EXPLICIT TIMING AND INTERSPERSAL INTERVENTIONS FOR MULTIPLICATION FLUENCY OF UPPER ELEMENTARY SCHOOL STUDENTS

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This work is dedicated to my family and to my friends,
who have been extremely supportive
throughout graduate school and life, in general.
They have helped me become who I am today.

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ABSTRACT

EXPLICIT TIMING AND INTERSPERSAL INTERVENTIONS FOR MULTIPLICATION FLUENCY OF UPPER ELEMENTARY SCHOOL STUDENTS

by Alyssa R. Warshay

Researchers have demonstrated the effectiveness of timing and interspersal interventions for improving mathematics computation fluency, but few studies have occurred for more than four sessions or 1 week (Calderhead, Filter, & Albin, 2006; Codding et al., 2007; McCurdy, Skinner, Grantham, Watson, & Hindman, 2001; Skinner, Hurst, Teeple, & Meadows, 2002; Van Houten & Thompson, 1976). Additionally, researchers have suggested that explicit timing is most effective when items are easy and least effective when items are difficult (Codding et al., 2007; Rhymer, Skinner, Henington, D'Reaux, & Sims, 1998; Rhymer, Henington, Skinner, & Looby, 1999; Rhymer et al., 2002). Therefore, the current study examined the relationship between students' initial level of fluency and the effectiveness of interspersal and explicit timing among 23 students going into fourth, fifth, and sixth grade. The interventions took place for 2 weeks at two summer programs with 1.5-2.5 hours of academic activities 4 days per week. The study included eight intervention worksheets and a pre-intervention and post-intervention assessment targeting 2-digit by 2-digit multiplication facts.

The pre-intervention assessment and post-intervention assessments were weak measures of intervention effectiveness. However, the treatment session data indicated significant effects for both interventions. The interspersal intervention group gained a mean of 10.67 DCM (d = .54), and the explicit timing group gained a mean of 23.8 DCM (d = 2.46). Due to the small sample size, visual analysis was used to examine the effectiveness of each intervention for each level of fluency. Similar to previous findings, explicit timing was more effective for students at

instructional and mastery fluency levels, and interspersal was more successful for students at the frustrational fluency level.

The purpose of empirically validating academic interventions is to provide teachers with options to assist students. Few explicit timing and interspersal studies have examined the effects across repeated exposure to these interventions. This study demonstrated that explicit timing and interspersal are quick and simple interventions that teachers can incorporate in the curriculum in order to significantly impact their students' levels of fluency. Additionally, this study provided support for a growing body of literature investigating the initial fluency level by intervention interaction.

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CHAPTER I

INTRODUCTION

Functional skills in mathematics are helpful in our daily lives, but a solid foundation in mathematics goes beyond the ability to calculate change from a purchase, tip at a restaurant, or the mileage of one's car. Success in mathematics education through a minimum of high school Algebra II correlates with important life outcomes including the attainment of a bachelor's degree and earning an income in the top quartile of our nation (National Mathematics Advisory Panel [NMAP], 2008). The National Assessment of Educational Progress (NAEP) of 2009 indicated in the "Nation's Report Card" that the number of U.S. students in the fourth and eighth grades who had reached "proficient" levels in mathematics achievement more than doubled since 1990; yet, the proportion of proficient U.S. students was only 39% for fourth graders and 34% for eighth graders in 2009 (U.S. Department of Education, 2010). These results indicate that U.S. students in the primary grades do not achieve adequate levels of proficiency in math, and they do not catch up by middle school, the period in which they move beyond more basic skills in preparation for high school algebra courses. Therefore, it is necessary to provide teachers with practical interventions that can be utilized classroom-wide in elementary schools and that target the acquisition and mastery of basic math skills, such as arithmetic.

Haring, Lovitt, Eaton, and Hansen (1978) defined four progressive stages of learning in their Instructional Hierarchy, which includes acquisition, fluency, generalization, and adaptation. The acquisition phase begins when one first learns a skill and ends when one demonstrates the skill with accuracy (i.e., makes few mistakes). The second stage of the Instructional Hierarchy is the fluency stage. Students in the fluency stage perform the skill with ease while maintaining high accuracy levels (Haring et al., 1978). Learning basic facts in mathematics initially requires

use of tedious strategies such as counting on one's fingers or use of concrete manipulatives, but one who has become fluent can recall facts immediately and automatically, allowing for the allocation of more cognitive resources to higher-level reasoning and problem-solving (e.g., word problems, long division, and algebraic expressions) (Kulak, 1993).

Development of fluency facilitates generalization, which involves applying an acquired skill to a novel situation that is similar to the instructional situation, such as using knowledge of math facts to solve a single-step story problem (Haring et al., 1978). Adaptation involves using acquired skills in novel real-life situations, such as using mathematical problem-solving skills to determine the best unit price of an item in a store. Although adaptation and generalization are useful for applying mathematics to real-world situations, fluency is an important prerequisite skill. Once students have surpassed the acquisition phase of basic math calculation skills, teachers need access to interventions that provide sufficient learning trials to build fluency.

Before selecting an intervention appropriate for a student's level, it is necessary to first determine at which level the student currently performs. Shapiro (2004) defined levels of fluency of mathematics computation in order to assist teachers and other educators with this task. The lowest skill level is "frustrational," which is defined as obtaining 19 or less digits correct per minute (DCM) and 8 or more digits incorrect per minute (DIM). Students reach the "instructional" level when they are able to complete 20-39 DCM with no more than 7 DIM. Students who have become fluent or reached Shapiro's (2004) "mastery" fluency level in a mathematics operation score 40 or more DCM and no more than 2 DIM on a worksheet of that

problem type. In order to reach the next fluency level by increasing DCM and reducing DIM, students need repeated practice with a given problem type.

According to the NMAP (2008), most mathematics curricula in the United States do not include enough opportunities for students to practice basic computation "to the point of fast and efficient solving of single-digit addition, subtraction, multiplication, and division with whole numbers, much less fluent execution of more complex algorithms as early as children in many other countries," (p. 26) resulting in the outcome that many students never reach such proficiency. With the majority of U.S. students failing to become proficient in math by the fourth grade, elementary school teachers need access to evidenced-based fluency-building interventions, such as explicit timing and interspersal. This is especially important considering the first goal of the Elementary and Secondary Education Act (ESEA, formerly No Child Left Behind) is for all children to reach grade-level proficiency in reading and math by 2014 (U.S. Department of Education, 2008.)

Explicit Timing Intervention

Research has demonstrated that providing students with brief time limits to complete independent assignments often increases students' rates of responding (e.g., Codding et al., 2007; Miller, Hall, & Heward, 1995; Rhymer, Henington, Skinner, & Looby, 1999; Rhymer & Morgan, 2005; Rhymer, Skinner, Henington, D'Reaux, & Sims, 1998; Rhymer et al., 2002; Van Houten & Thompson, 1976). In these studies, when students were explicitly instructed to work for one or more brief (e.g., 1-minute) intervals, students correctly completed more math problems compared to control conditions in which students were unaware of being timed. When these explicit timing interventions were completed, students were informed of their time limits to work and instructed to work as quickly as possible without making mistakes. Although the

accuracy of students' responses has sometimes diminished when they have more rapidly paced themselves (Rhymer et al., 1998), most researchers have not found statistically significant reductions in accuracy compared to control conditions (Codding et al., 2007; Evans-Hampton, Skinner, Henington, Sims, & McDaniel, 2002; Miller et al., 1995; Rhymer et al., 1999; Van Houten & Thompson, 1976). Thus, interventions that utilize explicit timing may be useful for building fluency, because they increase response rates without sacrificing accuracy. Additionally, explicit timing interventions require less than 10 minutes of class time to pass out worksheets, time students, and collect worksheets. Guidelines on timing depend on grade level and problem type, with older grades typically being timed for longer periods of time. Guidelines and a problem worksheet generator are available online and free of cost by Intervention Central (http://interventioncentral.org).

Explicit timing has been empirically validated with participants of varying demographics. The effectiveness of explicit timing has been demonstrated with elementary school students in general education (e.g., Codding et al., 2007; Miller et al., 1995; Rhymer et al., 1999; Rhymer & Morgan, 2005; Rhymer et al., 1998) and in special education (e.g., Miller et al., 1995) and with "poor school performance" (e.g., Van Houten & Thompson, 1976, p. 227). Explicit timing has also resulted in success for students of varying ethnicities, including Hispanic students (e.g., Codding et al., 2007), African-American students (e.g., Rhymer et al., 1999), and White students (e.g., Codding et al., 2007; Rhymer & Morgan, 2005; Rhymer et al., 1999). Therefore, explicit timing for mathematics computation has been extensively supported by research.

Some researchers have suggested explicit timing may only be effective when students have first demonstrated a minimum level of skill acquisition (Rhymer et al., 1998). Rhymer and colleagues (2002) found that the explicit timing method was most effective for increasing math

problem completion rates of problems that were relatively easy (i.e., mastery level of fluency). Three sixth grade classrooms completed worksheets with easy (first grade addition), medium (third grade subtraction), or difficult (sixth grade multiplication) problems. Although students completed more problems on the worksheets during the explicit timing condition as compared to the no-timing condition, the greatest gains occurred for the worksheets with easy problems and the least gains occurred for the worksheets with difficult problems (Rhymer et al., 2002).

Codding and colleagues (2007) also observed an interaction between fluency level and explicit timing. Second and third grade students completed subtraction problems during explicit timing, cover-copy-compare (CCC), or control conditions. CCC involves five steps: looking at a math problem, covering the problem, rewriting the problem from memory, uncovering the problem, and comparing the copied problem to the original. For 6 weeks, all participants completed two curriculum based assessment (CBA) probes per week to monitor progress. Following the CBA probes, participants in the CCC and explicit timing group received their respective interventions for 5 minutes, while the control group returned to their normal classrooms. On average, each participant attended 10 intervention sessions. Overall results indicated no significant difference between the three conditions for digits correct per minute (DCM). However, an interesting pattern emerged when initial fluency level was examined. Students initially at instructional fluency gained 7 DCM in the explicit timing condition compared to 4.6 DCM in the CCC and control condition. However, students initially at frustrational fluency gained more DCM in the CCC and control condition compared to the explicit timing condition. Therefore, an interaction between initial fluency level and most appropriate intervention appears to exist. For example, the explicit timing intervention appears to be most appropriate for students who have already acquired the skill and need to increase their

fluency (i.e., initially at the instruction level or mastery level) (Codding et al., 2007; Rhymer et al., 2002). These findings are important in the field of mathematics intervention research, because teachers need to know which interventions to use based on their students' initial fluency levels. Given that only two studies have examined the relationship between explicit timing and initial fluency level, further research is needed.

Furthermore, it is necessary to determine the utility of the explicit timing intervention within a classroom over an extended period of time such as an entire semester or school year. Only two studies have examined the effects of explicit timing on mathematics computation for more than 1 week and four sessions (Codding et al., 2007; Van Houten & Thompson, 1976). However, Van Houten and Thompson (1976) combined explicit timing with corrective feedback; therefore, the effects of explicit timing alone could not be analyzed. Although teachers tend to combine instruction, feedback, reinforcement, and correction procedures, researchers must examine the effectiveness of each component of the intervention. Given that the effects of explicit timing could be based on a novelty effect, future explicit timing studies should measure the effects of this intervention over a more prolonged time period (Rhymer et al., 2002).

Interspersal Intervention

Interspersal refers to alternating easy, brief tasks with more difficult tasks in order to increase response momentum (e.g., 1-digit plus 1-digit problem followed by three 2-digits times 2-digits problems). The addition and placement of easy tasks in between more difficult tasks may increase the rate of reinforcement inherent in academic assignments, thus increasing the response rate, enhancing the attention to task, and facilitating more work completion than control worksheets (Skinner, Wallace, & Neddenriep, 2002). Because math computation worksheets are often assigned for completion during independent seatwork, any method teachers have available

to improve attending to these worksheets may be especially helpful. Given that classrooms have numerous distractions that may interfere with worksheet completion, assignments with greater rates of reinforcement may facilitate sustained academic engagement during independent seatwork (Skinner, Robinson, Johns, Logan, & Belfiore, 1996). Moreover, interspersal worksheets may be created free of cost using the Math Worksheet Generator provided by Intervention Central (http://www.interventioncentral.org) and do not require additional instructional time, because the interspersed problems are brief enough that students complete the same number of target problems on interspersed worksheets as on control assignments (Billington, Skinner, & Cruchon, 2004; Billington, Skinner, Hutchins, & Malone, 2004; Cates & Dalenberg, 2005; Cates & Skinner, 2000; Cates et al., 1999; Clark & Rhymer, 2003; Logan & Skinner, 1998; Johns, Skinner, & Nail, 2000; Rhymer & Morgan, 2005; Skinner, Fletcher, Wildmon, & Belfiore, 1996; Skinner, Robinson, et al.,1996; Skinner et al., 1999; Wildmon, Skinner, Watson, & Garrett, 2004).

