lack of skill development, whereas performance deficits include poor performance due to motivational or environmental variables.

Lannie and Martens (2008) used a treatment package composed of self-monitoring plus reward to improve the mathematic performance of four 5th grade students. They found mixed results in that two of their participants displayed decreasing and variable trends in accuracy beyond the acquisition stage of the intervention. They concluded that this was because the students were able to earn more rewards during the fluency stage of the intervention for rate alone, but not accurate rate of completion. Lannie and Martens (2008) concluded that interventionists should ensure that contingent rewards are not only used for fluency, but for the combination of fluency and accuracy.

Researchers have also looked at the use of contingent reward alone to improve the accuracy of mathematics performance. Miller, Duffy, and Zane (1993) examined the effects of contingent reward on the accuracy of self-correction of homework for 13, sixth-grade students. They found that when students were rewarded with days of no homework for self-correction accuracy and percentage of homework problems completed correctly, both accuracy and achievement increased. Inaccuracy decreased from 5.8% to 1.4%. O'Neil, Sugrue, and Baker (1995) conducted a study to determine if the mathematics results from the National Association of Educational Progress were due to the influence of incentives on student performance. Students in eighth and twelfth grade were offered monetary incentives for completion of accurate problems on the NAEP assessment. Specifically, students were rewarded one dollar for every question answered correctly. Researchers found that a financial incentive resulted in substantial differences between the incentive group and control group for eighth grade students in the study. They also concluded that it is possible that differences were not found between the groups of twelfth grade students, because the financial incentive may not have been enough to motivate older students (O'Neil et al., 1995).

Cover-Copy-Compare

CCC is a self-delivered corrective feedback technique that was first described by Skinner, Turco, Beatty, and Rasavage (1989). CCC is a multi-component instructional package that is effective in increasing both fluency and accuracy of mathematic skills (Mong & Mong, 2010; Poncy et al., 2007). CCC has also been found to be an effective intervention for general education as well as special education students across a wide variety of subject areas (Smith, Dittmer, & Skinner, 2002). CCC involves five steps: "(1) look at the problem, (2) cover the problem with an index card, (3) write the problem and solution on the right side of the page, (4) uncover the problem and solution, and (5) evaluate the response" (Shapiro, 2004, pp. 218-219). With regard to the instructional hierarchy, CCC is most appropriate for students at the accuracy stage, as the immediate self-evaluation component prevents students from making inaccurate responses (Mong & Mong, 2010).

Several studies have used CCC to intervene with students who demonstrated difficulties in mathematics. Mong and Mong (2010) examined the effects of CCC and Math to Mastery on the mathematics fluency of three second grade students. They found that while Math to Mastery was found to be more effective than CCC for two of the participants, both interventions were still effective at increasing accuracy from baseline scores across participants. In yet another study, Grafman and Cates (2010) compared the effectiveness of standard CCC and a modified version on the mathematics fluency and accuracy of 47 second-grade students. They found that both the standard CCC and modified CCC interventions resulted in significantly higher digits correct per minute from pre-test to post-test. They also found that students had significantly higher correct digits per minute under the standard CCC condition versus the modified CCC condition.

CCC has been found to be a useful intervention for individuals with cognitive and behavioral disabilities. Poncy et al. (2007) compared the effects of CCC and taped problems on the fluency and accuracy of a 10-year old student with borderline cognitive functioning. They found that both CCC and taped problems were effective at substantially improving the accuracy and fluency of the student's performance. Cieslar, McLaughlin, and Derby (2008) used CCC to improve the math and spelling performance of a high school student diagnosed with a behavioral disorder and receiving special education services in the areas of reading, written expression, and mathematics. After the CCC intervention, the student's math accuracy increased from 0% to 89%.

Poncy, Skinner, and Axtell (2010) examined the effects of CCC as a part of an intervention package in which students only practiced unknown problems. Eight third grade elementary school students received intervention for math fluency and accuracy by first identifying unknown problems, practicing the correct response, then undergoing a one minute fluency drill. The researchers found that all of the students displayed significant improvements in math performance from baseline (Poncy et al., 2010). In a similar study, Poncy and Skinner (2011) used CCC as part of an intervention package that also utilized a group reward component. In this study, students completed the CCC procedure individually, took a timed-test, then were rewarded for meeting group goals. They found that the intervention package produced increases in math fluency that were maintained over time.

Codding, Chan-Iannetta, Palmer, and Lukito (2009) also examined the effectiveness of CCC as part of an intervention package. In their study they compared the effects of CCC alone, and the combined effects of CCC with two types of performance feedback regarding goal setting. The participants in their study included general education sixth-grade students identified as having difficulties in mathematics fluency and accuracy. They found that all three forms of the CCC intervention produced more computational gains over the control condition. Consequently, across several studies, there is empirical support for CCC for improving math computation accuracy and fluency.

Constant Time Delay

Time delay is an instructional strategy designed to facilitate near-errorless learning through the use of modeling and prompting (Schuster, Stevens, & Doak, 1990). There are two known types of time delay procedures: constant and progressive (Hughes, Fredrick & Keel, 2002; McCallum et al., 2006). In progressive time delay (PTD) procedures, the amount of time between the presentation of the target stimulus and response prompt can gradually increase or gradually decrease systematically across trials. In CTD, the amount of time between the presentation of the target stimulus and response prompt remains constant across trials. In both types of time delay procedures, the initial interval between the presentation of the stimulus and response prompt is 0s. After students reliably respond during the 0s interval, the interval is either gradually increased (PTD) or increased to a fixed amount of time (CTD) to allow students more time to respond before the response prompt is presented (Hughes et al., 2002). For example in PTD the interval between the presentation of the target stimulus and response prompt may systematically increase from 1s to 3s, whereas the interval would remain at 3s for all trials during CTD (McCallum et al., 2006). CTD intervals between the presentation of the target stimulus and response prompt usually range between 2s and 5s (Coleman-Martin & Heller, 2004).

CTD has been found to be an effective and efficient intervention for individuals with various levels of developmental disabilities and for individuals without developmental disabilities. Head, Collins, Schuster, and Ault (2011) examined the effects using time delay procedures for teaching social studies facts to high school students with intellectual disabilities and behavioral disorders. In this study, the examiners compared the effects of using CTD and simultaneous prompting procedures for teaching state capitals to four high school students. They found that both procedures were effective in teaching the social studies facts, with simultaneous prompting being slightly superior. In another study looking at the effectiveness of CTD with individuals with disabilities, Dogoe, Banda, Lock, and Feinstein (2011) used CTD procedures to teach two young adults with autism to read product warning labels. In this study, the participants earned praise after stating, defining, and providing the contextual meaning of key words within five seconds. By the end of the study, the participants' ability to read, define, and generalize product warning labels substantially increased.

CTD can also be implemented in an individual or group format. In one group administered CTD study of students in integrated and resource classrooms, the investigators used a procedure in which students had to write down their target word before responding on a dry erase board (Keel, Slanton, & Blackhurst, 2001). In another condition in the study, all of the students had to write down the target word before the target student responded. Keel et al. (2001) found that the CTD procedure was not only effective in increasing spelling of the target students' specific target words, but it was also effective in increasing the students spelling of everyone else's target words through observational learning. In similar studies evaluating the effectiveness of CTD in group format, Winterling (1990) and Ross and Stevens (2003) taught elementary school students with mild disabilities spelling using target vocabulary words. Similar to the Keel et al. (2001) study, Winterling (1990) and Ross and Stevens (2003) found that the use of CTD to teach target spelling lists not only increased student accuracy of their personal target list, but also resulted in observational learning for peer target students' lists.

Several researchers have examined the effects of CTD in an individual format. Cates et al. (2007) compared the effects of CTD and CCC on the acquisition, maintenance, and adaptation of spelling words of three general education students. They found whereas while CCC resulted in higher levels of acquisition across students, CTD resulted in greater maintenance for two of the three students. Daughtery, Grisham-Brown, and Hemmeter (2001) used an embedded approach of CTD procedures to teach counting to three preschool children with speech and language delays. They found that the students' responding drastically increased from baseline when the CTD procedures were imbedded into the student's natural activities, such as playing with blocks. The students also maintained their high levels of responding post-intervention.

