

A COMPARISON OF INTERSPERSAL RATIOS  
WITHIN AN EXPLICIT TIMING INTERVENTION TO  
INCREASE MULTIPLICATION FACT FLUENCY

By

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Abstract: Interspersal has been examined in the literature as a means to modify interventions and homework assignments by providing theorized reinforcement for the completion of easier problems interspersed into more difficult problems. The current study aimed to examine if any of the included interspersal ratios were more effective at increasing multiplication fact fluency than a no interspersal condition, as well as which interspersal ratio was the most effective. Participants included 62 fourth grade students in general education placements. Participants were placed, using stratified randomization, into one of the four groups: 0 %, 10 %, 20 %, and 40 % interspersal ratios. All participants received four minutes of intervention each school day, with assessment of the dependent variable, DCPM on a timed assessment, occurring following every third day of intervention. Results indicated no differences between groups in neither final observation point scores nor slopes. However, all groups grew an average of 22.16 DCPM over the course of the 132 minutes of intervention, validating ET as an effective intervention to increase multiplication fluency. Subgroup analyses of low-performing students' data was performed to examine differential responses. Low-performing students were defined as those scoring at or below 20 DCPM at the initial observation period. Subgroup analyses indicate no interspersal is more effective than all interspersal groups; although, the only statistically significant difference was between the no interspersal and the 20 % interspersal groups ( $p = .05$ ). Additionally, the 40 % interspersal group scored significantly higher at the final observation point than the 20 % interspersal group ( $p = .01$ ). These results indicate that while ET with no interspersal is the most effective, some interspersal ratios are more effective than others. Limitations to the study include a limited range of interspersal ratios examined, lack of generalizability due to the use of only one grade level of participants in the general education setting and the inclusion of only one skill, and low power, which may have affected the lack of statistically significant results.

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## CHAPTER I

### INTRODUCTION

Academic instructional time and on-task engagement have been linked to academic achievement (Albers & Greer, 1991). Since academic instructional time is fixed within a school day, efficiency of instruction is important to student academic gains. Efficiency can potentially be increased by increasing learning rates, which are defined as behavior divided by instructional time required for the change to occur (Skinner, 2008). Albers and Greer (1991) suggest increasing learning trials—which include an antecedent, student response, and consequence—may produce gains in academic achievement. However, an increase in complete learning trials may also require additional instructional time, resulting in slower learning rates over time (Skinner et al., 1997). Therefore, it is important to find ways to increase learning rates while maintaining a fixed amount of instructional time.

Mathematics instruction in public education has been unable to produce desired results with 61 percent of fourth-grade students scoring below the proficiency level on standardized

assessments (National Mathematics Advisory Panel (NMAP), 2008). In the Task Group Reports of the National Mathematics Advisory Panel, fluency was discussed as foundational for later success in algebra. They recommended that fluency building should occur in the elementary grades in order to prepare students for later mathematics achievement. Fluency is defined as the efficiency with which students are able to solve problems. It is often reported as a rate. For example, in mathematics, a fluency metric commonly used is digits correct per minute (DCPM; Deno, 2003). According to Haring and Eaton (1978), there is a sequence of expected student responding when learning a new skill. This is known as the instructional hierarchy. The first aspect of student responding is accuracy, followed by fluency. Fluency can be increased with repeated practice and the addition of reinforcement. Accuracy and fluency set the foundation for students to be able to maintain and generalize academic skills. Building computational fluency can have an effect on the maintenance and generalization of early mathematics skills to later skills.

Since basic mathematics proficiency is often inadequate (NMAP, 2008), it is important to continually refine and examine interventions to determine the most efficient and cost effective practices. As fluency is fundamental to basic skill proficiency, it is potentially the most beneficial area of performance to target. Some common fluency interventions include Explicit Timing (Van Houten & Thompson, 1976), Cover, Copy, and Compare (CCC; Skinner, Turco, Beatty, & Rasavage, 1989), Taped Problems (TP; McCallum, Skinner, & Hutchins, 2004), and Flashcard drill procedures (Nist & Joseph, 2008).