Skinner (2002) proposed that interspersal is effective because the completion of each discrete task within an assignment (e.g., completion of a 2-digit plus 2-digit problem) is a conditioned reinforcer within the overall assignment (e.g., math assignment with 25 problems). This is referred to as the discrete task completion hypothesis. Students have learned that the completion of each discrete task (e.g., math problem) brings them closer to finishing the entire assignment, which has been paired with teacher praise, parent approval, and/or time to work on another task (Skinner, 2002). The discrete task completion hypothesis is based on Herrnstein's (1961) matching law, which states that when an organism is presented with two incompatible behaviors, the organism will engage in the behavior that provides the greater rate of reinforcement. If students prefer academic assignments with more problems that are brief or

easy, because these assignments have greater rates of reinforcement compared to control assignments, then students will be more likely to engage in on-task behavior when assigned interspersal worksheets compared to control conditions (Skinner, 2002). Several studies measured behavior directly during interspersal assignments and demonstrated that interspersal worksheets resulted in more on-task behavior during assigned math computation worksheets (Calderhead, Filter, & Albin, 2006; McCurdy, Skinner, Grantham, Watson, & Hindman, 2001; Skinner, Hurst, Teeple, & Meadows, 2002). Other studies have compared the rate of problem completion (i.e., reinforcement rate) on control and interspersal worksheets, indicating that students preferred interspersal assignments over traditional assignments despite the greater number of total problems on interspersal worksheets (Billington, Skinner, et al., 2004; Billington, Skinner, Hutchins, et al., 2004; Cates & Dalenberg, 2005; Cates & Skinner, 2000; Cates et al., 1999; Clark & Rhymer, 2003; Logan & Skinner, 1998; Johns et al., 2000; Rhymer & Morgan, 2005; Skinner, Fletcher, et al., 1996; Skinner, Robinson, et al.,1996; Skinner et al., 1999; Wildmon, et al. 2004).

Empirically validated interventions require an extensive literature demonstrating effectiveness with various groups of individuals. The positive effects of interspersal have been demonstrated with students in elementary school (e.g., Hawkins, Skinner, & Oliver, 2005; Rhymer & Morgan, 2005), in middle school (e.g., Robinson & Skinner, 2002; Wildmon et al., 2004), and in high school (e.g., Cates & Skinner, 2000; Johns et al., 2000). These effects have been established with students in the general education curriculum (e.g., Billington, Skinner, & Cruchon, 2004; Rhymer & Morgan, 2005) along with students diagnosed with learning disabilities (e.g., Johns et al., 2000; Wildmon et al., 2004) or enrolled in remedial math classes (e.g., Cates & Skinner, 2000). Interspersal has also been effective with students labeled as

emotionally-impaired (Skinner, Hurst, et al., 2002). Therefore, the interspersal intervention has an extensive literature that has been validated with diverse groups of students.

In addition to worksheets completed by hand, these effects were demonstrated with problems completed on the computer (Johns et al., 2000). Also, some researchers found that students would rather complete interspersal assignments with *more target* problems than the control assignments (Cates et al., 1999; Cates & Skinner, 2000). Robinson and Skinner (2002) examined the effect of performance level on interspersal interventions. The participants were seventh-grade students identified by their mathematics teacher and special education director as at-risk for failing mathematics. Participants completed the Multiplication and Mental Computation subtests of the *KeyMath-Revised* (Connolly, 1988). The Multiplication subtest was a pencil-and-paper subtest and was considered a low-attention task, because there was no time limit. The Mental Computation subtest included problems that were read aloud or presented on an easel, and students provided answers orally without the use of paper or writing utensils. This test was considered high-attention. The control assignment consisted of the problems from the actual subtests, whereas the interspersed assignments consisted of additional easy problems interspersed throughout the subtests.

Robinson and Skinner (2002) found no significant differences in students' performance on the interspersal condition and the control condition for the Multiplication subtest. However, 24 of 30 participants scored higher on the Mental Computation subtest during interspersal than on the control Mental Computation. To further analyze these differential results, students were categorized as high-scoring (i.e., scored above the median on the control Mental Computation subtest) or low-scoring (i.e., scored below the median on the control Mental Computation subtest). Interestingly, low-scoring students performed significantly better during interspersal as

compared to control; whereas, high-scoring students performed equally well during the control and interspersal conditions (Robinson & Skinner, 2002). Given that the median was 39% correct, it is unclear how many of the high-scoring students would be at the instructional fluency level or the mastery fluency level; furthermore, it is unclear how many of the low-scoring students would be at the instructional fluency level or the frustrational fluency level. However, this study was the first to examine the interaction between students' initial fluency level and effectiveness of the interspersal intervention; yet, many questions remain unanswered thus requiring additional research to fully understand this interaction.

Comparison Research

Two studies have directly compared explicit timing and interspersal interventions to determine which intervention produces the greatest gains in number of math problems completed correctly (Clark & Rhymer, 2003; Rhymer & Morgan, 2005). The first study compared explicit timing and interspersal for college students using 3-digit minus 3-digit subtraction problems as the target problems and 1-digit minus 1-digit subtraction problems as the interspersed/easy problems (Clark & Rhymer, 2003). On the first trial, students completed the same number of target problems on the explicit timing assignment as the interspersal assignment. For the second trial, students completed significantly more target problems on the explicit timing assignment as compared to the interspersal assignment. Accuracy levels remained approximately 88% correct for both interventions across both trials.

The second study was a replication of Clark and Rhymer (2003) using third grade students (Rhymer & Morgan, 2005). Target problems consisted of 2-digit minus 2-digit subtraction problems requiring borrowing in the one's column (e.g., 24-16) and interspersed/easy problems consisted of subtraction of a 1-digit number from a 1-digit number. During all three

trials, students completed more target problems correctly during explicit timing as compared to interspersal. Although both of these studies directly compared two empirically-validated interventions, neither of these studies examined students initial fluency level and it is unknown if this variable would have produced differential results. Furthermore, neither of these studies compared the long-term effectiveness of the two interventions. Teachers require interventions that can be used beyond the duration of one week; however, only five studies have examined either intervention alone for more than four sessions or beyond 1 week (Calderhead et al., 2006; Codding et al., 2007; McCurdy et al., 2001; Skinner et al., 2002; Van Houten & Thompson, 1976). Thus, additional research is required to determine the appropriateness of each intervention at a given level of fluency and also which intervention is superior in the long-term (Rhymer & Morgan, 2005).

Present Study

Previous research comparing explicit timing and interspersal interventions consisted of three or fewer sessions administered over a period less than 1 week (Clark & Rhymer, 2003; Rhymer and Morgan, 2005). Moreover, studies of these interventions that were conducted for more than a brief duration examined the effects of only one of the interventions rather than comparing explicit timing and interspersal (Calderhead et al., 2006; Codding et al., 2007; McCurdy et al., 2001; Skinner et al., 2002; Van Houten & Thompson, 1976). Van Houten and Thompson (1976) also included a teacher-feedback and self-correction component, making it difficult to determine which component was most crucial to the positive outcome. Additionally, interventions typically take place for periods of longer than 1 week. Therefore, the current study examined the effects of interspersal and explicit timing for eight sessions lasting 2 weeks and

compared these two interventions with fourth, fifth, and sixth grade students on 2-digit by 1-digit multiplication problems without carrying.

Additionally, the current study examined the relationship between students' initial level of fluency (i.e., frustrational, instructional, or mastery) on these target problems and the effectiveness of each intervention. The impact of fluency was examined, because previous research suggested that students' initial levels of fluency or performance resulted in differential outcomes for explicit timing and interspersal interventions (Codding et al., 2007; Rhymer et al., 1998; Rhymer et al., 1999; Rhymer et al., 2002; Robinson & Skinner, 2002). This research suggested that explicit timing may be most beneficial for students at instructional and mastery fluency levels (Codding et al., 2007; Rhymer et al., 1998; Rhymer et al., 1999; Rhymer et al., 2002) , while interspersal may be more effective for lower-performing students (i.e., at frustrational fluency levels) (Robinson & Skinner, 2002).

Hypothesis One

It was predicted that both explicit timing and interspersal would result in greater mean digits correct per minute (DCM) on post-intervention assessments compared to pre-intervention assessments with no statistically significant changes in accuracy due to no corrective feedback.

Hypothesis Two

It was predicted that, compared to interspersal, explicit timing would produce greater increases in DCM when examining changes from pre-intervention to post-intervention assessments. This prediction was based on previous research indicating that explicit timing produces higher rates of problem completion than interspersal (Clark & Rhymer, 2003; Rhymer & Morgan, 2005).

Hypothesis Three

It was predicted that explicit timing would produce more DCM than interspersal for students at the instructional level and at the mastery level. This prediction was based on research that explicit timing is more effective for problems that are relatively easy (Codding et al., 2007; Rhymer et al., 1998; Rhymer et al., 1999; Rhymer et al., 2002).

Hypothesis Four

It was predicted that interspersal would produce more DCM than explicit timing for students at the frustrational level. This prediction was based on Robinson and Skinner's (2002) finding that interspersal increased the rate of responding for low-performing students but not for high-performing students who took a timed test. Although performance level (i.e., accuracy) is not identical to fluency level, these concepts are related. Thus, it was expected that results would be similar to those found by Robinson and Skinner (2002).

Hypothesis Five

It was predicted that, compared to interspersal, explicit timing would produce gains in fluency level for more students at the instructional level when examining changes from pre-intervention to post-intervention assessments. However, it was also predicted that, compared to explicit timing, interspersal would produce gains in fluency level for more students at the frustrational level when examining changes from pre-intervention to post-intervention assessments. Although this hypothesis is similar to the previous two hypotheses, it is important to examine qualitative fluency levels in addition to measures such as DCM in light of the ESEA goal that all students reach proficiency in mathematics and reading by 2014 (U.S. Department of Education, 2008). ESEA requires students to demonstrate "proficiency" in specific subject areas

on high-stakes testing. Other qualitative descriptors include “basic,” “below basic,” and “advanced.” A student may improve in terms of DCM, but if that student does not progress through qualitative levels of proficiency, high-stakes testing will not detect any improvement.

The pre-intervention and post-intervention assessments were used, because these measures may provide a measure of generalization outside of the intervention environment. It is important that students’ responses generalize to other situations, because they are expected to perform skills in a variety of settings, including high-stakes testing, and teachers will not always be able to manipulate the environment in order to encourage higher response rates.

CHAPTER II

METHOD

Participants

The original participant pool included 86 students enrolled in two summer school programs for fourth, fifth, and sixth graders in the Midwest that included academic components. All students present at the time of the interventions were required by their teachers to complete the assignments, but the students' data was not analyzed without both student assent and parental consent.

One program was a summer day camp conducted by a rural Midwestern school district. For the 2009-2010 academic years, 34.2% of students in this district were eligible for free or reduced lunch (Center for Educational Progress and Information [CEPI], 2011). This day camp consisted of a full-day program that included field trips, arts and crafts, games, swimming, and other sports activities. This five-days-per-week day camp included up to 2.5 hours of educational activities on four of those days. Students were enrolled for periods of one to ten weeks, and all fifth and sixth grade students, of which there were 49, were invited to participate in the study. Out of those invited to participate, twelve were excluded for refusing assent, four were excluded for failing to provide assent, one was excluded due to a parent's refusal of consent, and fourteen were excluded for failing to return parental consent forms. Of the 18 remaining who assented to the study and whose parents (intervention assessments as well as all 8 intervention sessions. Therefore, only three students from this program were included in the data analysis. All of these students were entering sixth grade in the fall.