In another study looking at individual performance, Schuster et al. (1990) used a CTD procedure to teach vocabulary to three fifth-grade students with learning and behavioral disabilities. They found that the CTD procedure not only taught the students their target definitions in a short amount of time, but also promoted generalization and maintained effects for as long as 14 weeks after the last intervention session. Similar results were found in Koscinski and Gast's (1993) study of the effectiveness and efficiency of using CTD to teach multiplication facts to three elementary students with learning disabilities. They found that the CTD procedure was both effective and efficient in teaching the multiplication facts to the students and promoted generalization to reverse facts, a horizontal presentation orientation, and paper-and-pencil task.

Purpose of the Current Investigation

Because of the problem of academic failure in United States schools, it is important for researchers to accurately identify ways to alleviate these problems before students fall further behind. Early intervention is necessary to effectively provide students with the tools that they need to succeed and gain mastery over skill areas before they are exposed to new skill areas without a basic fundamental understanding of what is required. A brief experimental analysis is a quick method for identifying individual instructional needs for students who do not respond to general instruction. An extended analysis phase allows practitioners to become confident that the student will respond to the intervention and that the results will remain stable over time.

Although there is a great amount of literature available that examines the utility of BEAs in the area of reading, there is limited research available in the area of mathematics. The Resisener (2009) study conducted a BEA of math interventions with an extended analysis phase and found that the initially identified intervention was more effective than the comparison conditions. Unfortunately, comparing initially identified interventions to no intervention control conditions during the extended analysis for three of four participants limits the evaluation of treatment utility of BEA. The purpose of the current investigation was to add to the literature on math BEAs and improve upon the Reisener (2009) design problems by implementing a more rigorous comparison of intervention components, by specifically not including the control condition in the extended analysis.

This study addressed the following research questions:

1. During a BEA of math interventions, will students demonstrate differential responding across interventions?
2. During a BEA of math interventions, will students make immediate gains in correct digits relative to baseline performance?
3. Will the intervention identified as most effective during the BEA, when compared to the least effective intervention, produce stable, valid, and reliable data during the extended analysis phase?

CHAPTER III

METHODOLOGY

Participants and Setting

Four lower elementary students were selected from general education classrooms (first and second grade) within a southeastern state. The school was located in a rural community that served 2,355 students in grades K-12. Approximately 89% of those students received free or reduced lunch and 55% were Caucasian. The participants were referred by their teachers for demonstrating poor work completion and performance in mathematics. Criteria for participation also included (a) not currently receiving mathematics interventions through the Tier process, (b) not identified as having a specific learning disability in mathematics, and (c) scoring below the 25th percentile on grade level AIMSweb M-CBM probes. Parental consent (Appendix A) was obtained from the participants' parents prior to participation and additional screening. All sessions were conducted in a quiet location outside of the classroom setting. Sessions took place approximately four times per week during non-instructional times during school hours. Sessions averaged twenty minutes in length.

All four participants were referred by their teachers due to concerns regarding math computation performance. Kyle was an eight-year-old, Caucasian male in second grade; Mark was a seven-year-old, Caucasian male in second grade; Julie was an eight-year-old, Caucasian female in second grade; and Patrick was a seven-year-old, Caucasian male in first grade. All students were in general education classes, not receiving math intervention services at their schools, and not identified as having a specific learning disability in mathematics.

Materials

A specific set of addition and subtraction problems were used for each experimental condition. During screening and generalization multiple skill M-CBM probes from AIMSweb.com were used. AIMSweb probes are based on expected skill outcomes for students based on grade level and time of year (i.e., Fall, Winter, and Spring) and are used for assessment and progress monitoring (Shinn, 2004). Winter norms were used for this study due to the time of year the study was conducted. Above Average scores on AIMSweb probes fall at or above the 75^{th} percentile, Average scores fall between the 25^{th} and 74^{th} percentile, and Below Average scores fall at or below the 24^{th} percentile. Based on a previous study using AIMSweb M-CBM probes, the reported alpha for AIMSweb M-CBM probes is .93. Based on previous studies using AIMSweb M-CBM probes, the reported interscorer agreement for AIMSweb M-CBM probes ranges from .83 to .93 (NCS Pearson Inc., 2010). Specific sets of single skill probes were used during the BEA, extended analysis, and independent verification phase that were generated via math-aids.com by the primary investigator.

Mathematics calculation problems that included addition and subtraction facts were used. Addition probes contained randomly selected computational problems for addition facts that ranged from 0 + 0 to 20 + 20 for first grade probes, and 0 + 99 to 99 + 99 for second grade probes. Subtraction probes contained randomly selected subtraction facts that ranged from 0 - 0 to 99 – 99 for second grade probes. A number of problems of each type (i.e., 1 digit plus 1 digit addition, 2 digit plus 2 digit addition, 1 digit minus 1 digit subtraction, and 2 digit minus 2 digit subtraction) were downloaded from AIMSweb.com and created via math-aids.com. Each AIMSweb probe contained multiple skill math computation problems that were arranged vertically in five rows and five columns on one worksheet (totaling 25 problems). Each math-aids.com probe contained an equal number of single skill math computation problems that were arranged vertically in five rows and five columns on one worksheet (totaling 25 problems).

CCC worksheets were generated using a web based math worksheet generator (i.e., math-aids.com). CCC sheets contained either a specific set of addition or subtraction facts. Blank index cards, as well as index cards displaying addition and subtraction facts were also used. Rewards included a variety of low-cost items including small edibles, small toys, pencils, erasers, and stickers.

Dependent Variables and Data Collection

The primary dependent variable was total correct digits (CD) using standard AIMSweb procedures for math in which probes are administered for 2 minutes for students in grades 1 – 3 (Shinn, 2004). Correct Digits (CD) is a rate-based measure that is calculated by counting the correct number of digits that a participant writes in 2 minutes. A digit was scored as correct if it appeared in the correct column. For example, the addition problem 11 + 13 = could be scored as 0, 1, or 2 digits correct. An answer of 24 would result in 2 correct digits because the numerals in the tens and ones columns are correct. An answer of 25 would be scored as 1 correct digit because only the tens column is correct. An answer of 42 would be scored as 0 correct digits because neither the tens or ones columns are correct. Participants were also given credit for legible, but reversed numbers (Shinn, 2004). Data were scored by graduate students in school psychology, who were already trained to score math CBM data to a 90% agreement criterion.

Experimental Design

For the BEA, a brief multielement design was used to compare the effects of various intervention conditions on math computational fluency compared to baseline during the BEA. Baseline was implemented prior to the BEA. For baseline, three single skill probes were administered to each participant. During the brief multielement phase the order of intervention conditions was randomized for each participant. During the extended analysis phase, the intervention that produced the highest CD compared to baseline was compared to the intervention that produced the lowest CD compared to baseline. Following the extended analysis phase, an independent verification phase was implemented to control for multiple treatment interference (Dermer & Hoch, 1999). Intervention conditions for the BEA and extended analysis included the following four conditions with a unique multi-skill problem set: reward, CCC, CTD, and control (see Appendices B, C, D, and E). The conditions were based on the acquisition and fluency stages of the instructional hierarchy. The reward condition was used to test for skill versus performance deficits (Duhon et al., 2004). CCC was used as an intervention to target accuracy (Poncy et al., 2007). CTD was used as an intervention to target fluency (McCallum et al., 2006).