Van Houten and Thompson (1976) examined the effects of timed practice on students' skill performance on basic addition and subtraction facts, while holding instructional time constant. During conditions, baseline and explicit timing, students practiced addition and subtraction facts for 30 minutes. During the explicit timing condition, students were told they would be timed for 1-minute timings throughout the 30-minute session. Students made significant gains in the explicit timing condition (increase in rate of correct problems per minute from 6.8 at baseline to 10.5 after

explicit timing). Further research has provided more evidence in support of using explicit timing procedures to increase mathematics basic fact fluency (Coddington et al. 2007; Rhymer et al. 1998, 1999; Rhymer and Morgan 2005; Van Houten and Thompson 1976).

There are many hypotheses as to why interspersal may be an effective additive component to interventions. The addition of reinforcement to instructional practices has been shown to increase learning rates (Van Houten, Hill, & Parsons, 1975). The use of interspersal as reinforcement may also increase the probability that students will exhibit higher rates of engagement (Hawkins, Skinner, & Oliver, 2005) and attention (Neef, Iwata, & Page, 1977) during assignments. Some research suggests that student attention is imperative to intervention use, and that opportunities to respond are irrelevant without student attention and engagement (Skinner, Wallace, & Neddenriep, 2002). Additional benefits of interspersal may include increased pacing of tasks (Carnine, 1976; Van Houten & Little, 1982) and improved student self-efficacy (Neef et al., 1977).

Interspersal has been used across literacy and mathematics skills using several different procedures and ratios. Interspersal involves interspersing easier, or maintenance, items into more difficult, or acquisition, items (Cates, 2005). Since the cornerstone of interspersal is a manipulation of the items within a set of items, it can be used as a modification to multiple interventions. While conflicting results have been reported for interspersal training, this could be due to the variable procedures, ratios, and targeted skills (Billington, Skinner, Hutchins, & Malone, 2004; Billington, Skinner, & Cruchon, 2004; Cooke, Guzakas, Pressley, & Kerr, 1993; Roberts & Shapiro, 1996; Roberts, Turco, & Shapiro, 1991). Though interspersal has yet to be consistently effective, certain components of interspersal interventions have sound theoretical underpinnings. For example, successful completion of discrete tasks may serve as a conditioned reinforcer (Skinner, 2002), and items with low task difficulty may serve as more salient reinforcers. By interspersing easy problems into difficult problems, students are placed on a ratio schedule of reinforcement.

One area to consider is how to most effectively deliver an interspersal intervention, or to

determine the standard procedures and structure of the intervention. Since interspersal combines previously mastered tasks with acquisition tasks, evaluating the most effective ratios of these tasks is also important. Most of the research indicates that when there are more acquisition items involved than maintenance items, student-learning gains are greater (Roberts, Turco, & Shapiro, 1991; Roberts & Shapiro, 1996; Skinner & Oliver, 2005). These findings have been consistent across literacy and mathematics skills.

Roberts, Turco, and Shapiro (1991) examined four ratios of difficult/easy items (10/90, 20/80, 30/70, 40/60, 50/50) on vocabulary word acquisition of 42 elementary school students. Their results indicate that ratios with higher ratios of difficult items were more effective at increasing word acquisition than higher ratios of easy problems. Roberts and Shapiro (1996) examined three ratios of difficult/easy items (20/80, 50/50, and 90/10) on reading, in terms of increasing unknown words, decreasing incorrect words, increasing words read correctly, and increasing accuracy on answers to comprehension questions on curriculum based assessments. An interspersal flashcard procedure was used to increase vocabulary words known. Results, again, indicate that higher ratios of difficult items were more effective for increasing desired performance of all skills measured than higher ratios of easy items.

Hawkins, Skinner, and Oliver (2005) examined the effects of interspersing difficult/easy items in three ratios: no interspersal, 1:1, and 1:3 on increasing task completion and accuracy of mathematics computations assignments. Results show that students in the 1:3 group showed significantly higher accuracy on assigned tasks ( $p < .05$ ). Cooke and Reichard (1996) examined three ratios of difficult/easy problems (30/70, 50/50, and 70/30) on multiplication and division facts of six sixth graders receiving special education services for learning disabilities and emotional-behavioral disabilities. Their results showed the 70/30 interspersal ratio was the most effective at increasing known problem accuracy for the majority of the students. These results are consistent with other

findings.