The second program was an academic-based summer program that took place in a suburban school district in the Midwest. During the 2009-2010 school year, 10.5% of the

students in this school district were eligible for free or reduced lunches (CEPI, 2011). In this second program, students were enrolled in one of two academic classes that specifically targeted math skills and met for 1.5 hours, four days per week for three weeks. The first class was advertised for students who were entering sixth grade in the fall and needed additional instruction and review to prepare them for middle school math classes. There were 16 students enrolled in this course and invited to participate in the intervention. One student refused assent, and four did not return parental consent forms. One student from the explicit timing group was omitted after it was discovered that he merely copied the two-digit number from each problem in order to appear to complete assignments faster than his classmates. He announced that he finished all the problems on the worksheet before the end of the time limit, and after several of his worksheets were examined, it was clear that this student did not attempt to solve any of the problems. After his data was removed, eight students remained in the final sample, and all of them participated in all intervention sessions as well as target pre-intervention and post-intervention assessments.

The second class included students entering fourth and fifth grade in the fall. Its purpose was to build and refine basic math skills using the Everyday Mathematics Curriculum (http://everydaymath.uchicago.edu), which was used across this district in elementary school math classes. Out of the 21 students enrolled in this class, 2 students did not return parental consent forms, and 6 did not complete all of the intervention sessions, resulting in a total of 12 participants from this classroom in the final sample. Of the final 12 students, 7 of these students were in the fifth grade, and 5 of them were in the fourth grade.

In summary, there were a total of 86 participants across two summer programs and three classrooms invited to participate in the study. In the final sample, there were 23 participants: 11

were entering sixth grade, 7 were entering fifth grade, and 5 were entering fourth grade. Three (13%) were enrolled in a rural school district, and twenty (87%) were enrolled in a suburban school district. When questioned about their ethnicities, 14 (60.9%) participants identified themselves as Caucasian/White, 8 (34.8%) identified as African American/Black, and one (4.3%) identified as Asian/Pacific Islander. The disability status of the participants was unknown.

Measures

The primary researcher created 18 math computation worksheets. An overview of the order of presentation is provided in Appendix A. The researcher discussed the contents of the worksheets (2-digit by 1-digit multiplication without carrying) with a middle school administrator in the suburban district, and he recommended utilizing the worksheets with students in the elementary-level summer programs. The primary researcher also discussed the worksheets with the summer program administrator who is an elementary school teacher during the regular school year. This administrator believed the worksheets to be appropriate with her school's fourth, fifth, and sixth grade students. No consultation took place regarding the rural summer day camp; however, most camp counselors were not certified teachers, and so they did not have the expertise of the administrators of the suburban district. Furthermore, the mathematics scope and sequence at each school district were examined, and it was found that both districts taught 2-digit by 1-digit multiplication in the third grade. Therefore, students entering fourth, fifth, and sixth grade should have acquired this skill prior to the current study.

Two worksheets were identical and served as the pre-intervention and post-intervention target problem assessments for both intervention groups. These were labeled *C-2* and *C-4* (see Appendix B). Each target problem assessment was comprised of 150 2-digit times 1-digit (2x1)

multiplication problems without carrying (i.e., *target* problems) and was designed with the Intervention Central Math Worksheet Generator (http://www.interventioncentral.org). Eight additional worksheets, the explicit timing worksheets, were created in this fashion for the explicit timing group intervention sessions, and they were labeled *A-1* through *A-8* (see Appendix C). Although the pre- and post-intervention target problem assessments were nearly identical to the explicit timing worksheets, they had different administration directions, which are explained below.

The final eight worksheets, the interspersal worksheets, were labeled *B-1* through *B-8* (see Appendix D) and consisted of 150 problems. Fifty of these problems were brief (1x1) problems without regrouping obtained from the Math Facts Café worksheet generator (http://www.mathfactcafe.com). One hundred problems were target (2x1) problems that were identical to the first one hundred problems on each of the explicit timing worksheet. For example, worksheet *B-1* included the first 100 target problems from worksheet *A-1*, as well as 50 brief problems from the Math Facts Café worksheet generator. Each interspersal worksheet began with a brief problem, followed by two target problems, then one brief problem, then two target problems, and so on.

Procedures

The main researcher obtained consent from administrators and then from teachers or camp counselors participating in the research (see Appendices E and F). Then, the researcher trained a research assistant in administration procedures. The sessions at the summer day camp in the rural school district were led by the research assistant. The sessions at the suburban summer school were conducted by the main researcher.

All students present at the time of the interventions were required by their teachers to complete the assignments, but the students' data was not analyzed without both student assent and parental consent. On the first day, each classroom of students first received two sharpened pencils and a student assent form (see Appendix G). The researcher read the student assent form aloud to the students, explained the assent form, answered questions, and collected the assent forms when students completed them. Next, demographic surveys were passed out and completed. These surveys included information about students' age, grade in the fall and ethnicity (see Appendix H). The need for parental consent was explained to the students at this time, although parental consent forms (see Appendix I) had been sent home at least one day earlier. Students were informed that they would receive small prizes for returning the forms with parent signatures, regardless of whether parents provided or refused consent. Finally, the pre-intervention assessment was administered.

After the pre-intervention assessment took place, the main researcher collected the names of students from each classroom and randomly assigned half of the students in each classroom to the interspersal group and half to the explicit timing group. The remaining worksheets were administered in the following order: (1) first intervention session (A-1 for explicit timing group and B-1 for interspersal group), (3) second intervention session (A-2 for explicit timing group and B-2 for interspersal group), (4) third intervention session and so on, until all 8 intervention worksheets corresponding to each group were administered, and finally, (5) the post-intervention target problem assessment. In the rural school district, the primary researcher conducted the pre-intervention assessment, while the research assistant conducted the eight intervention sessions and the post-intervention assessment. In the suburban school district, the primary researcher

conducted the pre-intervention as post-intervention assessments, as well as all eight intervention sessions.

Prior to each intervention session, the researcher or research assistant pulled one intervention group out of the classroom at a time to administer the worksheets for that group. Once the worksheets were administered, the students returned to the classroom, and the second group of students was pulled out for the intervention. This continued on a daily basis until all eight sessions were completed. During subsequent sessions, the researcher or research assistant pulled one group at a time out of the classroom to administer the intervention worksheets. This continued until all eight sessions were completed. Due to time limitations, two worksheets were sometimes completed at one session. For example, the post-intervention target problem assessment was administered immediately after the final intervention session. When two worksheets were administered in one day, the second worksheet was passed out and administered immediately after the first worksheet was administered and collected. All directions were read aloud a second time as well. The intervention sessions, as well as the pre-intervention and post-intervention assessments were completed within a 2-week period. If a student in the suburban summer learning program missed an intervention session due to absence, the researcher met with the student individually to make up the missing worksheets in sequence prior to completing the worksheet for the current day. Unfortunately, the structure of the rural summer day came did not make it possible for to make up missed worksheets.

Worksheet Administration

Before students completed a worksheet, the researcher read a script aloud, informing the students that they were to begin working and to stop working when cued by the researcher. The directions for the pre- and post-intervention assessments as well as the interspersal sessions were

identical: the researcher asked students to work as quickly as possible without making mistakes, to complete the problems beginning from left to right without skipping any, and to continue on to the next page after they finished the current page. The researcher or research assistant also asked them to raise their hands if they finished before told to stop. This would allow for the researcher to record the completion time, in order to calculate how many digits were completed per minute. The researcher then timed the students for three minutes before the worksheets were collected. The researcher and assistant monitored students during the sessions to ensure that students were not copying others' work and to redirect those who skipped problems.

The explicit timing worksheet administration included some additional procedures. The researcher or research assistant announced that there would be a 3-minute time limit and that students would be stopped and started three times, once after each minute elapsed. When told to stop, they would circle their current problem and place their pencils in the air.

Treatment Integrity

To ensure that all procedures were followed as planned, packets were created for the main researcher and the research assistant that included directions for administering each type of worksheet and treatment integrity checklists for each session (see Appendix J). The treatment integrity checklists listed each crucial procedure for a particular session and a box to check "yes" or "no" following the procedure. Both researchers adhered to protocol for 100% of the sessions.

Dependent Variables

The dependent variables were digits correct per minute (DCM) and accuracy. DCM was calculated by adding the number of correct digits in correct sequence in an answer and dividing by 3 minutes. Digits incorrect per minute (DIM) was calculated by adding the number of digits

that are incorrect and dividing by 3 minutes. Accuracy was calculated by dividing DCM by the sum of DCM and DIM, and multiplying this number by 100. DCM and accuracy were calculated for the pre-intervention assessment, the post intervention assessment, and each of the eight intervention sessions.

Target-problem fluency levels for the pre-intervention assessment, the post-intervention assessment, the initial treatment session, and the final treatment session were categorized using the guidelines set forth by Shapiro (2004). Students at a frustrational level completed 19 or less digits correct per minute (DCM) and/or 8 or more digits incorrect per minute (DIM). Instructional level was defined as obtaining 20-39 DCM and/or 3-7 DIM. Mastery level was demonstrated by scoring 40 or more DCM and 2 or less DIM. The percent of students at each fluency level, before and after the study, were specified.

Interscorer Agreement

The primary researcher trained two assistants in scoring procedures. The assistants were required to score one sample explicit timing worksheet and one sample interspersal worksheet prior to scoring actual data. Once the primary researcher and the two assistants scored one interspersal worksheet and one explicit timing worksheet without any discrepancies, the research assistants scored the actual worksheets. The primary researcher then independently scored target digits correct on 22.3% of the math worksheets to obtain interscorer agreement. Interscorer agreement was computed by dividing the total number of agreements (digits scored the same by the primary researcher and research assistants) across the worksheets by the sum of agreements and disagreements (digits scored differently by the primary researcher and research assistants) across the worksheets. Interscorer agreement was 99.3%.

CHAPTER III

RESULTS

Hypothesis One

The first hypothesis stated that each intervention would lead to improvement in DCM from pre-intervention assessment to post-intervention assessment, but accuracy levels would remain consistent. Paired samples t-tests were conducted to determine the effectiveness of the interventions, independently of one other, based on the changes from the pre-intervention target problem assessment to the post-intervention target problem assessment. For each intervention group, a paired samples t-test was conducted using DCM as the dependent variable, and a paired samples t-test was conducted using accuracy as the dependent variable.

DCM

Means and standard deviations for DCM for pre-intervention and post-intervention target problem assessments are presented in Table 1. For the interspersal group, there was no statistically significant difference in DCM between pre-intervention and post-intervention, t (9) = - .85, p = .412, d =.17. For the explicit timing group, there was no statistically significant difference in DCM between the pre-intervention and post-intervention, t (12) = .23, p = .827, d = .24. Therefore, the first hypothesis was not supported. These results indicate that no change in DCM occurred as a result of explicit timing or interspersal when examining pre-intervention and post-intervention assessments. Although no statistically significant results were obtained, it should be noted that standard deviation was large and number of participants was small thus contributing to non-significant findings. However, there was a small effect, indicating that there was a slight change from pre-intervention to post-intervention DCM that may have been detected

with a larger sample size (Cohen, 1992). Visual analysis of the data indicated an increasing trend from session one to session eight; therefore, session data were analyzed in the following exploratory analyses.

Table 1. *Mean DCM and Mean Accuracy (and Standard Deviations) for Pre-Intervention and Post-Intervention Assessments by Intervention Group*

Group	*N*	Pre-intervention DCM	Post-intervention DCM	Pre-intervention Accuracy	Post-intervention Accuracy
Interspersal	13	45.33 (22.97)	40.82 (9.67)	97.93 (1.85)	98.18 (2.28)
Explicit Timing	10	37.53 (15.70)	38.87 (13.58)	95.25 (10.25)	93.94 (10.14)

Means and standard deviations for DCM by intervention session and intervention group are presented in Table 2. For the interspersal condition, a paired samples t-test was conducted on DCM from initial session to final session and there was a statistically significant difference, t (12) = 6.08, p = .000, d =.54. Thus, even with the small sample size, interspersal resulted in 10.67 more DCM in the final intervention session compared to the initial session. For the explicit timing condition, a paired samples t-test was conducted on DCM from initial session to final (eighth) session, and there was a statistically significant difference, t (9) = 7.77, p = .000, d = 2.46. Thus, even with the small sample size, explicit timing resulted in 23.8 more DCM in the final intervention session compared to the initial session.