Procedure

Baseline was implemented to assess the performance of the participants on grade level probes before intervention. Following baseline, the BEA was implemented which consisted of four intervention conditions: (a) reward, (b) CCC, (c) CTD, and (d) control. Each BEA condition contained a unique set of math probes, and the conditions were presented in a randomized order across participants. After the BEA, the extended analysis phase was implemented and the participants once again received single skill probes. The probes given during the extended analysis were the same set of unique probes that were assigned to each BEA condition. During the extended analysis phase, the intervention that displayed the highest gains relative to baseline was compared to the intervention that displayed the lowest gains compared to baseline. In the event that the BEA did not produce differentiated effects, the conditions were repeated until there were obvious visible differences. For some participants, there were not obvious visible differences; therefore, the average of the scores was calculated to determine the most effective intervention. Once the superior intervention was determined in the extended analysis, the participant continued to receive intervention based on that intervention condition with their single skill probes. During the intervention phase, every third session included an AIMSweb grade-level probe (i.e., multi-skill probe) to assess for generalization.

Screening and Baseline

Once students were identified by their teacher for (a) demonstrating poor work performance and completion in mathematics and (b) not having a specific learning disability in mathematics, their parents were notified and written consent was requested from them. Once consent was received, participants were asked to complete three grade-level AIMSweb M-CBM probes to determine if the participants demonstrated math computation deficits in addition or subtraction. Probes were administered using standard AIMSweb procedures for M-CBM. Based on AIMSweb norms, participants whose median scores on the probes fall below the 25^{th} percentile qualified to participate in this study. Once a student met all inclusion criteria, they proceeded with baseline. Grade-level, single-skill probes were administered to assess participants' performance during baseline. As shown in Table 1, the type of computation problem administered varied across participants, but was constant across conditions. Baseline continued until participants' performance displayed a decreasing trend or until their performance remained low but stable.

Table 1

Participant Computation Problems

Participant	Target Skill	Number Group	Regrouping
Kyle	Addition	0-99	Yes
Patrick	Addition	0-20	No
Julie	Subtraction	0-99	Yes
Mark	Subtraction	0-99	Yes

Reward Condition. A unique set of either addition or subtraction facts was administered to each participant by the primary investigator. During this condition, participants were able to select a reward contingent on the student's math fluency exceeding a pre-determined goal. Rewards included a variety of low-cost items including edibles, small toys, pencils, erasers, and stickers. The goals were determined for each individual based on a 10% increase over the student's median baseline performance (Gilbertson, Witt, Duhon, & Dufrene, 2008). Before the participant was presented with the probe, he or she was able to see the rewards that were available from which to immediately choose if the goal was met. Participants were given the probe and told:

> Today you will be able to earn a prize if you exceed your goal for digits correct. At the end of the session, I will calculate your digits correct and tell you whether you can pick a prize out of the reward box. I want you to write your answers to several math problems. Look at each problem carefully before you answer it. When I say 'begin' write your answer to the first problem and work across the page. Then go to the next row. Try to work each problem. If you come to one you really don't know how to do, put an 'X' through it and go to the next one. If you finish the first side, turn it over and continue working. Are there any questions? Begin.

The participants were given two minutes to complete the probe. Immediately after two minutes elapsed, the examiner scored the probes and informed the participant whether or not he/she met the criterion needed to earn a reward. If the participant met the criterion, he or she was able to immediately choose a reward.

Cover-copy-compare. A unique set of either addition or subtraction facts were administered to each participant by the principal investigator. During this condition, the participant was given two math worksheets with 10 math problems and answers on the left side and of the worksheets, and the same problems, unanswered on the right side of the sheet. The participants were told to look at the first item and answer on the left side of the worksheet. After that they were told to cover the problem and answer with an index card. Then the participant wrote the answer from memory on the right side of the paper. After that the participant uncovered the answer on the left side of the worksheet to check his/her response. If the answer was written correctly, the participant moved on to the next problem on the sheet. If the answer was written incorrectly, the participant immediately received corrective feedback and repeated the procedure until he/she produced the correct response (Rathvon, 2008). Immediately after the CCC intervention, the participant was given a CBM probe that corresponded with the practiced facts.

Constant time delay. A unique set of either addition or subtraction facts was administered to each participant by the principal investigator. Twenty randomly selected addition or subtraction facts were presented to each participant on 4 x 6 index cards. The participant was shown an index card with a math problem without the answer. The participant was then asked to read the problem aloud and provide the answer if known. If the participant responded correctly the examiner praised the participant and presented the next card. If the participant responded incorrectly or took longer than three seconds, the examiner told the participant the answer and had him/her repeat the problem (McCallum et al., 2006). The examiner presented as many cards as possible within five minutes. After five minutes elapsed, the participant was presented with a CBM probe that contained the same facts that were practiced during the intervention.

Control. No instructional components or feedback were provided during the control condition. The participants were asked to complete an M-CBM probe under standard conditions. The M-CBM probe included a unique set of randomly selected problems as was done for the instructional conditions described above.

Extended Analysis

The extended analysis component was implemented to determine if the results of the BEA would remain constant over numerous intervention sessions. The extended analysis included the random, rapid alternation of the least effective and most effective interventions as identified by the BEA. During the extended analysis, the order of interventions were randomized; however, no intervention was implemented for more than three consecutive sessions.

Interscorer Agreement

Interscorer agreement was calculated for at least 30% of both AIMSweb and single skill probes for each participant for each phase of the study. The primary investigator and another graduate student were given the probes that were completed by the students and the corresponding answer sheets to compare answers and check for accuracy. Interscorer agreement was calculated based on the agreement and disagreement for the occurrence and nonoccurrence of a correct digit. The percentage of agreement was calculated by dividing the total number of agreements by the total number of agreements plus disagreements, and then multiplying by 100. Agreement had to be above 90% before a scorer was allowed to collect and score data for this study. Average interscorer agreement was 100% for Patrick, 100% for Mark, 98% for Kyle and 96% for Julie.

Treatment Integrity

The primary investigator conducted the BEA, extended analysis, and intervention sessions for each of the four participants. Another graduate student was also present for each BEA condition and 30% of the sessions conducted during the later phases to collect treatment integrity data. A treatment integrity checklist was completed for each experimental condition during each session. (see Appendixes F-I). Interscorer agreement was calculated for all of the BEA conditions, and at least 30% of the intervention sessions for each participant during the extended analysis and intervention phases. Interscorer agreement for treatment integrity was calculated based on the agreement and disagreement for intervention steps involved. If the principal investigator missed a step, the other scorer prompted her immediately to implement the step. Treatment integrity ranged from 92-100% across phases. Specifically, treatment integrity for reward, CTD, and CCC averaged 98%, while control averaged 100%. One factor that affected integrity was the order of instructions. The participants were given their probes and pencils before the instructions were completely read and the timer was started (as outlined on the integrity sheet). This presented a problem as the students often attempted to start the problems before the instructions were completely read to them.

Data Analysis

Visual analysis was used to evaluate data during the BEA, extended analysis, and intervention phases (determined through visual analyses of level, trend, and variability around level and trend). Criteria for determining the most effective intervention during the BEA and extended analysis was derived from Malloy, Gilbertson, and Maxfield's (2007) "Decision- Making Steps Used for Selecting Effective Treatments Based on Brief Experimental Analysis Results" (p. 298). Effectiveness decisions were based on (a) the most CD when compared to baseline on grade level probes or (b) more CD when compared to other conditions. It should be noted that these recommendations were based on a study using a reading BEA; however, the decision making process can still be applied to mathematics BEAs. Mean scores for CD were also calculated and compared across phases.

CHAPTER III

RESULTS

The results of the brief experimental analyses for all participants are displayed in Figures 1, 2, 3, and 4. All participants demonstrated improvements in math computation during at least one condition during brief experimental analyses and during extended analysis and intervention phases as well. Results are reported in terms of CD per two minutes across all phases. During the brief experimental and extended analyses, results are reported for CD per two minutes for single skill instructional probes. During the intervention phase, for all participants, results are reported for CD per two minutes for single skill instructional probes as well as grade-level multi-skill probes that were used to assess generalization.