While there has been research on interspersal ratios, methodology and ratios have differed across studies. The purpose of the current study is to develop a standard procedure for an interspersal intervention designed to increase fluency of multiplication facts, as well as to determine if the interspersal intervention is more effective than the standard explicit timing intervention without interspersal. A third purpose of this study is to determine if there is an optimal ratio of difficult-to-easy items within the intervention and if there is a ratio where interspersal becomes ineffective, or even harmful, to student growth.

There are two questions the current study aims to answer: 1) Do interspersal procedures increase multiplication fluency more efficiently than non-interspersal procedures, and 2) Is there is an optimal ratio of easy-to-difficult problems within interspersal procedures? Efficiency refers to the controlling of instructional time. Since all groups will receive interventions within a fixed time period, learning rates within groups can be calculated to determine intervention efficiency.

It is hypothesized that at least one interspersal ratio will be more effective than no interspersal procedures and that interspersal ratios with higher levels of difficult items will be more effective than ratios with lower levels of difficult items.

## CHAPTER II

### REVIEW OF LITERATURE

#### **Instructional Hierarchy and Mathematics Fluency**

Haring and Eaton (1978) outlined an instructional hierarchy, wherein there are four stage of learning: acquisition, fluency, generalization, and adaptation. Maintenance is said to be a part of each stage. During the acquisition stage, a learner acquires a new skill. The targeted area of intervention at this stage is skill accuracy. Learners gain automaticity and quickness of acquired skills in the fluency stage. This automaticity is proposed to increase the ability to conceptualize and generalize math skills (Pellegrino & Goldman, 1987; Poncy et al., 2009; Poncy et al., 2007). During the generalization stage, learners apply skills on which they are accurate and fluent to different applications. In the adaptation stage, students learn to apply mastered skills in novel settings. While teachers should use instructional techniques to progress skills through these stages in general education, some students require additional supports, known as interventions.

When examining interventions, it is important to determine which skill(s) an intervention

targets, so progress can be measured adequately. In research, the intervention should match the dependent variable expected to change as a result of treatment. Given the lack of research in the area of math fluency, the current review focuses on math fluency as an area of interest in need of further research.

A recent shift has been noticed in math education, with an emphasis on computational fluency. The 2008 Task Group Reports of the National Mathematics Advisory Panel (NMAP) states that computational fluency and automatic recall of basic addition, subtraction, multiplication, and division facts are an expected skill by conclusion of the elementary grade. This report states that addition and subtraction should be at mastery level of fluency at the conclusion of third grade and multiplication, and division should reach mastery levels of fluency before the end of fifth grade. However, research examining what constitutes mastery on fluency measures is limited and recommendations vary (Howell et al., 1993; VanDerHeyden & Burns, 2009).

Fluency of math facts is seen as an important skill level to increase conceptual understanding of generalized math skills and to promote skill maintenance and problem-solving skills (Pellegrino & Goldman, 1987; Shapiro, 2011; Woodward, 2006). Students who use more inefficient procedures to solve problems, such as counting, can often make errors and take more time to complete problems, taking away from their deeper understanding of math concepts. While teaching math facts and procedures for memorizing or solving problems can reduce the occurrence of inefficient strategies for solving problems, it can have limited effects on math fluency, given the low levels of opportunities to respond in instructional lessons. Therefore, it is necessary to add a practice component to instruction in order to increase students' opportunities to respond to stimuli, leading to increased math fact and computational fluency (Poncy, Skinner, & Jaspers, 2007).

Early math fluency research by Pellegrino and Goldman (1987) argued that additional practice on skills for which students continued to use inefficient strategies should be utilized to increase skill fluency, or automaticity. Their argument was that once students gained automaticity of the skills, they would be able to focus their attention on more complex tasks without simple computation difficulties to slow them down. This research set the tone for researchers interested in building students' skill fluency.