Table 2. *Mean DCM (and Standard Deviations) by Intervention Session and Intervention Group*

		Intervention Sessions							
Group	*N*	1	2	3	4	5	6	7	8
Interspersal	13	25.54 (8.38)	28.87 (4.41)	34.59 (12.67)	32.54 (9.38)	33.80 (10.92)	31.05 (8.84)	36.64 (9.79)	36.21 (9.05)
Explicit Timing	10	27.63 (10.80)	32.50 (8.78)	33.50 (9.77)	36.40 (14.94)	34.90 (11.82)	42.87 (19.58)	43.13 (14.83)	51.43 (14.79)

Accuracy

Means and standard deviations for accuracy for pre-intervention and post-intervention assessments are presented in Table1. For the interspersal group, there was no statistically significant difference in accuracy between pre-intervention and post-intervention, t (9) = .43, p = .673, d = .07. For the explicit timing group, there was no statistically significant difference in accuracy between pre-intervention and post-intervention, t (12) = -.53, p = .610, d = .12. These results support the hypothesis. However, visual analysis of the data suggested a slight increasing trend for the explicit timing condition from the initial to the final session; therefore, session data were analyzed in exploratory analyses.

Means and standard deviations for accuracy by intervention sessions and intervention group are presented in Table 3. For the interspersal condition, a paired samples t-test was conducted on accuracy from initial session to final session, and there was no statistically significant difference, t (12) = .47, p = .647, d = .15. For the explicit timing condition, a paired samples t-test was conducted on accuracy from initial session to final session and there was no statistically significant difference, t (9) = 1.71, p = .121, d = .54. Therefore, neither intervention resulted in diminished accuracy levels. Cohen's d was small for all tests conducted except the difference in initial and final intervention accuracy for the explicit timing group, which resulted in a medium effect (Cohen, 1992). Thus, a larger sample size may have led to statistically significant increases in accuracy for the explicit timing condition.

Table 3. *Mean Accuracy (and Standard Deviations) by Intervention Session and Intervention Group*

		Intervention Session							
Group	*N*	1	2	3	4	5	6	7	8
Interspersal	13	98.51 (2.81)	98.27 (2.49)	98.99 (2.31)	98.83 (1.78)	98.48 (2.42)	98.18 (3.36)	99.08 (1.43)	98.81 (1.60)
Explicit Timing	10	91.16 (16.64)	93.23 (12.28)	91.69 (16.65)	91.94 (15.33)	93.31 (12.86)	94.45 (11.36)	95.06 (9.02)	95.31 (9.12)

Hypothesis Two

The second hypothesis stated that, compared to interspersal, explicit timing would produce greater gains in DCM when examining changes from pre-intervention to post-intervention assessments. To test this hypothesis, two independent samples t-tests were conducted: one to compare group differences in DCM on the pre-intervention assessment and the other to compare these differences on the post-intervention assessment. No difference on the pre-intervention assessment would indicate that the groups started out at similar levels. Differences on the post-intervention assessment would demonstrate that one intervention led to greater progress than the other.

Pre-intervention and Post-intervention Assessments

The assumption of homogeneity of variance between the two intervention groups on the pre-intervention assessment was tested using Levene's test, which indicated equal homogeneity of variance in DCM between the interspersal and explicit timing groups on the pre-intervention assessment (p =.357). There was no statistically significant difference in pre-intervention DCM between the two groups, t (21) = .92, p = .369, d = .40.

The assumption of homogeneity of variance between the two intervention groups at post-intervention assessment was tested using Levene's test, which indicated equal homogeneity of

variance in DCM between the interspersal and explicit timing groups on the post-intervention (p = .464). There was no statistically significant difference in post-intervention DCM between the two groups, t (21) = .40, p = .691, d = .18.

Although no statistically significant results were obtained, it should be noted that standard deviation was large and number of participants was small thus contributing to non-significant findings. However, a medium effect was detected at pre-intervention, indicating that a larger sample of participants may have resulted in a statistically significant difference between the two groups at pre-intervention assessment. Visual analysis of the data indicated an increasing trend from the initial to the final session; therefore, session data were analyzed in the following exploratory analyses.

Initial and Final Intervention Sessions

The assumption of homogeneity of variance was tested using Levene's test, which indicated equal homogeneity of variance in DCM between interspersal and explicit timing during the initial session (p =.772). There was no statistically significant difference in DCM between the two groups during the initial intervention session, t (21) = .53, p = .605, d = .23.

The assumption of homogeneity of variance was tested using Levene's test, which indicated equal homogeneity of variance in DCM between interspersal and explicit timing during the final intervention session (p = .113). There was a statistically significant difference in DCM between the two groups, t (21) = 3.05, p = .006, d = .67. Therefore, students completed significantly more DCM during the final session in the explicit timing intervention as compared to the final session in the interspersal intervention, and the second hypothesis was partially supported.

Hypothesis Three

The third hypothesis predicted that explicit timing would produce more DCM than interspersal for students at instructional and mastery fluency levels. Due to the small sample size of participants, no statistical analyses could be utilized to evaluate this hypothesis. Thus, descriptive and visual analyses were used.

Instructional Fluency Level

DCM. Mean DCM by intervention session for participants at instructional fluency level on the initial intervention worksheet are presented in Table 4. On the initial intervention worksheets, nine participants in the interspersal group and six participants in the explicit timing group scored at the instructional fluency level. Participants in the interspersal group began with an average of 29.81 DCM and ended with an average of 38.93 DCM, resulting in an average gain of 9.12 DCM across the eight sessions. Participants in the explicit timing group began with an average of 27.00 DCM and ended with an average of 44.11 DCM, resulting in an average gain of 17.11 DCM across the eight sessions. These data indicate that the participants in the explicit timing group who were initially at instructional fluency gained an average of 7.99 more DCM than the participants from the interspersal group who were initially at instructional fluency.

Table 4. *Mean DCM (and Standard Deviations) by Intervention Session for Participants at Instructional Fluency Level at Initial Intervention Session*

		Intervention Session							
Group	*N*	1	2	3	4	5	6	7	8
Interspersal	9	29.81 (5.80)	30.04 (4.19)	36.04 (13.13)	35.55 (7.34)	37.85 (9.45)	32.30 (6.87)	38.11 (8.55)	38.93 (8.03)
Explicit Timing	6	27.00 (4.00)	31.83 (4.66)	34.06 (3.65)	35.50 (3.93)	34.45 (4.55)	36.61 (7.86)	37.89 (5.77)	44.11 (5.63)

Accuracy. Mean accuracy by intervention session for participants at instructional fluency level on the initial intervention worksheet are presented in Table 5. Participants in the interspersal group began with an average of 98.88% accuracy and ended with an average of 98.95% accuracy. Participants in the explicit timing group began with an average of 98.80% accuracy and ended with an average of 99.65% accuracy. Thus, for participants initially at the instructional level, there was little difference in accuracy between the two intervention groups.

Table 5. *Mean Accuracy (and Standard Deviations) by Intervention Session for Participants at Instructional Fluency Level at Initial Intervention Session*

		Intervention Session							
Group	*N*	1	2	3	4	5	6	7	8
Interspersal	9	98.88 (2.93)	97.65 (2.77)	98.69 (2.74)	98.66 (2.08)	98.98 (1.95)	98.68 (2.37)	99.05 (1.40)	98.95 (1.77)
Explicit Timing	6	98.80 (1.95)	98.61 (1.56)	99.48 (0.92)	99.01 (1.34)	93.34 (1.03)	99.85 (0.36)	99.03 (1.21)	99.65 (0.60)

Mastery Fluency Level

DCM. Mean DCM by intervention session for participants at mastery fluency level on the initial intervention worksheet are presented in Table 6. On the initial intervention worksheets, no participants in the interspersal group and two participants in the explicit timing group scored at the mastery fluency level. Participants in the explicit timing group began with an average of 42.50 DCM and ended with an average of 73.34 DCM, resulting in an average gain of 30.84 DCM across the eight sessions.

Table 6. *Mean DCM (and Standard Deviations) by Intervention Session for Participants at Mastery Fluency Level at Initial Intervention Session*

		Intervention Sessions							
Group	*N*	1	2	3	4	5	6	7	8
Interspersal	0	--	--	--	--	--	--	--	--
Explicit Timing	2	42.50 (1.17)	44.67 (2.83)	44.00 (1.41)	56.50 (13.90)	48.83 (12.02)	71.50 (11.55)	65.17 (7.30)	73.34 (2.35)

Accuracy. Mean accuracy by intervention session for participants at mastery fluency level on the initial intervention worksheet are presented in Table 7. Participants in the explicit timing group began with an average of 99.61% accuracy and ended with an average of 99.55% accuracy. Thus, for participants initially at the mastery fluency level, there was no difference in accuracy.

Table 7. *Mean Accuracy (and Standard Deviations) by Intervention Session for Participants at Mastery Fluency Level at Initial Intervention Session*

		Intervention Sessions							
Group	*N*	1	2	3	4	5	6	7	8
Interspersal	0	--	--	--	--	--	--	--	--
Explicit Timing	2	99.61 (0.56)	100.00 (0.00)	99.25 (0.02)	99.75 (0.35)	99.46 (0.77)	99.79 (0.30)	99.77 (0.33)	99.55 (0.01)

Hypothesis Four

The fourth hypothesis predicted that interspersal would produce more DCM than explicit timing for students at the frustrational level. As with the third hypothesis, it was not possible to analyze the fourth hypothesis due to the small sample of participants. Nevertheless, alternative ways of evaluating these hypotheses are discussed in the subsequent exploratory analyses.

DCM

Mean DCM by intervention session for participants at frustrational fluency level on the initial intervention worksheet are presented in Table 8. On the initial intervention worksheets, four participants in the interspersal group and two participants in the explicit timing group scored at the frustrational fluency level. Participants in the interspersal group began with an average of 15.92 DCM and ended with an average of 30.09 DCM, resulting in an average gain of 14.17 DCM across the eight sessions. The mean DCM for participants in the explicit timing group was 14.67 on the initial intervention session and 51.5 on the final intervention session. Thus, the explicit timing group gained a mean of 36.83 DCM, or 18.55 more DCM than the interspersal group's average gain.

Table 8. *Mean DCM and (Standard Deviations) by Intervention Session for Participants at Frustrational Fluency Level at Initial Intervention Session*

		Intervention Session							
Group	*N*	1	2	3	4	5	6	7	8
Interspersal	4	15.92 (3.59)	26.25 (4.23)	31.34 (12.74)	25.75 (10.94)	24.67 (8.87)	26.00 (11.74)	33.34 (12.93)	30.09 (9.13)
Explicit Timing	2	14.67 (13.67)	22.33 (8.49)	21.34 (16.50)	19.00 (17.92)	22.36 (17.44)	33.00 (30.64)	36.83 (23.33)	51.50 (22.87)

Accuracy

Mean accuracy by intervention session for participants at frustrational fluency level on the initial intervention worksheet are presented in Table 9. Participants in the interspersal group began with an average of 97.70% accuracy and ended with an average of 98.51% accuracy. Participants in the explicit timing group began with an average of 59.78% accuracy and ended with an average of 78.06% accuracy. While the trend in accuracy of the interspersal group was

consistently high for all sessions, the trend for the explicit timing group increased across the sessions and resulted in a mean gain of 18.28%.

Table 9. *Mean Accuracy (and Standard Deviations) by Intervention Session for Participants at Frustrational Fluency Level at Initial Intervention Session*

		Intervention Session							
Group	*N*	1	2	3	4	5	6	7	8
Interspersal	4	97.70 (2.73)	99.69 (0.63)	99.67 (0.66)	99.20 (0.97)	97.36 (3.30)	97.05 (5.26)	99.14 (1.73)	98.51 (1.32
Explicit Timing	2	59.78 (2.95)	70.32 (5.54)	60.76 (9.98)	62.92 (0.59)	69.05 (3.37)	72.92 (1.40)	78.43 (5.71)	78.06 (1.76)

Hypothesis Five

It was predicted that, compared to interspersal, explicit timing would produce more gains in fluency level for students at the instructional level when examining changes from pre-intervention to post-intervention assessments. However, it was also predicted that, compared to explicit timing, interspersal would produce more gains in fluency level for students at the frustrational level when examining changes from pre-intervention to post-intervention assessments.

Pre-intervention and Post-intervention Assessments

Cross tabulation of fluency level, using pre-intervention and post-intervention target assessments, are presented in Table 10. Interspersal resulted in one additional participant reaching mastery criteria on the post-intervention assessment compared to the pre-intervention assessment, and explicit timing resulted in two additional participants reaching mastery criteria on the post-intervention assessment compared to pre-intervention. Therefore, this hypothesis was partially supported given that two participants in the explicit timing group progressed from instructional mastery as compared to only one participant in the interspersal group.