Kyle

Screening and Baseline. During screening, three grade-level, multi-skill math probes were administered to Kyle. His mean CD score was 11, which placed him, according to national norms (NCS Pearson, Inc., 2010), at the 10th percentile and in the Below Average range. During baseline, three grade-level math-aids.com addition math probes were administered to Kyle. His mean CD score was 6.33, which placed him, according to national norms (NCS Pearson, Inc., 2010), into the Below Average category for math computation. Graphic representation of Kyle's data is presented in Figure 1.

Brief multielement phase. For Kyle, baseline was followed by CCC, control, CTD, and reward, respectively. In the CCC condition he computed math addition facts at a rate of 5 CD per two minutes. In the control condition, his performance decreased to 3 CD per two minutes. In the CTD condition, his performance increased to 8 CD per two minutes. In the reward condition, performance increased to 13 CD per two minutes, indicating a substantial change in level from the baseline condition. All math intervention conditions resulted in an increase in math computation compared to the mean baseline score. The brief multielement phase revealed that reward was the indicated intervention for Kyle, and CCC was the least effective intervention. Specifically, reward resulted in the greatest increase in correctly computed addition facts.

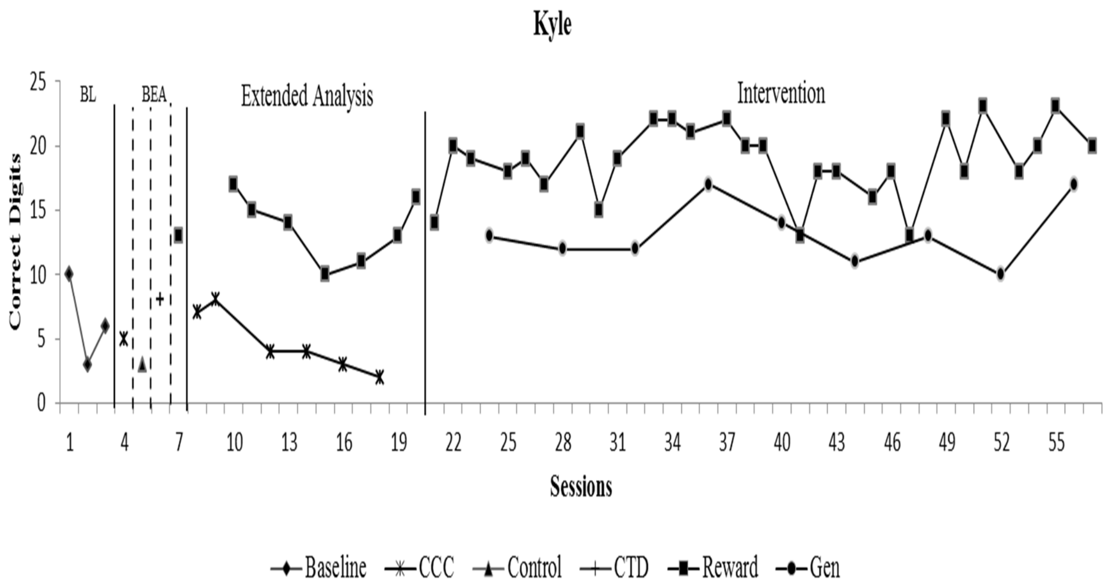

Figure 1. BEA, Extended Analysis, and Intervention for Kyle.

Extended analysis phase. The extended analysis included rapid alteration of the indicated and least effective interventions identified during the BEA. For Kyle, this included rapid alternations of CCC and reward. He received 13 intervention sessions. Seven of these sessions consisted of reward, and the remaining sessions consisted of CCC. The mean score for reward was 13.71 CD, whereas the mean score for CCC was 4.66 CD. Visual analysis of the data revealed that performance during reward was generally superior to performance for CCC. For CCC a downward trend was visible, but there was more variability for reward. Nonetheless, separation between the indicated and least effective interventions at the end of the extended analysis phase was displayed.

Intervention phase. Kyle received 28 reward sessions during the intervention phase. The mean score for the interventions phase was 18.89 CD with scores ranging from 14 to 23 CD. Visual analysis of the data did not reveal an immediate change in level after introduction of the intervention (compared to the extended analysis phase). Although there was variability throughout the intervention phase, a slight upward trend was visible for Kyle during the intervention phase, and all data points stayed substantially above the baseline data points. Kyle received 9 AIMSweb grade-level multi-skill CBM probes for generalization during the intervention phase. The mean score for the generalization probes was 13.22 which was slightly greater than his screening mean score (11). While there was some variability in performance for generalization probes, trend was largely flat.

Patrick

Screening and Baseline. During screening, three grade-level, multi-skill math probes were administered to Patrick. His mean CD score was 3, which placed him, according to national norms (NCS Pearson Inc., 2010), below the 10th percentile and in the Below Average range. During baseline, three grade-level, math-aids.com subtraction math probes were administered to Patrick. His mean CD score was 0.66, which placed him, according to national norms (NCS Pearson, Inc., 2010), into the Below Average category for math computation. Graphic representation of Patrick's data is presented in Figure 2.

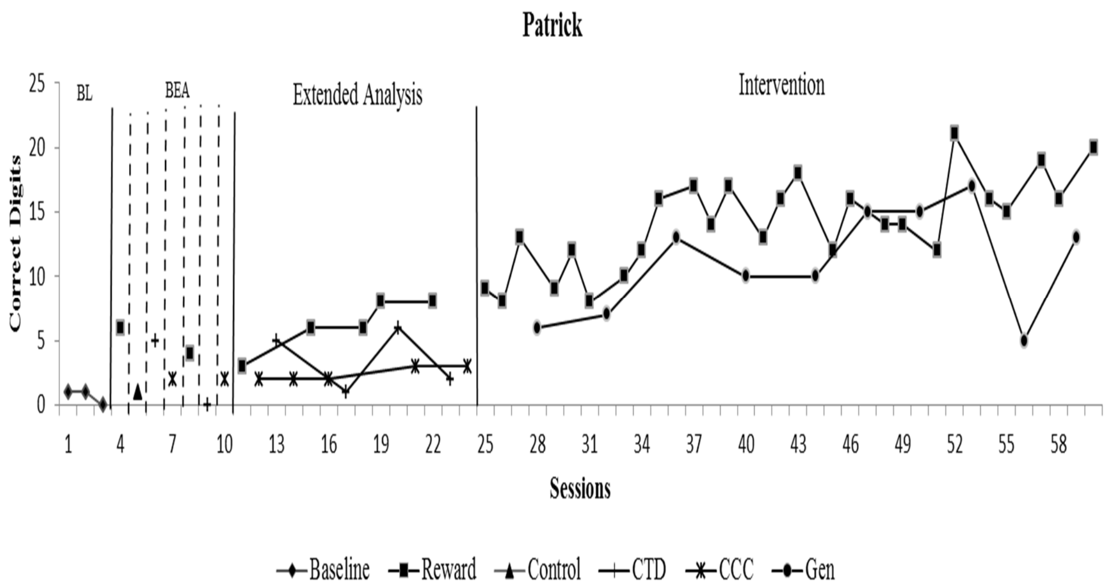

Figure 2. BEA, Extended Analysis, and Intervention for Patrick.

Brief multielement phase. For Patrick, baseline was followed by reward, control, CTD, and CCC, respectively. Because there was little differentiation between conditions, the conditions were repeated during the BEA in the same order. With the reward condition, he computed math subtraction facts at a rate of 6 CD per two minutes during the first administration and 4 CD per two minutes during the second administration, indicating a substantial change in level from the baseline condition. In the control condition, Patrick's performance decreased to 1 CD per two minutes. In the CTD condition, Patrick's performance increased to a rate of 5 CD per two minutes for the first administration, then decreased to 0 CD per minutes during the second administration. In the CCC condition, Patrick's performance remained stable at 2 CD per two minutes across both administrations. All math intervention conditions, resulted in an increase in math computation compared to the mean baseline score. The brief multielement phase revealed that reward was the indicated intervention for Patrick, and both CTD and CCC were the least effective intervention. Specifically, reward resulted in the greatest increase in correctly computed subtraction facts.