Jordan and colleagues (2003) screened students on expected mathematics skills, based on grade-level curriculum. Skills included exact computation, approximate computation, immediate retrieval of math facts, word problems, and more. Students were observed using finger counting as a common inefficient strategy across all skills. Over the four measures, students grew significantly on the automatic retrieval of math facts if they were categorized as having reading difficulties (intercept = 1.00) without math difficulties. Students who were categorized as having math difficulties did not differ significantly from other groups. These findings indicate that students with math difficulties have slower learning rates than those without math difficulties. This supports the notion that students with math difficulties should receive targeted interventions to increase math fact accuracy and fluency. Geary (2004) also noted the difference in skill level on multiple mathematics skills areas between those with and without math difficulties. Geary reports that students with math difficulties often used inefficient strategies to solve math problems, such as finger counting, which can lead to slow and inaccurate completion of math-related assignments.

Poncy, McCallum, and Schmitt (2010) furthered this research by examining different instructional methods on increasing fluency. There are currently two main schools of thought in instruction: constructivist and behavioral. This study compared the effects of interventions from each school of thought on increasing students' subtraction fluency. The behavioral intervention used was cover, copy, and compare (CCC), wherein students are presented with a model, cover it,



write the problem and answer, then compare their response to the model. The constructivist intervention was a modification of *Facts Their Way* (FTL; Leutzing, 2002). FTL focuses on instruction using fact families. Visual analyses indicate no separation between the control set and the FTL intervention set of problems; however, a very steep upward trend can be observed on the set of problems on which the CCC intervention was used. Results indicate CCC is more effective than FTL at increasing math fact fluency, which adds to the empirical support for behavioral instructional methods.

Poncy and colleagues (2010) state that while there are solid instructional strategies for generalization of math skills, there is rarely adequate practice of these skills and the basic retrieval computation skills to promote student growth. In this study, the researchers built fluency of addition facts using explicit timing with goal setting, feedback, and reinforcement. Once students had reached a fluency level of 40 digits correct per minute (DCPM), they were given a conceptual lesson utilizing the think-addition strategy. Using this strategy, students are taught to view subtraction as a reverse of addition, which focuses on part-part-whole relationships. Using the problem  $4 + 2 = 6$  as an example, six would be the whole of the equation, while four and two would represent the two parts. Following this lesson, students practiced the strategy using a cloze procedure, wherein students had to supply one part of an addition equation when given a part and a whole. Visual analyses showed excellent trends in addition fluency across participants; however, students did not generalize to subtraction fluency following the conceptual lesson and cloze procedure practice. Possible hypotheses for the lack of generalization include lack of fluency on all skills in all phases, as well as students having no explicit instruction in the area of subtraction – simply part-part-whole relationships.

While there is research that supports that students who struggle with mathematics often evidence deficits across multiple basic math skills (Geary, 2004; Jordan et al., 2003), there is little empirical research exploring the significance of fluency in mathematics skills; however, it is often

used as the measured behavior in intervention studies, with the intent to increase performance on DCPM, or a similar fluency measure. Coddling and colleagues (2009) conducted a meta-analysis of current math intervention studies and found that 48 percent of the included 37 studies used a fluency measure as the dependent variable, indicating nearly half of all math intervention studies examine interventions to increase math fluency. While there has been little research in this area, the literature supports that fluency of basic facts is connected to comprehension of concepts and generalization to higher-level skills (Gersten & Chard, 1999; Pellegrino & Goldman, 1987).

### **Academic Instructional Time**

With the introduction of high-stakes testing, national learning standards, and legislation that holds schools accountable for student academic growth, instructional efficiency is becoming an important area of interest for educators. Due to ever-growing expectations, the implementation of effective instruction and time management is imperative, increasing the need for research examining the comparative effectiveness of evidence-based interventions. Those interventions that produce high rates of learning using relatively little time and resources are highly valuable to public education.

Coates (2003) examined available data from the Illinois State Board of Education from 1995-1997. Data showed teachers spent an average of 146.95 minutes per day on language arts instruction, 52.43 minutes per day on mathematics instruction, 29.36 minutes per day on social studies instruction per day, and 29.19 minutes per day on science instruction. As can be seen, the majority of the instructional day was spent teaching language arts (56.97 percent). However, the instructional minutes reported represent only 4.29 hours of the school day. If a typical school day is seven hours and students are given 45 minutes for lunch and recess, this leaves 1.95 hours unaccounted for in the school day, given these data. Additionally, the assumption is that the 4.29 hours spent on effective, evidence-based instruction. However, on a standardized measure, students consistently scored higher on mathematics ( $M = 281.3$ ) than on reading ( $M = 245.1$ ),

even though students received over an hour and a half more instruction in the area of language arts than in math every school day. These results do not support the hypothesis that more instructional time leads to better student growth and performance. Again, it is important to consider the quality of instruction, rather than instructional time alone, and data on instructional quality was not reported.