Only one participant, who was in the explicit timing group, was at the frustrational fluency level at pre-intervention assessment. That participant remained at the frustrational fluency level at post-intervention. Because there was only one participant at the frustrational fluency level on the post-intervention assessment, the second part of this hypothesis could not be evaluated.

Table 10. *Summary of Cross Tabulation of Pre-intervention and Post-intervention Assessment Fluency Levels*

	Fluency Level					
	Pre-Intervention			Post-Intervention		
Group	Frustrational	Instructional	Mastery	Frustrational	Instructional	Mastery
Interspersal						
N	0	8	5	0	7	6
% of Group	0%	61.5%	38.5%	0%	53.8%	46.2%
Explicit Timing						
N	1	5	4	1	3	6
% of Group	10.0%	50.0%	40.0%	10.0%	30.0%	60.0%

Initial and Final Intervention Sessions

Given the discrepant results between DCM for the pre-intervention assessment and the initial session along with the discrepant results between DCM for the post-intervention assessment and the final intervention session, session data were examined to further test this hypothesis. Cross tabulation of fluency level using initial session DCM and final session DCM are presented in Table 11.

Table 11. *Summary of Cross Tabulation of Initial and Final Fluency Levels*

	Fluency Level					
	Initial Session			Final Session		
Group	Frustrational	Instructional	Mastery	Frustrational	Instructional	Mastery
Interspersal						
N	4	9	0	0	7	6
% of Group	30.8%	69.2%	.0%	.0%	53.8%	46.2%
Explicit Timing						
N	2	6	2	2	2	6
% of Group	20.0%	60.0%	20.0%	20.0%	20.0%	60.0%

Instructional fluency. In the interspersal group, five out of the nine participants initially at the instructional fluency level progressed to mastery fluency. The other four remained at the instructional level. Explicit timing resulted in four out of six participants initially at the instructional fluency level progressing to the mastery fluency level, while two participants at the instructional fluency level remained at that level.

Frustrational fluency. Interspersal resulted in three participants at the frustrational fluency level progressing to the instructional fluency level, and one participant at the frustrational fluency level progressing to the mastery fluency level. There were two participants at the frustrational fluency level initially, and both remained at the frustrational fluency level on the final intervention session.

Therefore, the fifth hypothesis was supported. The data suggest that interspersal is the better intervention for participants at the frustrational fluency level, because all four participants progressed, meanwhile the two participants at frustrational fluency in the explicit timing intervention did not progress. Regarding instructional fluency level, the data suggest that explicit timing may be slightly superior to interspersal, because 66.67% of the participants in the explicit

timing intervention progressed, whereas 55.56% of the participants in the interspersal intervention progressed.

CHAPTER IV

DISCUSSION

The current study compared interspersal and explicit timing for students in fourth, fifth, and sixth grade while completing multiplication problems given that only two published studies have directly compared these interventions. It is essential that researchers directly compare one empirically validated intervention to another empirically validated intervention instead of merely comparing to a control condition. This study also compared these two interventions over a span of eight sessions across 2 weeks, which is a longer time span than most of the previous research studies examining interspersal and explicit timing. The purpose of empirically validating academic interventions is to provide teachers with options within the classroom to assist students. Therefore, academic interventions in the research literature should mimic classroom conditions as closely as possible and ideally maintain effectiveness over an extended period of time. This study also examined if the results obtained during the intervention conditions would generalize to assessments conducted outside of the session (i.e., pre-intervention and post-intervention assessments), and if the students' initial fluency level influenced the effectiveness of interspersal and explicit timing, thus providing teachers with guidelines regarding when to use each intervention.

It was predicted that both explicit timing and interspersal would result in higher mean DCM on post-intervention assessments compared to pre-intervention assessments, but there would be no statistically significant changes in accuracy, because no corrective feedback was to be provided to participants. When pre-intervention assessment and post-intervention assessment were compared, no statistically significant differences for interspersal or explicit timing were found. However, session data indicated a statistically significant increase from the initial session

to the final session. Specifically, within eight sessions and 2 weeks, students in the interspersal intervention gained 10.67 DCM, and students in the explicit timing intervention gained 23.8 DCM, while mean accuracy remained consistently high for both groups. Furthermore, students in the explicit timing intervention gained twice as many DCM as students in the interspersal intervention, which is consistent with previous research indicating that students perform better during explicit timing as compared to interspersal (Clark & Rhymer, 2003; Rhymer & Morgan, 2005). In summary, the current study found that the pre-intervention and post-intervention target problems assessments were weak measures of the effectiveness of interspersal and explicit timing, but examination of the data within the treatment sessions provided significant effects for both interventions.

The present study also predicted that explicit timing would be more effective in increasing DCM than interspersal for students at instructional and mastery fluency levels. This was analyzed using initial and final session data as well. For participants initially at instructional fluency, the participants in the explicit timing group gained markedly more DCM (17.11) than the participants in the interspersal group (9.12). Because both groups of participants maintained accuracy levels above 90%, it was concluded that explicit timing was more effective than interspersal for participants at the instructional fluency level. This is greater than the gain of 7.0 DCM Codding et al. (2007) found among second and third grade students who began a 6-week (average of 10 sessions) explicit timing intervention at the instructional level in single-digit subtraction. It could not be determined that either intervention led to greater improvement for participants at mastery fluency, because there were no participants in the interspersal group who initially scored mastery level fluency. Although there were only two participants initially at

mastery level fluency, explicit timing appeared effective for improving their computation, because their average gain was 30.84 DCM across the 8 sessions.

Regarding students at the frustrational fluency level, it was predicted that interspersal would be more effective in increasing DCM than explicit timing. Of the participants initially at a frustrational level, those assigned to the interspersal intervention gained an average of 14.17 DCM, while those in the explicit timing group gained an average of 36.83 DCM. Participants in the explicit timing group began the intervention sessions with a mean accuracy of 59.78% and ended with a mean accuracy of 78.06%, but participants in the interspersal group consistently obtained intervention session mean accuracy levels above 97%. Because the interspersal group maintained a higher accuracy rate and simultaneously improved in DCM, it appears that the interspersal intervention was most effective for participants initially at a frustrational fluency level. However, the growth in DCM for both interventions is greater than the 2.0 DCM gain for second and third grade students initially at the frustrational level in Codding et al. (2007).

Furthermore, it was predicted that explicit timing would lead to gains in fluency level for more students initially at the instructional level, but interspersal would result in gains in fluency level for more students initially at the frustrational level. For participants initially at frustrational fluency level, interspersal is the better intervention, because all four participants progressed, whereas the two participants in the explicit timing intervention did not progress. For participants initially at instructional level, explicit timing seems slightly more effective, because 66.67% of the participants in the explicit timing intervention progressed whereas 55.56% of the participants in the interspersal intervention progressed.

In summary, these results are consistent with previous research that demonstrated students tend to complete more total problems on the explicit timing worksheets without

sacrificing accuracy, and these effects were present despite the small sample size (Clark & Rhymer, 2003; Rhymer & Morgan, 2005). The present study offers preliminary evidence to support the use of explicit timing and interspersal over extended periods of time to build fluency of multiplication computation in upper elementary school students and specifically that explicit timing leads to greater improvements in DCM than interspersal. However, the results also indicate that teachers must consider students' initial fluency levels to select the most appropriate intervention: interspersal may be most appropriate for students at the frustrational fluency level, but explicit timing may be more effective for students at higher instructional levels.

Limitations

One limitation of this study is the small sample size of 23 participants. It is possible that the results would have demonstrated a different pattern with a larger sample of participants. Half of the original participant pool was excluded from the study, mostly due to absences and lack of obtaining parental consent. It is plausible that the pattern of responding would have been different if a greater proportion of students from the preliminary participant pool were used in the final sample. Having a larger sample would have also allowed for further analyses such as examining differences between school districts, classrooms, and grades in school.

A second limitation may be that the generalizability to the classroom setting may have been reduced, because the students' teachers did not administer the worksheets to the entire classroom simultaneously. In the current study, the students in each classroom were split into two groups, with each group receiving the intervention outside of the classroom. Although teachers did not administer the interventions, the process of dividing the classroom for small group instruction with a second adult may not be so different from a typical school situation.

Additionally, there was no control group in this study. It is possible that the students made gains only as a result of teacher instruction or another third variable. Although many studies include a control condition, the ethics of denying students empirically validated interventions for experimental control are questionable.

Finally, 20 of the 23 participants were recruited via their attendance at a summer program to remediate math skills. It is unknown to what extent the effects of the curriculum had on the participants' performance during this study. However, students were randomly assigned to either the interspersal or explicit timing intervention; therefore, learning that occurred outside of the treatment session should equally effect both interventions. This limitation is common when empirically validating academic interventions using children because children continue to learn within the school/home setting while participating in research studies.

Recommendations for Future Research

It may be beneficial for future research to examine the effects of explicit timing and interspersal in sessions that are administered by mathematics teachers, as such a study would aid in determining if the effects generalize to the classroom setting. It would also be helpful to replicate research with a larger sample size, so that differences between grades, classrooms, and other demographics of the students may be examined. Although this study did extend the research by conducting eight intervention sessions, two weeks remain a relatively brief period of time in comparison to an entire semester or academic year. Even longer-term use of explicit timing and interspersal interventions, compared to control subjects, may allow for a more in-depth analysis and comparison between the two interventions. A control condition would allow examination of typical growth rates for comparison children within the schools.

Conclusions

Although the number of rigorous studies in mathematics teaching, learning, assessment, and remediation continue to grow, "these studies are only beginning to yield findings, and their number remains comparatively small" (p. xxvi, NMAP, 2008) The NMAP urged researchers to "produce methodologically rigorous scientific research in crucial areas of national need, such as the teaching and learning of mathematics" (p. xxvi). Specifically, research that identifies effective instructional practices is needed and knowledge gained from such research must be disseminated to mathematics educators. Despite its limitations, the present study provides an example of such an instructional practice and adds to the body of evidence indicating that explicit timing and interspersal are brief, effective strategies for building math computation fluency with elementary school students.

Interventions that maximize student learning rates, thus providing the most efficient use of instructional time are important when determining the most appropriate interventions to use (Cates, et al., 2003). Each explicit timing or interspersal worksheet can be prepared in less than 5 minutes using a free online math worksheet generator (e.g., http://www.interventioncentral.org). Moreover, the instructional time required is merely the time needed to pass out worksheets, read the directions aloud, and allow the students to work 3-5 minutes. In the current study, the interspersal participants gained an average of 10.67 DCM, and the explicit timing participants gained an average of 23.8 DCM. Thus, these interventions demonstrate an efficient use of classroom time, because they may be delivered to many students simultaneously in less than 10 minutes and appear to result in immense gains. Teachers require empirically validated interventions to use with students either classwide or individually based on the students' initial fluency level. This study demonstrated that explicit timing and interspersal are quick and simple

interventions that teachers can incorporate in the curriculum in order to significantly impact their students' levels of fluency. This study provided support for a growing body of literature investigating the initial fluency level by intervention interaction. It is becoming apparent that explicit timing should not be used with students at the frustrational fluency level, where interspersal may be more appropriate. However, explicit timing is the preferred intervention for students at the instructional fluency level, because it produces significantly greater effects than interspersal.

APPENDICES

APPENDIX A

ORDER OF WORKSHEET PRESENTATION

Explicit Timing Group				Interspersal Group			
Worksheet		Number of Problems	Problem Type	Worksheet		Number of Problems	Problem Type
Pre-Intervention Assessment		150	2X1 no carrying	Pre-Intervention Assessment		150	2X1
Intervention	A1	150	2X1	Intervention	B1	150	100 2X1 50 1X1
	A2	150	2X1		B2	150	100 2X1 50 1X1
	A3	150	2X1		B3	150	100 2X1 50 1X1
	A4	150	2X1		B4	150	100 2X1 50 1X1
	A5	150	2X1		B5	150	100 2X1 50 1X1
	A6	150	2X1		B6	150	100 2X1 50 1X1
	A7	150	2X1		B7	150	100 2X1 50 1X1
	A8	150	2X1		B8	150	100 2X1 50 1X1
Post-Intervention Assessment		150	2X1	Post-Intervention Assessment		150	2X1

Note. The 2x1 problems did not include carrying. The 1x1 problems did not include regrouping.