Extended analysis phase. The extended analysis included rapid alteration of the indicated and least effective interventions identified during the BEA. Because there was little differentiation in performance between CTD and CCC, both of these interventions were rapidly alternated with reward. Patrick received 14 intervention sessions. Five of these sessions consisted of reward, four sessions consisted of CTD, and five sessions consisted of CCC. The mean score for the reward condition was 6.2 CD. The mean score for CTD was 3 CD, and the mean score for CCC was 2.4 CD. Visual analysis of the data revealed that performance during reward was generally superior to performance for CTD and CCC. For CCC performance was stable and at a low level, but there was more variability for CTD. For reward, an increasing trend was visible as well as slight separation between the indicated intervention and the least effective interventions at the end of the extended analysis phase.

Intervention phase. Patrick received 26 reward sessions during the intervention phase. The mean score for the interventions phase was 14.11 CD with scores ranging from 8 to 21 CD. Visual analysis of the data revealed a change in level after introduction of the intervention (compared to the extended analysis phase). Although there was variability throughout the intervention phase, an upward trend was visible for Patrick during the intervention phase and all data points stayed substantially above the baseline data points. Patrick received 10 AIMSweb CBM probes for generalization during the intervention phase. The mean score for the generalization probes was 11.1. Although there was variability in performance on the generalization probes, the mean performance was substantially greater than the mean performance during screening (3). Additionally, performance for generalization probes generally trended upward throughout the intervention phase with noted decrease in performance during one session.

Julie

Screening and Baseline. During screening, three grade-level, multi-skill math probes were administered to Julie. Her mean CD score was 14.33, which place her, according to national norms (NCS Pearson Inc., 2010), between the 10th and 25th percentile and in the Below Average range. During baseline, three grade-level, math-aids.com subtraction math probes were administered to Julie. Her mean CD score was 12, which placed her, according to national norms (NCS Pearson, Inc., 2010), into the Below Average category for math computation. Graphic representation of Julie's data is presented in Figure 3.

Brief multielement phase. For Julie, baseline was followed by CTD, control, reward, and CCC, respectively. Because there was little differentiation between conditions, the conditions were repeated during the BEA in reverse order. With the CTD condition Julie computed math subtraction facts at a rate of 16 CD per two minutes for the first administration, then decreased to 5 CD per two minutes for the second administration. In the control condition, Julie's performance decreased to 9 CD per two minutes. In the reward condition, Julie computed math subtraction facts at a rate of 9 CD per two minutes for the first administration, then slightly decreased to 8 CD per two minutes for the second administration.

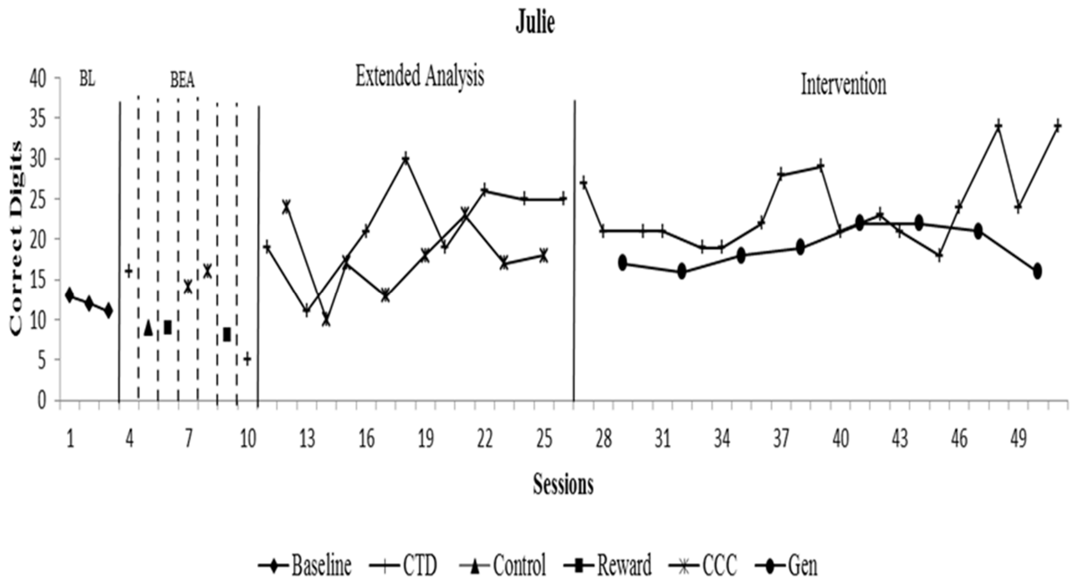

Figure 3. BEA, Extended Analysis, and Intervention for Julie.

In the CCC condition, Julie computed math facts at rate of 14 CD per two minutes, then slightly increased to 16 CD per two minutes during the second administration, indicating a change in level from the baseline condition. Only the CCC intervention condition resulted in a consistent increase in math computation compared to the mean baseline score. The second implementation of the brief multielement phase revealed that CCC was the indicated intervention for Julie, and CTD was the least effective intervention. Specifically, CCC resulted in the greatest increase in correctly computed subtraction facts during the second implementation of the brief multielement phase compared to baseline.

Extended analysis phase. The extended analysis included rapid alteration of the indicated and least effective interventions identified during the BEA. For Julie, this included rapid alternations of CCC and CTD. Julie received 16 intervention sessions. Eight of these sessions consisted of CCC, and the remaining eight sessions consisted of CTD. The mean score for the CCC condition was 17.5 CD, while the mean score for

CTD was 22 CD. Visual analysis of the data revealed that performance during CTD was generally superior to performance for CCC. For both CCC and CTD an increasing trend was visible, but there was great variability across both conditions. Separation between the indicated and least effective interventions at the end of the extended analysis phase was not clearly displayed; therefore, the intervention that had the greatest overall mean improvement was chosen for the intervention phase.

Intervention phase. Julie received 17 CTD sessions during the intervention phase. The mean score for the interventions phase was 23.88 CD with scores ranging from 18 to 34 CD. Visual analysis of the data revealed a negative change in level after introduction of the intervention (compared to the extended analysis phase). Although there was variability throughout the intervention phase, an upward trend was visible during the end of the intervention phase and all data points stayed substantially above baseline.

Julie received 8 AIMSweb CBM probes for generalization during the intervention phase. The mean score for the generalization probes was 18.87 which was greater than her screening mean score (14.33). Julie's performance on the generalization probes initially displayed a slight upward trend; however, performance slightly trended downward near the end of the phase.

Mark

Screening and Baseline. During screening, three grade-level multi-skill math probes were administered to Mark. His mean CD score was 9.66, which placed him, according to national norms (NCS Pearson Inc., 2010), at the 10th percentile and in the Below Average range. During baseline, he was administered three grade-level, math-aids.com subtraction math probes. His mean CD score was 4, which placed him, according to national norms (NCS Pearson, Inc., 2010), into the Below Average category for math computation. Graphic representation of Mark's data is presented in Figure 4.