Karweit and Slavin (1981) collected data on time on instruction from teachers, observed students' time on task, and measured academic achievement, to determine the extent to which instructional time affects achievement. Although teachers reported district-mandated times allotted for instruction in math, observations revealed that the time actually spent on instruction was often less than the reported time. Results show that across observations, teachers lost an average of about 86 minutes of instructional time per week. The study also measured the amount of time students were engaged. For second and third grade students, the amount of time students were engaged and the rate at which students were engaged were the only significant predictors of student growth between the pre-test and post-test of achievement, indicating instructional minutes are only effective when students are actively engaged.

Vannest and Parker (2010) collected data to support the use of *Teacher Time Use* (TTU) instrument, which measures several teaching activities with the purpose of analyzing time spent in multiple activities during a school day. Their results supported the use of the TTU and outlined some guidelines for its use. For example, it is recommended that several days of data be collected, as this reduces the error rate and trends can be observed. The TTU has been used in further studies to examine the amount of time teachers spend on instructional activities.

A more recent study examined time on teaching in special education (Vannest et al., 2011). Special education teachers were sampled from Texas school districts (N = 31; 25 female, 6 male). Teachers taught in one of four settings: adaptive behavior classrooms, resource room,

content mastery, and coteaching. Results show that teachers overall spent about 20 percent of the observed times on academic instruction, with the remaining 80 percent being spent on assessment, behavior managements, and instructional support. Instructional support accounted for an additional 17 percent of teacher time. These results show that teachers spent just over one-third of the school day actively engaging students in instruction. The results from these studies show that very little time was spent on instructional activities in the four observed settings, reiterating the warrant for more efficient time management strategies in the classroom, as well as increased instructional time.

Overall, researchers have found that very little time is spent on instructional activities across multiple educational settings (Coates, 2003; Karweit & Slavin, 1981; Vannest & Hagan-Burke, 2010; Vannest et al., 2011; Vannest & Parker, 2010; Vannest et al., 2010). Additionally, limited support has been found connecting time spent on teaching to student academic achievement (Coates, 2003). Despite the current literature, which has a very small base, those in education have supported a connection between instructional time and outcomes (Fisher & Berliner, 1985). A more appropriate measure of instructional time may be academic learning time (ALT), which involves active instruction by the teacher and active engagement by the student (Fisher & Berliner, 1985). While there are several hours of learning possible per school day, the amount of time scheduled for instruction is even less than the amount of time available. Likewise, the amount of time actually utilized for instruction is less than the amount of time scheduled.

Furthermore, the amount of time students are actively engaged in instructional activities is less than the amount of time spent on instruction), leading much of an instructional day to be wildly inefficient (Gettinger & Ball, 2010). Gettinger and Ball (2010) outline best practices for school psychologists when working with teachers on instructional time. Overall

recommendations are for teachers to establish effective classroom management procedures, to use effective instruction, interactive teaching to encourage student engagement, and differentiating instruction based on student skill level and need. Further research is warranted to examine a causal relationship between ALT and student outcomes.

### **Learning Trials**

Albers and Greer (1991) measured the effects of the rates of the three-term contingency trial, also known as a learning trial, on two junior high students with diagnosed learning disabilities using a multiple baseline design, followed by a reversal for one student. The baseline mean learning trial rate was .41 per minute. The treatment phase aimed to increase this rate to 1.25 per minute. The dependent variables were the rates of correct and incorrect student responses. Visual analyses revealed the first student's correct and incorrect responding increased during the treatment phase (by 1.03 and .28, respectively). Similar results were found for the second student. The second student's baseline and treatment phases were verified and replicated two times by a reversal. These results indicate increasing learning trials can also increase correct responses and decrease incorrect responses on assignments.