APPENDIX B

WORKSHEET C-2/C-4

NAME: _____ TEACHER:_____

GRADE: _____ DATE: _____

SCHOOL:_____

13 x 2	33 x 2	88 x 1	21 x 1	24 x 1	24 x 2
55 x 1	41 x 2	77 x 1	13 x 2	21 x 3	14 x 1
61 x 1	12 x 2	11 x 3	14 x 2	13 x 2	16 x 1
22 x 2	31 x 1	80 x 1	68 x 1	87 x 1	11 x 2
83 x 1	31 x 2	13 x 2	62 x 1	12 x 1	23 x 1

22 x 2	79 x 1	17 x 1	41 x 2	21 x 3	23 x 2
84 x 1	51 x 1	23 x 2	13 x 2	18 x 1	42 x 2
72 x 1	21 x 3	57 x 1	36 x 1	11 x 3	62 x 1
10 x 2	83 x 1	12 x 2	34 x 2	22 x 3	72 x 1
30 x 2	14 x 2	12 x 2	87 x 1	12 x 2	54 x 1

12 x 2	32 x 3	22 x 3	31 x 2	27 x 1	44 x 2
44 x 1	11 x 3	31 x 2	23 x 3	31 x 2	32 x 2
62 x 1	14 x 2	47 x 1	11 x 2	41 x 2	32 x 2
12 x 2	77 x 1	22 x 2	31 x 2	72 x 1	84 x 1
76 x 1	66 x 1	11 x 4	16 x 1	31 x 2	43 x 1

30 x 3	13 x 2	12 x 1	21 x 3	42 x 2	70 x 1
22 x 2	11 x 3	32 x 1	49 x 1	31 x 2	33 x 3
11 x 2	23 x 2	12 x 1	36 x 1	11 x 4	34 x 1
58 x 1	13 x 2	35 x 1	61 x 1	21 x 1	22 x 2
23 x 1	32 x 3	33 x 2	11 x 4	10 x 4	78 x 1

89 x 1	68 x 1	57 x 1	23 x 2	54 x 1	22 x 2
21 x 4	42 x 2	20 x 3	40 x 1	86 x 1	42 x 2
64 x 1	40 x 1	26 x 1	31 x 2	63 x 1	33 x 1
66 x 1	24 x 2	74 x 1	46 x 1	10 x 3	84 x 1
31 x 1	14 x 2	54 x 1	22 x 1	32 x 2	22 x 1

APPENDIX C

WORKSHEET A-1

NAME: _____ TEACHER:_____

GRADE IN FALL: _____ DATE: _____

SCHOOL DISTRICT:_____

80 x 1	40 x 2	33 x 2	12 x 4	72 x 1	46 x 1
41 x 2	21 x 4	20 x 3	13 x 3	38 x 1	93 x 1
41 x 2	13 x 3	12 x 2	32 x 1	63 x 1	13 x 3
73 x 1	57 x 1	54 x 1	32 x 3	88 x 1	89 x 1
33 x 3	76 x 1	33 x 2	31 x 3	18 x 1	60 x 1

87 x 1	42 x 2	20 x 3	12 x 1	75 x 1	11 x 3
20 x 3	80 x 1	12 x 4	82 x 1	21 x 2	88 x 1
11 x 2	32 x 2	20 x 3	12 x 3	38 x 1	12 x 2
11 x 2	23 x 1	32 x 1	79 x 1	24 x 2	16 x 1
84 x 1	43 x 2	23 x 2	10 x 2	88 x 1	12 x 3

44 x 2	74 x 1	91 x 1	11 x 3	24 x 2	10 x 3
11 x 2	33 x 2	17 x 1	94 x 1	18 x 1	23 x 2
26 x 1	16 x 1	32 x 2	10 x 2	43 x 2	39 x 1
16 x 1	21 x 4	80 x 1	13 x 3	31 x 2	87 x 1
27 x 1	41 x 2	22 x 2	54 x 1	78 x 1	84 x 1

32 x 1	24 x 2	25 x 1	87 x 1	53 x 1	43 x 1
11 x 2	32 x 1	36 x 1	41 x 1	12 x 1	84 x 1
33 x 2	21 x 3	11 x 3	23 x 3	84 x 1	22 x 3
11 x 1	23 x 3	12 x 4	33 x 2	85 x 1	27 x 1
81 x 1	66 x 1	32 x 2	22 x 2	33 x 2	22 x 2

13 x 2	33 x 3	72 x 1	58 x 1	16 x 1	68 x 1
66 x 1	83 x 1	14 x 2	74 x 1	73 x 1	21 x 2
33 x 2	24 x 2	19 x 1	43 x 2	33 x 3	34 x 2
35 x 1	33 x 1	11 x 4	31 x 3	21 x 3	72 x 1
12 x 2	30 x 2	41 x 1	15 x 1	23 x 3	10 x 2

APPENDIX D

WORKSHEET B-1

NAME: _____ TEACHER:_____

GRADE IN FALL: _____ DATE:_____

SCHOOL DISTRICT:_____

1 x 5	40 x 2	33 x 2	1 x 7	72 x 1	46 x 1
5 x 1	21 x 4	20 x 3	2 x 4	38 x 1	93 x 1
8 x 1	13 x 3	12 x 2	1 x 1	63 x 1	13 x 3
4 x 1	57 x 1	54 x 1	1 x 3	88 x 1	89 x 1
1 x 6	76 x 1	33 x 2	7 x 1	18 x 1	60 x 1

1 x 2	42 x 2	20 x 3	7 x 1	75 x 1	11 x 3
4 x 2	80 x 1	12 x 4	1 x 1	21 x 2	88 x 1
4 x 1	32 x 2	20 x 3	1 x 3	38 x 1	12 x 2
1 x 6	23 x 1	32 x 1	1 x 4	24 x 2	16 x 1
1 x 2	43 x 2	23 x 2	0 x 8	88 x 1	12 x 3

0 x 3	74 x 1	91 x 1	6 x 1	24 x 2	10 x 3
4 x 2	33 x 2	17 x 1	0 x 9	18 x 1	23 x 2
4 x 1	16 x 1	32 x 2	1 x 5	43 x 2	39 x 1
2 x 2	21 x 4	80 x 1	3 x 3	31 x 2	87 x 1
9 x 0	41 x 2	22 x 2	0 x 3	78 x 1	84 x 1

4 x 1	24 x 2	25 x 1	2 x 3	53 x 1	43 x 1
2 x 0	32 x 1	36 x 1	9 x 1	12 x 1	84 x 1
5 x 0	21 x 3	11 x 3	1 x 7	84 x 1	22 x 3
3 x 3	23 x 3	12 x 4	7 x 1	85 x 1	27 x 1
2 x 4	66 x 1	32 x 2	0 x 3	33 x 2	22 x 2

1 x 9	33 x 3	72 x 1	1 x 6	16 x 1	68 x 1
5 x 0	83 x 1	14 x 2	5 x 1	73 x 1	21 x 2
8 x 1	24 x 2	19 x 1	4 x 0	33 x 3	34 x 2
3 x 0	33 x 1	11 x 4	8 x 0	21 x 3	72 x 1

APPENDIX E

ADMINISTRATOR CONSENT FORM

CMU
CENTRAL MICHIGAN UNIVERSITY

School Administrator Consent Form

Study Title: Comparison of Explicit Timing and Interspersal Interventions for Increasing Multiplication Fluency of Upper Elementary School Students

Research Investigators' Names and Departments:

Alyssa Warshay
Doctoral Candidate in School Psychology
Psychology Department

Katrina Rhymer, PhD
Associate Professor
Psychology Department

Contact information for researchers:

Alyssa Warshay
Sloan Hall 101
Central Michigan University
Mount Pleasant, MI 48859
(xxx) xxx-xxxx
alyssa.warshay@gmail.com

Dr. Katrina Rhymer
Sloan Hall 138
Central Michigan University
Mount Pleasant, MI 48859
(989) 774-6468
rhyme1kn@cmich.edu

Introductory Statement

I would like to ask your permission to carry out a mathematics intervention at the_____ Program in the _____ School District. This project will help to evaluate which of several mathematics interventions is most effective when implemented for 10 sessions across a period of 3-5 weeks. I will compare how many multiplication problems students complete and how accurately students complete these problems.

What is the purpose of this study? The purpose of this research study is to compare two brief interventions that may be implemented by teachers in the classroom to determine which is most effective for students.

What will teachers do in this study? How long will it take? Teachers will meet with the researcher prior to beginning the study to briefly review procedures. This meeting will require no more than 20 minutes. Then, I will conduct sessions 3-4 days each week for 3 weeks. I will

conduct the intervention outside of the students' regular classroom with half of the students at a time. The first session will require approximately 15 minutes of class time. The last session will require approximately 10 minutes. The other 9 sessions will require approximately 5-10 minutes of class time. The researcher will provide all materials, including worksheets, pencils, and directions for the administering worksheets. Before the researcher administers any worksheets, teachers will be asked to pass out the parental consent forms and to instruct students to have their parents complete the forms and then to bring them back to school the next day. Teachers will not have to instruct students or pass out any materials other than the parental consent form. Teachers will be provided with a written description of the interventions, and asked to rate the feasibility of conducting the interventions in their classrooms.

What will students do in this study? Students will complete the worksheets in class as instructed. All students will complete the worksheets, regardless of whether parents provide consent and students provide assent. However, the researcher will only score and analyze the data for those students who provide assent and whose parents provide consent. During the first session, students will be asked to complete assent forms and a brief demographic survey, regarding their age, grade, gender, and ethnicity. Filling out the survey will assist with the interpretation of the data and all information will be kept confidential. Completing the survey is voluntary and students will not be penalized for failing to answer every question.

Are there any risks of participating in the study? There are no risks, because the math problems used for this study are very similar to the types of problems assigned by teachers.

What are the benefits of participating in the study?
For students: Students are likely to improve their speed and accuracy of solving multiplication problems. This positive result may extend to other areas of mathematics, such as division, fractions, and multiplication word problems.
For teachers: Teachers will be educated about two brief interventions for improving fluency of math facts and calculation, which may be used in the future.
For the field of Education and School Psychology: This research will help determine what types of interventions are most helpful for improving computation fluency of upper elementary school students, as well as teachers' feasability for implementing these interventions. Thus, this research will contribute to the field of education and school psychology once the results are published and accessible to educators.
psychology once the results are published and accessible to educators everywhere.

Confidentiality. All information gathered will be kept confidential. On all documents, students' and teachers' names will be replaced by assigned numbers so that they cannot be connected to the data by anyone but the principal student investigator. Only the principal student investigator will have access to students' and teachers' personal information. Once the data is analyzed, the coding key that matches student names to numbers will be destroyed. When the results are presented and/or published, only group means will be discussed; the identities of participating schools, teachers, and participants will not be disclosed.

Will there be any compensation for participation? Teachers will receive a gift certificate for school supplies for their participation in the study. Students will receive a small reward (worth less than $.50) for returning signed parental consent forms, regardless of whether their parents provide consent.

Whom can I contact for information about this study? Please contact to call Alyssa Warshay (xxx-xxx-xxxx) or Dr. Katrina Rhymer (989-774-6468) with any questions about the research or about participants' rights.

Participation is voluntary. Administrators, all teachers, and all students are free to refuse participation in this research project or to withdraw consent and discontinue participation in the project at any time without penalty or loss of benefits. Your participation will not affect your relationship with the institution(s) involved in this research project.

If you are not satisfied with the manner in which this study is being conducted, you may report (anonymously if you so choose) any complaints to the Central Michigan University Institutional Review Board by calling 989-774-6777, or addressing a letter to the Institutional Review Board, 251 Foust Hall Central Michigan University, Mt. Pleasant, MI 48859.

Thank you for your consideration.

Sincerely,

Alyssa R. Warshay
School Psychology Doctoral Candidate
Central Michigan University

Katrina Rhymer, PhD
Associate Professor in Psychology
Central Michigan University

My signature below indicates that all my questions have been answered. I grant permission to Alyssa Warshay to conduct her thesis project at the _____ school district.

Name: _____

Title: _____

Signature: _____ Date:_____

A copy of this form has been given to me. _____ Initials

Please return this via fax to the Psychology Department at 989-774-2553 c/o Alyssa Warshay.