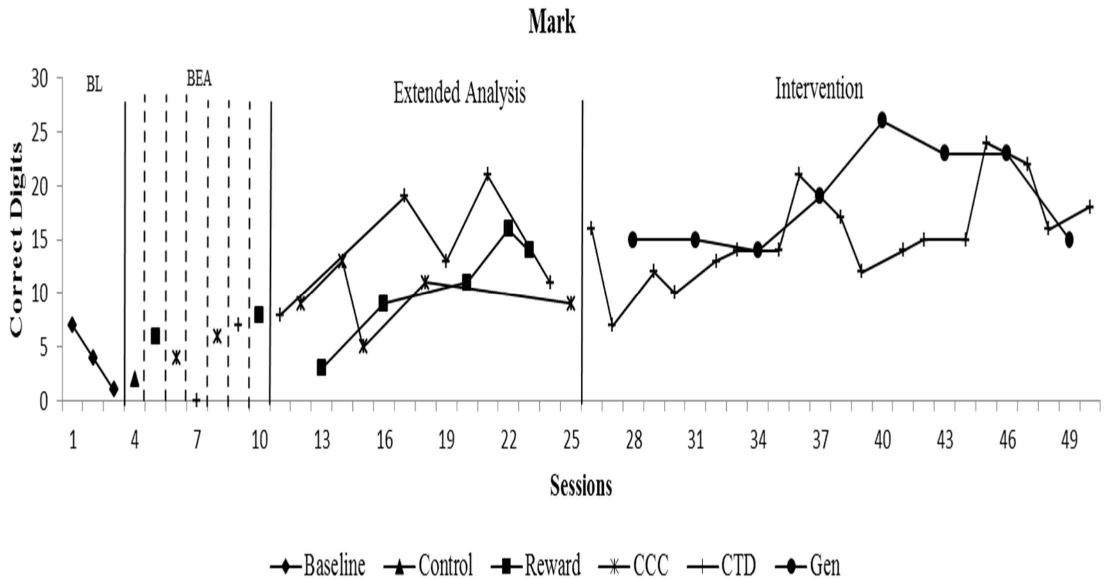

Figure 4. BEA, Extended Analysis, and Intervention for Mark.

Brief multielement phase. For Mark, baseline was followed by control, reward, CCC, and CTD, respectively. Because there was little differentiation between conditions, the conditions were repeated during the BEA. In the CTD condition Mark computed math subtraction facts at a rate of 0 CD per two minutes for the first administration, then increased to 7 CD per two minutes in the second administration. In the control condition, Mark computed math facts at a rate of 2 CD per two minutes. In the reward condition, Mark computed math subtraction facts at a rate of 6 CD per two minutes for the first administration, then slightly increased to 8 CD per two minutes for the second administration. In the CCC condition, Mark computed math facts at rate of 4 CD per two minutes, then slightly increased to 6 CD per two minutes during the second administration, indicating a change in level from the baseline condition. The brief multielement phase resulted in data that were largely undifferentiated. CTD was the most indicated intervention for Mark, and CCC was the least indicated as determined by their mean performance scores during the brief multielement phase.

Extended analysis phase. Because the BEA did not differentiate between the effectiveness of the intervention conditions, all interventions were rapidly alternated during the extended analysis. Mark received 15 intervention sessions. Five of these sessions consisted of reward, five sessions consisted of CCC, and 5 sessions consisted of CTD. The mean score for the reward condition was 10.6 CD, the mean score for CCC was 9.5 CD, and the mean score for CTD was 14.4 CD. Visual analysis of the data revealed that performance across conditions was not clearly differentiated; however, there was at least a modest difference between the CTD and reward conditions which were the two conditions with the greatest level of performance.

Intervention phase. Mark received 17 CTD sessions during the intervention phase. The mean score for the intervention phase was 15.29 CD with scores ranging from 7 to 24 CD. Visual analysis of the data did not reveal an immediate change in level after introduction of the intervention (compared to the extended analysis phase). Although there was great variability throughout the intervention phase, a slight upward trend was visible for Mark during the intervention phase and all data points stayed substantially above the baseline data points.

Mark received 8 AIMSweb CBM probes for generalization during the intervention phase. The mean score for the generalization probes was 18.75. Although there was variability in performance on the generalization probes, the mean performance was greater than the mean performance during screening (9.66).

CHAPTER IV

DISCUSSION

The current study tested the usefulness of brief experimental analyses of math computation interventions for identifying effective individualized interventions for elementary students referred for math computation interventions. To explore this, this study was driven by three separate research questions. The first sought to answer the question of whether students demonstrate differential responding across interventions during a BEA of math interventions. The second sought to answer the question of whether students will make immediate gains relative to baseline performance during a BEA of math interventions. The third question sought to answer the question of whether an intervention identified as most effective during the BEA will result in stable, valid, and reliable data during an extended analysis.

With regard to the first research question, results from this study indicated that clear differences between conditions during the BEA were evident for only one of the four participants. For Kyle, two of the three interventions resulted in an increase in math computation compared to the mean baseline score. The BEA revealed that reward resulted in the greatest increase in correctly computed addition facts. For the remaining participants, no clear distinction between interventions was visible during the initial BEA. Consequently, additional trials were conducted (i.e., replicating previous conditions).

For Patrick, Julie, and Mark, the BEA was replicated. Results from replicated BEAs found greater separation between conditions for Julie, but not for Patrick or Mark. So, whereas the initial BEA was not adequate for identifying interventions that were clearly more effective than the other conditions, one additional BEA was sufficient for identifying a condition that resulted in clearly greater performance for Julie. For Patrick and Mark, clear differences between conditions were not found during the BEA, therefore, all intervention conditions were compared to each other during the extended analysis. These results are similar to the Baraneck, Fineup, and Pace (2011) study which found that while BEAs are useful for finding interventions that produce above-baseline performance, it is unclear how effective BEAs are at differentially selecting effective interventions.

One potential explanation for the lack of clear differentiation between interventions during the initial BEA could be that math performance generalized across conditions because of multiple treatment interference. In addition to the strategies taught to them by the lead investigator, the students also incorporated strategies that that they were currently using in their classrooms. This may have resulted in the students solving problems in similar ways across conditions.

Another possible explanation for undifferentiated results during brief experimental analyses is that for the three participants with undifferentiated brief analyses, their initial performance was quite low. As a result, those students were likely to respond to a variety of interventions that simply included extra practice. Moreover, because their initial performance was so poor, their initial response to the range of interventions was likely going to be similar given that it would not be expected that those students would improve substantially after one or two exposures to an intervention.

With regard to the second research question, results from this study indicated that all participants did make immediate gains compared to baseline during the BEA of math interventions. These results are similar to previous BEA studies in which students quickly responded to one or two iterations of an intervention. These results are encouraging in that a BEA of instructional interventions may be able to quickly identify an intervention that holds some promise for positively affecting student performance (Codding et al., 2009; Duhon et al., 2004; Gilbertson et al., 2008). For Kyle and Patrick, all math intervention conditions resulted in an increase in math computation compared to the mean baseline score. For Julie, increases in subtraction computation were seen in CTD and CCC in the first implementation, and only in CCC in the second implementation. For Mark, increases in subtraction math computation were seen in CCC and reward in the first implementation of the BEA, and in all conditions during the second implementation.

With regard to the third research questions, results from this study indicate the interventions indicated as the most effective during the BEA were not always the most effective intervention during the extended analysis. For Kyle, reward was indicated as the most effective intervention during the BEA. Additionally, during extended analysis, reward continued to produce greater gains relative to the CCC condition. Moreover, Kyle's performance continued to improve during the intervention phase. For Patrick, reward was also indicated as the most effective intervention during the BEA and continued to demonstrate superior differential effectiveness during extended analysis. For Julie, CCC was indicated as the most effective intervention, but it produced unstable and unreliable data during the extended analysis. Further, the extended analysis indicated that CTD (which was indicated as the least effective intervention during the BEA) was actually the superior intervention for subtraction math computation. With regard to Mark, this question could not be answered because there was no differentiation in performance across interventions for his BEA; therefore, there was not an indicated most effective or least effective intervention during the extended analysis. These results are similar to the previous findings of Baraneck et. al (2011) in that, although there was not differentiation between interventions, the interventions produced performance gains relative to baseline and control. With regard to Mark's specific performance, he began each problem with a time-consuming regrouping procedure, without first analyzing the problem to determine if regrouping was necessary to solve it. For him, it may have been beneficial to add a component to the probe which required him to check if regrouping was necessary before computing the problem.

Limitations and Future Research

This study includes some limitations worthy of discussion. First, generalization of the effectiveness of the BEA on classroom performance was not assessed. Data were collected only on the effectiveness of the selected interventions on the specific skill sets, and generalization worksheets. Anecdotally, both Kyle and Patrick's teachers reported that they continued to perform poorly on math tests despite their improved performance during the intervention sessions. Although the type of problems on their classroom math tests and intervention probes were similar (typical skills that a student should be acquiring at that grade level), both students continued to perform below expectation outside of the intervention setting. Future research may identify expectations regarding the length of intervention implementation necessary for observing generalized gains such as improved performance on weekly classroom tests.