Greenwood et al. (1984) recommended requiring student responses in the same topography as would be expected in goal responses; however, Skinner and colleagues (1991) altered response topography to include a verbal response instead of a written response to increase the number of learning trials. Students increased skill performance more efficiently in the verbal response group and were given twice as many opportunities to respond. Skinner and colleagues (1997) also compared verbal to written responses in a cover, copy, and compare (CCC) intervention with two subjects. In the written response condition, students were required to respond to the stimuli in writing, while the verbal condition required to students to respond verbally to stimuli. Results were replicated in an alternating treatment, indicating the verbal

responses led to higher scores on the dependent variable (multiplication digits correct per minute) and higher rates of responding. This study supports the notion that increasing learning trials leads to an increase in learning rates.

### **Learning Rates**

Using learning rate as a measure of instructional or intervention effectiveness has been suggested in the literature (Skinner, 2010). Skinner (2010) argues that educators can use inappropriate interventions that can actually inhibit students' learning when appropriate measures and procedures are not used for analyzing data and student growth. Some research on learning rates focuses on inexact measures, such as growth per day, without accounting for instructional time. However, it is recommended that exact measures be used, as academic instructional time is fixed, and time management and efficiency is necessary. Therefore, learning rates should be calculated as the amount of learning divided by instructional minutes required to achieve that growth. For example, if a student was administered a math fluency intervention that took five minutes per day to implement, and the student grew five digits correct per week (five days per week), then the student's learning rate is .20 digits correct growth per instructional minute.

The purpose of some current intervention research is to compare interventions to determine which are the most effective at increasing learning rates. Two interventions may yield similar results, yet one requires twenty minutes to implement and the other requires ten minutes. In this situation, the intervention that requires only ten minutes to implement yields double the learning rate as the intervention that takes twenty minutes to implement. Therefore, the intervention that requires ten minutes would be considered the more effective intervention, as it uses less resources (e.g. time) but yields similar results as a much more time-invasive intervention. Increasing learning rates without increasing instructional time beyond the ability of school resources is an area of interest in intervention research and has important educational

implications.

### **Student Attention and Engagement to Intervention**

Research has shown that in order for students to make adequate growth when participating in evidence-based interventions, students must be engaged to the learning tasks (Cates, Burns, & Joseph, 2009). Levels of student engagement have ties to task difficulty. Gilbertson and colleagues (2008) examined student on-task behavior during three conditions of task difficulty: high, moderate, and easy. Students were administered multiple math skill probes, and the probes were assigned to one of the three conditions dependent on the students' scores. Visual analyses of the data indicate students were consistently observed as being more on-task during the moderate difficulty condition than in the high difficulty condition. Likewise, students were also observed as being more on-task during the easy condition than during the moderate condition. These results indicate that students are more engaged during tasks that require little effort, as opposed to difficult tasks.

The theory behind student preference research is that reducing student effort has the potential for increasing student engagement and success. However, reducing effort does not necessarily require that opportunities to respond be reduced. Interspersal has been examined as a means for reducing response effort while increasing response rate and student engagement, as well as altering student perceptions of task difficulty (Skinner, Wallace, & Neddenriep, 2002).

Using additive and substitutive interspersal procedures, many researchers have found that, when given a choice, students will choose to complete assignments with easier problems interspersed (Billington, Skinner, & Cruchon, 2004; Cates & Skinner, 2000; Wildmon, Skinner, Watson, & Garrett, 2004). In addition to students preferring interspersal assignments, researchers have measured increased attention and on-task behaviors during interspersal assignments when compared to control assignments (Dickinson & Butt, 1989; Horner, Day, Sprague, O'Brien, & Heathfield, 1991; McCurdy, Skinner, Grantham, Watson, & Hindman, 2001). Hawkins, Skinner, and Oliver (2005) propose three explanations for this increase in student on-task behavior

following the implementation of additional, but quicker or easier, items: increased pace, each discrete trial (problem completed) may serve as a reinforcer, and increased self-efficacy.