APPENDIX F

TEACHER CONSENT FORM

CMU
CENTRAL MICHIGAN UNIVERSITY

Teacher Consent Form

Study Title: Comparison of Explicit Timing and Interspersal Interventions for Increasing Multiplication Fluency of Upper Elementary School Students

Research Investigators' Contact Information:

Alyssa Warshay
Doctoral Candidate in School Psychology
Psychology Department
Sloan Hall 101
Central Michigan University
Mount Pleasant, MI 48859
(xxx) xxx-xxxx
alyssa.warshay@gmail.com

Dr. Katrina Rhymer
Associate Professor
Psychology Department
Sloan Hall 138
Central Michigan University
Mount Pleasant, MI 48859
(989) 774-6468
rhyme1kn@cmich.edu

Introductory Statement

I would like to ask your permission to carry out a mathematics intervention in your classroom. This project will help to evaluate which of several mathematics interventions is most effective when implemented for 10 sessions across a period of 3-5 weeks. I will compare how many multiplication problems students complete and how accurately students complete these problems.

What is the purpose of this study? The purpose of this research study is to compare two brief interventions that may be implemented by teachers in the classroom to determine which is most effective for students.

What will teachers do in this study? How long will it take? Teachers will meet with the researcher prior to beginning the study to briefly review procedures. This meeting will require no more than 20 minutes. Then, I will conduct sessions 3-4 days each week for 3 weeks. I will conduct the intervention outside of the students' regular classroom with half of the students at a time. The first session will require approximately 15 minutes of class time. The last session will require approximately 10 minutes. The other 9 sessions will require approximately 5-10 minutes of class time. The researcher will provide all materials, including worksheets, pencils, and directions for the administering worksheets. Before the researcher administers any worksheets,

teachers will be asked to pass out the parental consent forms and to instruct students to have their parents complete the forms and then to bring them back to school the next day. Teachers will not have to instruct students or pass out any materials other than the parental consent form. Teachers will be provided with a written description of the interventions, and asked to rate the feasibility of conducting the interventions in their classrooms.

What will students do in this study? Students will complete the worksheets in class as instructed. All students will complete the worksheets, regardless of whether parents provide consent and students provide assent. However, the researcher will only score and analyze the data for those students who provide assent and whose parents provide consent. During the first session, students will be asked to complete assent forms and a brief demographic survey, regarding their age, grade, gender, and ethnicity. Filling out the survey will assist with the interpretation of the data and all information will be kept confidential. Completing the survey is voluntary and students will not be penalized for failing to answer every question.

Are there any risks of participating in the study? There are no risks, because the math problems used for this study are very similar to the types of problems assigned by teachers.

What are the benefits of participating in the study?
For students: Students are likely to improve their speed and accuracy of solving multiplication problems. This positive result may extend to other areas of mathematics, such as division, fractions, and multiplication word problems.
For teachers: Teachers will be educated about two brief interventions for improving fluency of math facts and calculation, which may be used in the future.
For the field of Education and School Psychology: This research will help determine what types of interventions are most helpful for improving computation fluency of upper elementary school students, as well as teachers' feasability for implementing these interventions. Thus, this research will contribute to the field of education and school psychology once the results are published and accessible to educators.

Confidentiality. All information gathered will be kept confidential. On all documents, students' and teachers' names will be replaced by assigned numbers so that they cannot be connected to the data by anyone but the principal student investigator. Only the principal student investigator will have access to the code sheet linking individual characteristics to the data. Once the data is analyzed, this code sheet will be destroyed.

Will there be any compensation for participation? Teachers will receive a gift certificate for school supplies upon completion of the project. Students will receive a minor reward (up to a $.50 value) for returning signed parental consent forms, regardless of whether their parents provide consent.

Whom can I contact for information about this study? Please contact to call Alyssa Warshay (xxx-xxx-xxxx) or Dr. Katrina Rhymer (989-774-6468) with any questions about the research or about participants' rights.

Participation is voluntary. Administrators, teachers, parents, and students are free to refuse participation in this research project or to withdraw consent and discontinue participation in the project at any time without penalty or loss of benefits. Your participation will not affect your relationship with the institution(s) involved in this research project.

If you are not satisfied with the manner in which this study is being conducted, you may report (anonymously if you so choose) any complaints to the Central Michigan University Institutional Review Board by calling 989-774-6777, or addressing a letter to the Institutional Review Board, 251 Foust Hall Central Michigan University, Mt. Pleasant, MI 48859.

Thank you for your time and consideration.

Sincerely,

Alyssa R. Warshay
School Psychology Doctoral Candidate
Central Michigan University

Katrina Rhymer, Ph.D.
Associate Professor in Psychology
Central Michigan University

My signature below indicates that all my questions have been answered. I grant permission for Alyssa Warshay to conduct her thesis project with students in my classroom(s) in the _____ Program.

Name: _____ School:_____

Grade(s) taught: _____ Number of math classes:_____

Approximate number of students:_____

Signature: _____ Date:_____

Please sign this form and initial the bottom of all pages (including this one). Then return this form via fax to the Psychology Department at 989-774-2553 c/o Alyssa Warshay.

A copy of this form has been given to me. _____ Initials

APPENDIX G

STUDENT ASSENT FORM

CMU
CENTRAL MICHIGAN UNIVERSITY

Student Assent Form

Study Title: Comparison of Explicit Timing and Interspersal Interventions for Increasing Multiplication Fluency of Upper Elementary School Students

Research Investigators' Contact Information:

Alyssa Warshay
Doctoral Candidate in School Psychology
Psychology Department
Sloan Hall 101
Central Michigan University
Mount Pleasant, MI 48859
(xxx) xxx-xxxx
alyssa.warshay@gmail.com

Dr. Katrina Rhymer
Associate Professor
Psychology Department
Sloan Hall 138
Central Michigan University
Mount Pleasant, MI 48859
(989) 774-6468
rhyme1kn@cmich.edu

What is this research about?
We would like to use your worksheets in a research study about improving math skills. I will pass out math worksheets for you to work on in class. All students in your class will be completing these worksheets, but you may decide if I can have your worksheets to use in my study once your parents also say it is okay. Please ask questions at any time about the study. It is okay for you to change your mind about allowing me to have your math worksheets.

What will I do in this research? How long will it take? On the first day, I will ask you to write out some answers to question about yourself, including your age, birthday, and race/ethnicity. Then, I will give you two math worksheets to complete. For the next 10 school days, you will be assigned 1 worksheet each day in class. Each worksheet will take less than 5 minutes to complete. You will not have to spend extra time outside of math class on any worksheets.

Can anything bad happen to me? No, because these are the same types of problems your math teacher assigns you now.

Can anything good happen to me? There is a good chance you will improve your math skills.

Do I have other choices? Your teacher has decided that all students will complete the math worksheets during your class, so you do not have a choice about doing the work. But, you may choose not to let me have your worksheets. You also may choose not to answer the questions in the survey I give you on the first day.

Will anyone know I am in the research? Only I will know if you gave me permission to use your worksheets in my study. I will take your names off the worksheets before I use them in my study. Your name will be crossed out and changed to a number. I will keep a key that matches your name to your number. But, once I finish writing my research report, I will destroy the key so that no one will be able to match your name to your number.

Will I be paid? No. You will only receive a small prize for returning the parent form I sent home yesterday.

Whom can I talk to about the research? You may contact me, Ms. Warshay, at xxx-xxx-xxxx. You may also contact Dr. Rhymer at 989-774-6468.

What if I do not want to do this? You do not have to let me have your worksheets. You can say no at any time. No one will be upset with you if you do not want me to have your worksheets, but you still have to do the work in class each day, along with all of your classmates.

SIGNATURE CLAUSE

Do you want to let me have your worksheets for my research? **Please check the box, sign below, and initial each page.**

☐ *Yes, I will let you have my worksheets for your research study.*
☐ *No, you may not have my worksheets for your research study.*

_____
Name of Student (Print)

_____ _____
Signature of Student Date

_____ _____
Signature of Person Explaining Assent Date

A copy of this form has been given to me _____Subject's Initials

APPENDIX H

DEMOGRAPHIC SURVEY

Student Demographic Survey

Teacher's Name:_____

Birthday (month, day, & year): _____

Grade in School:_____

Please circle your answers below.

Race/Ethnicity: Caucasian/White African-American/Black

(you may select more than one) Hispanic/Latino Native American

Asian Native Hawaiian/ Pacific Islander

Biracial/Multiracial

Gender: Male/Boy Female/Girl

APPENDIX I

PARENT CONSENT FORM

Dear Parents/Guardians:

I am a graduate student at Central Michigan University (CMU) in the School Psychology Program. Currently I am conducting a research project entitled, "Comparison of Explicit Timing and Interspersal Interventions for Increasing Multiplication Fluency of Upper Elementary School Students in Mathematics." I am working under the supervision of Dr. Katrina Rhymer, Associate Professor in Psychology at CMU. I have permission from your child's teacher and the school administrator to provide math intervention worksheets for students that will be completed over a period of three weeks. All students in your child's class will complete these intervention worksheets during their summer program, but I need your permission to include your child's worksheets in my research. This project will help determine which of several types of worksheets is most beneficial for improving multiplication computation rate and accuracy.

This project is described in more detail in the enclosed form. I will use the results of this project to write a research paper required for my master's degree. This letter is to request your permission for your child to participate in the project. The overall results will be included in a research paper and a possible presentation, but the name of your child, his/her teacher, and his/her school will not be used in the paper or any presentation of the results.

Enclosed is a consent letter for you to either provide or refuse consent. Please check the appropriate box, initial each page, and return the letter to your student's teacher. Please keep the additional copy of the letter and consent form for your records. You may call me with questions at xxx-xxx-xxxx. You may also call my advisor, Katrina Rhymer, PhD, at 989-774-6468. *Regardless of your decision for your child to participate in the research,* if this form is completed and returned to your child's math teacher, your child will receive a small prize. Thank you for your time and cooperation.

Sincerely,

Alyssa Warshay
School Psychology PhD Student
Psychology Department
Central Michigan University

CMU
CENTRAL MICHIGAN UNIVERSITY

Parent/Guardian Consent Form

Study Title: Comparison of Explicit Timing and Interspersal Interventions for Increasing Multiplication Fluency of Upper Elementary School Students

Research Investigators' Contact Information:

Alyssa Warshay
School Psychology PhD Student
Psychology Department
Sloan Hall 101
Central Michigan University
Mount Pleasant, MI 48859
(xxx) xxx-xxxx
alyssa.warshay@gmail.com

Dr. Katrina Rhymer
Associate Professor
Psychology Department
Sloan Hall 138
Central Michigan University
Mount Pleasant, MI 48859
(989) 774-6468
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Introductory Statement
I am requesting permission to include your child's math worksheets in my research study. Your child's summer program administrators and teachers have allowed me to conduct a research project in your child's classroom, which will assist me in completing my degree in School Psychology. The project will involve all students in your child's class completing brief math worksheets on 4-5 days each week for 2-3 weeks This project will evaluate two commonly used mathematics interventions that have already been shown to be effective with students; however, we need to examine if one intervention is better than the other. I will compare how many multiplication problems students complete and how accurately students complete these problems.

What is the purpose of this study? The purpose of this study is to compare two effective mathematics interventions to determine which intervention is most effective for students.

What will my child do in this study? How long will it take my child to do this?
I will administer the worksheets to students during their class. All students will complete the worksheets, regardless of whether parents provide consent and students provide assent. However, I will only use the worksheets for those students whose parents consent to the study and for students who provide assent. During the first session, students will be asked to complete assent forms and a brief demographic survey, regarding their age, grade, gender, and ethnicity. Filling out the survey will assist with the interpretation of the data, and all information will be kept confidential. Completing the survey is voluntary and students will not be penalized for failing to answer every question on the survey or worksheets. Students will be complete math worksheets

daily using one of the mathematics interventions. Students will participate in this study for approximately 5-10 minutes daily for the 2 to 3-week period.

Are there any risks of participating in the study? There are no risks, because the math problems used for this study are very similar to the types of problems currently assigned by your child's teachers.

What are the benefits of participating in the study?
For students: Students are likely to improve their speed and accuracy of solving multiplication problems. This positive result may extend to other areas of mathematics, such as division, fractions, and multiplication word problems.
For teachers: Teachers will be educated about two brief interventions for improving fluency of math facts and calculation, which may be used in the future.
For the field of Education and School Psychology: This research will help determine what types of interventions are most helpful for improving computation fluency of upper elementary school students, as well as teachers' feasability for implementing these interventions. Thus, this research will contribute to the field of education and school psychology once the results are published and accessible to educators.