Second, there are some concerns regarding the external validity of these findings. In particular, it is unknown if these procedures are feasible in typical schools where access to expert consultation is not available. Assessment and intervention procedures in this study were conducted by graduate students outside of the student's classroom. As a result, it is unknown if these assessment, data-based decisions, and intervention procedures would be implemented with accuracy and integrity in schools that do not have access to expert consultation. Further, it should be noted that with a reward condition, the student is receiving immediate tangible rewards that influence how they perform on different tasks. For both Kyle and Patrick, reward was identified as the most effective intervention; and although they were able to receive immediate tangibles for intervention performance, this was not occurring in their classrooms. Providing tangibles to a few students a few times a week is feasible to a graduate student with a research budget, but not necessarily to a teacher which limited economic resources to reward an entire class. Future research could explore the way teachers and school personnel can implement BEAs within the confines of existing school-based resources.

Third, this study, as well as Reisener (2009), included elementary students receiving computation interventions for basic math computation facts. It is unknown if BEA of math interventions would be appropriate for much more complex math skills (e.g., solving algebraic equations). It may be that much more complex math skills require many intervention sessions before noticeable improvement can be observed. Therefore, the full external validity of BEA of math interventions is unknown.

Conclusion

Despite the limitations discussed above, this study is important in that it provides an additional empirical test of the usefulness of BEA of math computation interventions. The BEA literature is incredibly limited with regard to application to math computation interventions additional research is needed to determine the usefulness of BEA of math computation interventions. In terms of applied practice, while there is still limited empirical evidence for the usefulness of BEA of math computation interventions, practitioners may still consider using brief tests of intervention effectiveness prior to long-term implementation. Results from this study and previous research (Codding, Baglici et al., 2009; Daly et al., 2002; Duhon et al., 2004; Wilber & Cushman, 2006) indicate that BEAs are at least sensitive to immediate small gains in student performance and have the ability to identify an intervention that holds some promise for more long term implementation. Additionally, imbedded within all of this study's procedures was routine progress monitoring of students' response to intervention. As a result, even if a BEA-identified intervention is not substantially effective over an extended period of time, progress monitoring data will be available to assist school-based professionals in making data-based decisions regarding students' intervention services. Taking these things into consideration, it is important for educators to realize that BEAs are just one step in a data-based process that should be evaluated over time and modified as needed to suit the individual needs of the target student.

APPENDIX A

CONSENT FORM

Title of Study: Using Brief Experimental Analyses to Identify Effective Math Interventions for Early Elementary Students

Purpose of the Study: Your permission is requested for your child to participate in a study that is investigating the effectiveness of various math interventions.

Who Can Participate: First and second grade students who are identified by their teacher as a student who may benefit from interventions in the area of mathematics.

Procedures: Upon your permission, your child will be screened to determine if he/she qualifies for the study pending on his/her scores on curriculum based measures and a portion of a standardized test. If your child qualifies for the study, your child will receive a mathematics intervention. The intervention will be targeted to increase your child's addition and subtraction fluency. Granted permission, your child will participate intervention sessions in three to four times per week for approximately 20 minutes. Children participating in this study will not be removed from their class during core instruction time. During the first part of the intervention, your child will be presented with various well-established math interventions for increasing mathematics performance to determine which interventions are most effective for him/her. During the second part of the study, your child will receive further mathematic practice with the interventions that are identified as most effective for him/her.

Benefits: Your child may benefit by participating in this study because the intervention may improve your child's mathematics fluency.

Risks and Discomfort: There are few anticipated risks associated with participation. The student may feel uncomfortable/ embarrassed for being singled-out and taken out of class. In this event, you have the right to remove your child from participating at any time without penalty.

Confidentiality of Records: All information obtained during this study will be kept confidential, meaning that your child's name and any other identifying information will be withheld from all persons not connected with the study. Students will be given code numbers so that names will not be used on any data recording sheets or forms. At no time will paperwork contain your child's name. Please note that these records will be held by a state entity are therefore are subject to disclosure if required by law.

Participant's Assurance: Whereas no assurance can be made concerning results that may be obtained (since results from investigational studies cannot be predicted) the researcher will take every precaution consistent with the best scientific practice. Participation in this project is completely voluntary, and participants may withdraw from this study at any time without penalty, prejudice, or loss of benefits. Questions concerning the research should be directed to Chelsi Clark at (601)266-5255 or brad Dufrene at (601)266-5255. This project and consent notice have been reviewed by the Institutional Review Board, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research participant should be directed to the Chair of the Institutional Review Board, The University of Southern Mississippi, 118 College Drive #5147, Hattiesburg, MS 39406-0001, (601) 266-6820.

Sincerely,

Chelsi Clark, M.A.
School Psychologist-in-Training
Department of Psychology
Center
The University of Southern Mississippi

Brad A. Dufrene, Ph.D.
Supervisor
Director, School Psychology Service
Department of Psychology
The University of Southern
Mississippi

If you choose to allow your child to participate in the study, please read and sign the following:

I have had the purpose and procedures of this study explained to me and have had the opportunity to ask questions. I am voluntarily signing this form for my child to participate under the conditions stated. I have also received a copy of this consent for my own records.

____

Your Child's Name

____________________________________ ____________________

Signature of Parent Date

____________________________________ ____________________

Signature of Investigator Date

APPENDIX B

PROTOCOL FOR CONTINGENT REWARD

Materials: Timer, rewards box, math worksheet, pencil

Steps:

1. Place the math worksheet and the pencil in front of the student.
2. Tell the student: **"Today you will be able to earn a prize if you exceed your goal of _____correct digits. At the end of the session, I will calculate your digits correct and tell you whether you can pick a prize out of rewards box. I want you to write your answers to several math problems. Look at each problem carefully before you answer it. When I say 'begin' write your answer to the first problem and work across the page. Then go to the next row. Try to work each problem. If you come to one you really don't know how to do, put an 'X' through it and go to the next one. If you finish the first side, turn it over and continue working. Are there any questions?"**
3. Say **"Begin"** and start timing. When 2 min. has elapsed, ask student to stop and mark sheet where they stopped.
4. Immediately score the math worksheet. Count the number of correct digits in two minutes.
5. At the end of the session, tell the student: **"Today you have received digits correct. Therefore, you may [or may not] choose a prize from the rewards box."**
6. Record correct digits on the data collection sheet.

APPENDIX C

PROTOCOL FOR COVER-COPY-COMPARE

Materials: Training sheets of 10 math problems, with problems listed down the left side and the answer provided for each problem, one per student, one to three sets per session. You will also need assessment sheets with the same math problems listed down the left side but with blanks next to each problem for written responses.

Steps:

1. Tell the student he/she will be learning a new method of improving their mathematics performance called Cover, Copy, and Compare.

2. Give training sheets to the students.

3. Conduct a training session in which you teach students to follow the Cover, Copy, and Compare procedure:

   a. Silently read the first problem and the answer on the left side of the paper.

   b. Cover the problem and answer with an index card.

   c. Write the problem and answer from memory on the left side to check the written response,

   d. Uncover the problem and answer on the left side to check the written response.

   e. Evaluate the response.

   f. If the problem and answer are written incorrectly, repeat the procedure with that item before proceeding to the next item.

   g. Repeat this procedure with the rest of the problems on the sheet.

4. After demonstrating the steps, have the student complete one or more training

sheets and provide corrective feedback as needed.

5. For each session provide the student with sets of training sheets (one to three sets) and have them follow this procedure. After the training sheets are completed, administer the assessment sheets that correspond to the training sheets.
6. Allow the student to work on the assessment sheet for 2 minutes. Use a timer to keep time.
7. Tell the student to **"BEGIN,"** and start the timer. At the end of two minutes, say **"STOP,"** and mark the last item that the student completed. Count the number of correct DIGITS completed in two minutes.
8. Record the correct digits on the data collection sheet.