### **Explicit Timing**

Explicit timing (ET) is an evidence-based intervention designed to increase math fact fluency (Coddling et al. 2007; Rhymer et al. 1998, 1999; Rhymer and Morgan 2005). ET is particularly useful in the applied educational setting because it requires very little time to implement and can be administered in groups or entire classes. ET utilizes two parts of the three-term contingency, or learning trial: antecedent (problem to be completed) and student response (student answer to problem).

Van Houten and Thompson (1976) initially examined the effects of timed practice on students' skill performance on basic addition and subtraction facts, while holding instructional time constant. Under each condition, baseline and explicit timing, students practiced addition and subtraction facts for 30 minutes. The difference between the groups is that in the explicit timing condition, students were told they would be timed for 1-minute timings throughout the 30-minute session, while in the control condition, students were not timed other than for the whole 30 minute period. Students made significant gains in the explicit timing condition (increase in rate of correct problems per minute from 6.8 at baseline to 10.5 after explicit timing). Further research has continued to support explicit timing as a means of increasing students' accurate responding to mathematics problems (Miller, Haal, & Heward, 1995; Rhymer et al., 2002; Rhymer et al., 1999; Rhymer et al., 1998) and language arts skills (Van Houten, Hill, & Parsons, 1975; Van Houten et al., 1974).

Van Houten and colleagues (1974) examined the effects of explicit timing, along with feedback, on students' writing response rates. Participants were second and fifth grade students. During baseline, students were assigned a writing topic, and then were told to write as many words on the topic as they could, within ten minutes. Following this task, papers were collected, and experimenters scored total words written, barring words from nonsensical sentences.



Following baseline, students were shown a graph of previous performance and were told they would be timed for ten minutes using a new topic. Students were encouraged to beat their previous scores during each session. Student response rates increased significantly in both grades, based on visual analyses. Experimenters also rates students' writing higher in the areas of mechanical aspects, vocabulary, number of ideas, development of ideas, and internal consistency in the explicit timing condition. Results indicate that the addition of explicit timing of students' work, with performance feedback, is effective at increasing response rate and quality of writing samples.

In a replication of the previous study, Van Houten, Hill, and Parsons (1975) examined the effects of explicit timing and performance feedback, as well as public posting of scores and praise for success, on increasing students writing response rates. Participants were fourth grade students, separated by reading ability. Stronger readers were given 20 minutes to complete baseline assessments, while weaker readers were given ten minutes to complete baseline assessments, due to teacher preference and opinion on students' abilities. Following baseline, students were told they would be timed during all future writing challenges. After students completed the writing challenge each day, they counted the number of words they had written in order to be given immediate performance feedback. Several more phases were introduced, including the addition of praise to timing and feedback, the addition of public posting of results to timing and feedback, and a combination of all four components: timing, feedback, public posting, and praise. A reversal design was utilized to examine the effects of each component, as well as different combinations of components. Results indicate that students increased their response rates by almost double from the baseline condition to the timing and feedback condition. The stronger reading group increased from 4.5 words to 8.3 words per minute, and the weaker reading group increased from 1.8 words to 3.5 words per minute. The addition of public posting increased scores by an additional 2.5 words per minute and 1.9 words per minute, respectively. Praise increased responding in the strong readers group but had no effect on the weak readers

group. Results indicate that explicit timing is effective at increasing students' writing abilities and can be made more effective by adding feedback and public posting of scores.

Math fact fluency has been extensively researched as a target behavior and outcome of explicit timing interventions. Miller, Hall, and Heward (1995) examined the effects of explicit timing, along with feedback and self-correction on increasing math fact fluency. Student participants included one classroom of students receiving special education services and a first grade class. Dependent variables included the rate of correct student responses, the percentage of correct student responses, as well as on-task behavior during explicit timing intervention sessions. Three conditions were examined. Two conditions included delayed feedback (following day) – one of these conditions consisted of a ten-minute session without breaks, and the other condition consisted of seven one-minute timings. Students in the final condition were given two one-minute timings, immediately followed by feedback and self-correction, based on choral responses during feedback. Results for the first grade class indicate that the introduction of one-minute explicit timings increased students' rates of responding (mean increase from 4.8 to 7.3), and students' responding increased each time the explicit timing condition was re-introduced. Accuracy also increased from pre-test to post-test (mean increase from 82.5% to 90.4%). The final dependent variable, on-task behavior, increased from an average of 55.9% during baseline to an average of 80.1% during explicit timing conditions. Visual analyses indicate students in the special education classroom grew at similar rates as those in the first-grade class; however, the data from the special education class appeared to be more variable across all conditions. These results indicate that though students with math difficulties may need additional supports to enhance stabilization of student response data, students who receive and do not receive learn at similar rates under explicit timing conditions.