Will anyone know what my child says or does in this study? (Confidentiality) All information gathered will be kept confidential. On all documents, students' and teachers' names will be replaced by assigned numbers so that they cannot be connected to the data by anyone but the principal student investigator. Only the principal student investigator will have access to the code sheet linking individual characteristics to the data. Once the data is analyzed, this code sheet will be destroyed.

Will my child receive any compensation for participation?
Students who return this completed parent/guardian consent form will receive a small prize. Students receive this prize whether their parents provide or refuse permission to use their children's worksheets in the study. There is no compensation for completing the worksheets or allowing the researcher to use them.

Participation is voluntary. You are free to refuse to allow your child's worksheets to be included in this research project or to withdraw your consent and discontinue use of your child's worksheets in the project at any time. Your consent or refusal will not affect your or your child's relationship with the institution(s) involved in this research project. Teachers will assign worksheets to all students in the classroom, and students will be required to complete the worksheets as part of their in-class work, but whether you allow the researcher to use your child's worksheets is completely voluntary.

Any questions? Whom can I contact for information about this study? Please contact to call Alyssa Warshay (xxx-xxx-xxxx) or Dr. Katrina Rhymer (989-774-6468) with any questions about the research or about participants' rights.
If you are not satisfied with the manner in which this study is being conducted, you may report (anonymously if you so choose) any complaints to the Institutional Review Board by calling

989-774-6777, or addressing a letter to the Institutional Review Board, 251 Foust Hall Central Michigan University, Mt. Pleasant, MI 48859.

Please sign and return this form, with the appropriate box checked, indicating whether your child may participate in the research. You may keep this copy of this letter for your records.

Also, please initial the bottom of each page of the enclosed copy and return to your child's math teacher. Thank-you!

☐ ***YES, the researcher may use my child's worksheets in her research as described above. My signature below indicates that all my questions have been answered.***

_____ _____
Signature of Parent/Guardian Date Signed

_____ _____
Name of Child Grade

_____
Teacher/Class

☐ ***NO, I do NOT give permission for the researcher to use my child's worksheets in the research project described above.***

_____ _____
Signature of Parent/Guardian Date Signed

_____ _____
Name of Child Grade

_____
Teacher/Class

A copy of this form has been given to me. _____ Initials

APPENDIX J

ADMINISTRATION PROCEDURES: SCRIPTS AND CHECKLISTS

Pre-test Administration Procedures (Worksheet C-2)

(ALL STUDENTS TOGETHER – No Groups)

1. Pass out two sharpened pencils to each student.

2. Pass out Child Assent Forms - **2 per student**. Go over with them & answer any questions they have. Help them fill these out if necessary. Collect completed copy. The other is theirs.

3. Pass out Demographic Surveys. Assist them in completing these if necessary. Collect.

4. Pass out **C-2** worksheets. DO NOT LET STUDENTS OPEN THE PACKETS!

5. Instruct students to write their names, grade in the fall, and the date on the top page. Help them if needed. If there is no regular teacher, they should write their group number. If there is no regular group number, then ignore this. They should write M.P. (Mount Pleasant) or G.P. (Grosse Pointe) for school district. Make sure they do not turn the page to begin working until you instruct them.

6. Instruct them in the following way: "**You are to work as quickly as you can without making mistakes. Start in the top left corner of the first page. Work from left to right and do not skip problems. After you finish one page, go on to the next. Put your pencils in the air when you are told to stop. Raise your hand if you finish before I tell you to stop**. **Now, put your pencils in the air, and, begin.**"

7. Time students for 3 minutes. If any students stop early, record the time they finished. Walk around to make sure they do not skip problems and to ensure they turn the page and keep working after they finish each page.

8. Tell students: "**Stop. Put your pencils down. I'll come around to collect the worksheets now**."

9. Collect **C-2** worksheets. Place in the folder(s).

10. Collect the pencils.

11. Ask students if they have parent forms to return to you. If the form is completed, allow them to choose a prize.

12. Complete the Treatment Integrity Checklist.

Pre-Intervention (C-2) Treatment Integrity Checklist

Teacher/School District:_____

Person completing form:_____ Date:_____

Person administering worksheets: _____

Please check "yes" or "no" for each of the following:	**YES**	**NO**
1. Two pencils were passed out to each student.	**YES**	**NO**
2. The Child Assent form and Student Demographic Survey were passed out to students.	**YES**	**NO**
3. EACH form was read aloud to students.	**YES**	**NO**
4. Students were provided time to ask questions and to complete these forms. I watched to make sure they were completed correctly.	**YES**	**NO**
5. These forms were collected.	**YES**	**NO**
6. C-2 worksheets were passed out to students. Students were instructed to fill out the first page & assisted if necessary.	**YES**	**NO**
7. Directions were read aloud to students. Students did not begin working until instructed.	**YES**	**NO**
8. Students were timed for 3 minutes, then stopped. During this time an adult walked around to make sure directions were followed.	**YES**	**NO**
9. C-2 worksheets were collected.	**YES**	**NO**
10. Pencils were collected.	**YES**	**NO**
11. Students were asked if they had parent forms to return. Those who returned completed parent worksheets were given a prize.	**YES**	**NO**

Group A Administration Procedures

(Worksheets A-1 thru A-8)

1. Pass out two sharpened pencils to each student.

2. Pass out **A** worksheets . Tell students, "**DO NOT OPEN the packets until I say."**

3. Instruct students to write their names, grade in the fall, and the date on the top page. Help them if needed. If there is no regular teacher, they should write their group number. If there is no regular group number, then ignore this. They should write M.P. (Mount Pleasant) or G.P. (Grosse Pointe) for school district. Make sure they do not turn the page to begin working until you instruct them.

4. Then instruct them in the following way: "**You will have a three-minute time-limit. You are to work as quickly as you can without making mistakes. Start in the top left corner of the first page. Work from left to right and do not skip problems. After you finish one page, go on to the next. When I tell you to stop, circle the last number you wrote and put your pencils in the air. Raise your hand if you finish the worksheet before I tell you to stop. Now, put your pencils in the air. Okay, begin.**"

5. Time students for 1 minute. Tell students, "**Stop. Circle the last number you wrote. Put your pencils in the air. You will begin working when I say, until I again tell you to stop. Begin now**." If any students stop early, record the time they finished. Walk around to make sure students do not skip problems & to make sure they continue to the next page whenever they finish one.

6. Repeat step 5 once.

7. Time students for 1 last minute. Tell students: "**Stop. Put your pencils down. I'll come around to collect the worksheets."**

8. Collect the worksheets. Place in the folder.

9. Collect the pencils.

10. Ask students if they have parent forms to return to you. If the form is completed, allow them to choose a prize.

11. Complete the Treatment Integrity Checklist.

Worksheet A Treatment Integrity Checklist

Teacher's name:_____ Date:_____

Person completing form:_____ Worksheet #_____

Person administering worksheets: _____

Please check "yes" or "no" for each of the following:	**YES**	**NO**
1. Two pencils were passed out to each student.	**YES**	**NO**
2. Assignments were passed out.	**YES**	**NO**
3. Students were provided time to fill out the top page. They were assisted if necessary.	**YES**	**NO**
4. Directions were read aloud to students. Students did not begin working until instructed.	**YES**	**NO**
5. Students were stopped at each one-minute interval, told to circle the last number they wrote, and told to put their pencils in the air.	**YES**	**NO**
6. Students worked for a total of 3 one-minute intervals. During this time an adult walked around to make sure directions were followed.	**YES**	**NO**
7. Assignments were collected.	**YES**	**NO**
8. Pencils were collected.	**YES**	**NO**
9. Students were asked if they had parent forms to return. Those who returned completed parent worksheets were given a prize.	**YES**	**NO**

Group B Administration Procedures
(Worksheets B-1 thru B-8)

1. Pass out two sharpened pencils to each student.

2. Pass out **B** worksheets. Tell students, "**DO NOT OPEN the packet until I say."**

3. Instruct students to write their names, grade in the fall, and the date on the top page. Help them if needed. If there is no regular teacher, they should write their group number. If there is no regular group number, then ignore this. They should write M.P. (Mount Pleasant) or G.P. (Grosse Pointe) for school district. Make sure they do not turn the page to begin working until you instruct them.

4. Say, "**You are to work as quickly as you can without making mistakes. Start in the top left corner of the first page. Work from left to right and do not skip problems. After you finish one page, go on to the next. When I tell you to stop, put your pencils in the air. Raise your hand if you finish the worksheet before I tell you to stop**. **Please place your pencils in the air. Okay, begin.**"

5. Time students for 3 minutes. If any students stop early, record the time they finished. Walk around to ensure students do not skip problems & to make sure they continue on to the next page after they finish one.

6. After 3 minutes, say, "**Stop. Put your pencils down. I'll come around to collect the worksheets."**

7. Collect the worksheets. Place in the envelope.

8. Collect the pencils.

9. Ask students if they have parent forms to return to you. If the form is completed, allow them to choose a prize.

10. Complete the Treatment Integrity Checklist.

Worksheet B Treatment Integrity Checklist

Teacher's name:_____ Date:_____

Person completing form:_____ Session #_____

Person administering worksheets: _____

Please check "yes" or "no" for each of the following:	**YES**	**NO**
1. Two pencils were passed out to each student.	**YES**	**NO**
2. Assignments were passed out.	**YES**	**NO**
3. Students were provided time to fill out the top page. They were assisted if necessary.	**YES**	**NO**
4. Directions were read aloud to students. Students did not begin working until instructed.	**YES**	**NO**
5. Students were told exactly when to begin the worksheets & timed for 3 minutes. During this time an adult walked around to make sure directions were followed.	**YES**	**NO**
6. Students were stopped after 3 minutes.	**YES**	**NO**
7. Assignments were collected.	**YES**	**NO**
8. Pencils were collected.	**YES**	**NO**
9. Students were asked if they had parent forms to return. Those who returned completed parent worksheets were given a prize.	**YES**	**NO**

Post-test Administration Procedures (Worksheets C-4)

(ALL STUDENTS TOGETHER – No Groups)

1. Pass out two sharpened pencils to each student.

2. Pass out worksheets **C-4**. DO NOT LET STUDENTS OPEN THE PACKETS!

3. Instruct students to write their names, grade in the fall, and the date on the top page. Help them if needed. If there is no regular teacher, they should write their group number. If there is no regular group number, then ignore this. They should write M.P. (Mount Pleasant) or G.P. (Grosse Pointe) for school district. Make sure they do not turn the page to begin working until you instruct them.

4. Instruct them in the following way: "**You are to work as quickly as you can without making mistakes. Start in the top left corner of the first page. Work from left to right and do not skip problems. After you finish one page, go on to the next. Put your pencils in the air when you are told to stop. Raise your hand if you finish before I tell you to stop**. **Now, put your pencils in the air, and, begin.**"

5. Time students for 3 minutes. If any students stop early, record the time they finished. Walk around to make sure they do not skip problems and to ensure they turn the page and keep working after they finish each page.

6. Tell students: "**Stop. Put your pencils down. I'll come around to collect the worksheets now**."

7. Collect **C-4** worksheets. Place in the folder(s).

8. Collect the pencils.

9. Ask students if they have parent forms to return to you. If the form is completed, allow them to choose a prize.

10. Complete the Treatment Integrity Checklist.

C-3 & C-4 Treatment Integrity Checklist

Teacher/School District:_____

Person completing form:_____Date:_____

Person administering worksheets: _____

Please check "yes" or "no" for each of the following:	**YES**	**NO**
1. Two pencils were passed out to each student.	**YES**	**NO**
2. C-3 worksheets were passed out to students. Students were instructed to fill out the first page & assisted if necessary.	**YES**	**NO**
3. Directions were read aloud to students. Students did not begin working until instructed.	**YES**	**NO**
4. Students were timed for 3 minutes, then stopped.	**YES**	**NO**
5. C-3 worksheets were collected.	**YES**	**NO**
6. C-4 worksheets were passed out to students, blank side facing up. Students were instructed to fill out the first page & assisted if necessary.	**YES**	**NO**
7. Directions were read aloud to students. Students did not begin working until instructed.	**YES**	**NO**
8. Students were timed for 3 minutes, then stopped.	**YES**	**NO**
9. C-4 worksheets were collected.	**YES**	**NO**
10. Pencils were collected.	**YES**	**NO**
11. Students were asked if they had parent forms to return. Those who returned completed parent worksheets were given a prize.	**YES**	**NO**

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