APPENDIX D

PROTOCOL FOR CONSTANT TIME DELAY

Materials: Flash cards, timer/stopwatch, math worksheet(s), pencil, progress monitoring sheet

Steps:

1. Start timer for 5 mins.
2. Practice with the flash cards by presenting a card to the student. Say, **"What is this answer?"** Allow the student three seconds to respond.
3. If the student says the correct answer within 3 seconds, praise the student and repeat procedures with the next card.
4. If the student says the incorrect answer or does not answer within 3 seconds, provide the student with the correct answer, have them repeat you, then present the card again.
5. Move through as many cards as possible in 5 minutes.
6. After time has elapsed, administer the timed math worksheet on material specific to the intervention. Tell the student to write his or her name and the date on the top of the sheet. Then say, "T**he sheet on your desk is math problems. Start here (1st problem) and proceed across the line and then go to the next line without skipping. If you come to a problem that you cannot answer, put an X through it and go to the next problem. Try your hardest."**
7. Say begin and start the timer for 2 mins.
8. Tell student to stop when timer sounds.
9. Record correct digits on the data collection sheet

APPENDIX E

PROTOCOL FOR BASELINE, CONTROL, AND GENERALIZATION

Materials: Timer, math worksheet, pencil

Steps: Selects an appropriate math probe

1. Place the math worksheet and pencil in front of the student.
2. Say:

   "**We're going to take 2 - minute math test. I want you to write your answers to several kinds of math problems. Some are addition and some are subtraction. Look at each problem carefully before you answer it. When I say 'begin' write your answer to the first problem and work across the page. Then go to the next row. Try to work each problem. If you come to one you really don't know how to do, put an 'X' through it and go to the next one. If you finish the first side, turn it over and continue working. Are there any questions? Begin.**"

3. Say begin and start the timer for 2 mins.
4. Tell student to stop when timer sounds.
5. Record correct digits on the data collection sheet.

APPENDIX F

PROCEDURAL INTEGRITY CHECKLIST FOR CONTINGENT REWARD

Materials Checklist:

€ Student Data Collection Form

€ Student Math Worksheet

€ Rewards Box

€ Stopwatch or Digital Timer

€ Pen or Pencil

Steps:

€ Shows the student the prizes that can be earned from the prize box

€ Places the math worksheet and the pencil in front of the student.

€ Says: **"Today you will be able to earn a prize if you exceed your goal of _____correct digits. At the end of the session, I will calculate your digits correct and tell you whether you can pick a prize out of rewards box. I want you to write your answers to several math problems. Look at each problem carefully before you answer it. When I say 'begin' write your answer to the first problem and work across the page. Then go to the next row. Try to work each problem. If you come to one you really don't know how to do, put an 'X' through it and go to the next one. If you finish the first side, turn it over and continue working. Are there any questions?"**

€ Says **"Begin"** and starts timing.

€ Stops the timer after 2 minutes and asks the student to stop

€ Immediately scores the math worksheet.

€ Says, **"Today you have received digits correct. Therefore, you may [or may not] choose a prize from the rewards box."**

€ Allows the student to choose a prize if pre-set criterion was met

€ Records correct digits on the data collection sheet.

APPENDIX G

PROCEDURAL INTEGRITY CHECKLIST FOR COVER- COPY- COMPARE

Materials Checklist:

- € Student Data Collection Form
- € Student Math Worksheet
- € Student Training Sheet
- € Stopwatch or Digital Timer
- € Pen or Pencil

Steps:

- € Tells the student he/she will be learning a new method of improving their mathematics performance called Cover, Copy, and Compare.
- € Gives training sheets to the student.
- € Conducts a training session in which you teach students to follow the Cover, Copy, and Compare procedure:
    - o Silently read the first problem and the answer on the left side of the paper.
    - o Cover the problem and answer with an index card.
    - o Write the problem and answer from memory on the left side to check the written response.
    - o Uncover the problem and answer on the left side to check the written response.
    - o Evaluate the response.
    - o If the problem and answer are written incorrectly, repeat the procedure with that item before proceeding to the next item.

  - Repeat this procedure with the rest of the problems on the sheet.

- After demonstrating the steps, have the student complete one or more training sheets and provides corrective feedback as needed.
- Allows the student to work on the assessment sheet for 2 minutes.
- Uses a timer to keep time.
- Tells the student to **"BEGIN,"** and starts the timer.
- At the end of two minutes, says **"STOP,"** and marks the last item that the student completed. Counts the number of correct DIGITS completed in two minutes.
- Records the correct digits on the data collection sheet.

APPENDIX H

PROCEDURAL INTEGRITY CHECKLIST FOR CONSTANT TIME DELAY

Materials Checklist:

€ Student Data Collection Form

€ Student Math Worksheet

€ Flash Cards

€ Stopwatch or Digital Timer

€ Pen or Pencil

Steps:

€ Starts timer for 5 mins.

€ Practices with the flash cards by presenting a card to the student.

€ Says, **"What is this answer?"**

€ Allows the student three seconds to respond.

€ If the student says the correct answer within 3 seconds, praises the student and repeats procedures with the next card.

€ If the student says the incorrect answer or does not answer within 3 seconds, provides the student with the correct answer, have them repeat you, then present the card again.

€ Moves through as many cards as possible in 5 minutes.

€ After five minutes, administers the timed math worksheet on material specific to the intervention.

€ Tells the student to write his or her name and the date on the top of the sheet. Then says, "T**he sheet on your desk is math problems. Start here (1st problem)**

and proceed across the line and then go to the next line without skipping. If you come to a problem that you cannot answer, put an X through it and go to the next problem. Try your hardest."

€ Says **"BEGIN,"** and starts the timer.

€ Stops the time after two minutes and says **"STOP."**

€ Records correct digits on the data collection sheet.

APPENDIX I

PROCEDURAL INTEGRITY CHECKLIST FOR ACCURACY OF MATHEMATICS COMPUTATION CURRICULUM-BASED MEASUREMENT (M-CBM) DURING BASELINE, CONTROL, AND GENERALIZATION CONDITION

Testing Procedure

- € Selects an appropriate math probe.
- € Provides student with a pencil and math probe.
- € Says appropriate standardized directions accurately.
    - o Says "**We're going to take 2 - minute math test. I want you to write your answers to several kinds of math problems. Some are addition and some are subtraction. Look at each problem carefully before you answer it. When I say 'begin' write your answer to the first problem and work across the page. Then go to the next row. Try to work each problem. If you come to one you really don't know how to do, put an 'X' through it and go to the next one. If you finish the first side, turn it over and continue working. Are there any questions? Begin.**"
- € Starts stopwatch after directions.
- € Corrects Skipping or Overuse of X-ing.
- € Encourages student who stop to keep working.
- € Times accurately (2 minutes).
- € Says "Stop; Put your pencil down."
- € Stops stopwatch.
- € Scores probe immediately after administration.

APPENDIX J

IRB APPROVAL FORM

THE UNIVERSITY OF
SOUTHERN MISSISSIPPI

INSTITUTIONAL REVIEW BOARD
118 College Drive #5147 | Hattiesburg, MS 39406-0001
Phone: 601.266.6820 | Fax: 601.266.4377 | www.usm.edu/irb

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months.
  Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: **12011803**
PROJECT TITLE: **Using Brief Experimental Analyses to Identify Effective Mathematics Interventions for Early Elementary Students**
PROJECT TYPE: **Dissertation**
RESEARCHER/S: **Chelsi Clark**
COLLEGE/DIVISION: **College of Education & Psychology**
DEPARTMENT: **Psychology**
FUNDING AGENCY: **N/A**
IRB COMMITTEE ACTION: **Expedited Review Approval**
PERIOD OF PROJECT APPROVAL: **02/29/2012 to 02/28/2013**

Lawrence A. Hosman, Ph.D.
Institutional Review Board Chair

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