Rhymer and colleagues (1998) examined the effects of explicit timing on increasing African American students' response rates on math problems. Students were given four minutes to complete addition, subtraction, and multiplication problems in each session. During the

baseline condition, students completed problems for the entire four minutes without interruption. During the explicit timing condition, students were told they would be timed in one-minute intervals for a total of four minutes. Visual analyses of results show a clear level change in problem completion rates between the baseline and explicit timing conditions. Accuracy rates appear to remain semi-constant across conditions. These results indicate that explicit timing is an effective intervention for increasing student responses, but modifications may be necessary to increase students' accurate responding.

In a follow-up to the previous study, Rhymer and colleagues (1999) examined differences between Caucasian and African American students by administering an explicit timing intervention and measuring student progress on single-digit addition and subtraction fact fluency. During baseline, students were given four minutes and told to complete as many items as possible, but were not told how long they would be given. In the experimental condition, students were explicitly told they would be timed for four one-minute timings. After each minute, the students were instructed to stop, draw a circle around the last completed problem, and then get ready for the next timing. Number of completed problems and percentage of problems correct served as the dependent variables. Both African American (mean increase from 37 to 49) and Caucasian (mean increase from 34 to 44) showed statistically significant increases on total problems completed, but there were no differences between conditions on percentages of problems correct. There were no between-group differences, indicating Caucasian and African American students learn at similar rates when presented with explicit timing as a means to increase addition and subtraction fact response rates.

Rhymer and colleagues (2002) examined the effects of explicit timing on increasing single-digit addition and subtraction and 3 x 3 digit multiplication computation fluency in sixth grade students. Dependent variables included problem completion rates per minute and percentage of problems completed accurately. Initially, students were given the math worksheets to complete in an untimed condition. During the explicit timing condition, students were told

they would be allowed three minutes to complete as many items as possible. Results showed significantly higher response rates in the explicit timing condition for addition ( $M = 30.9$ ), subtraction ( $M = 12.1$ ), and multiplication ( $M = 1.9$ ) when compared to the baseline condition ( $M = 22.7, 10.6, \text{ and } 1.5$ , respectively). Students' percentage of problems completed correctly showed differences between conditions. These results support earlier research; indicating modifications may be needed to support accuracy growth.

Interventions are often initially implemented in the simplest form, and then modified to fit the needs of the student, based on the data. Modifications are most effective when the specific needs of the student are considered when tailoring interventions (Duhon et al., 2014). Some common modifications, which add the final part of the learning trial – consequence, have shown evidence of being effective in the literature. These include immediate feedback (Duhon et al., 2014; Gross and Duhon 2013; Van Houten, Hill, & Parsons, 1975), goal setting (Coddling et al. 2005), reinforcement (Freeland and Noell 1999), and self-graphing (Coddling et al., 2005). Interspersal is a potential modification with theoretical implications in the area of reinforcement.

### **Reinforcement to Increase Learning Rates**

Herrnstein (1961) authored a formula, known as the matching law, which can be used to predict behavior according to rates of reinforcement. If a student has the ability to engage in incompatible behaviors, whichever behavior leads to high rates of reinforcement will win. The matching law indicates that reinforcement has the ability to increase student behaviors.

Reinforcement can be an added component to any intervention that targets skills students have already acquired, such as fluency-building interventions. The purpose of reinforcement paired with an intervention is to increase motivation to perform a skill. Additionally, the increase in skill proficiency and ease of problem completion can serve as reinforcement. Skinner and colleagues (1996) examined the relationship between task difficulty and student preference. The control assignment consisted of 3 x 2 multiplication problems, whereas the experimental assignment consisted of some 3 x 2 multiplication problems, as well as interspersed single-digit

multiplication problems. Students were allotted 305 seconds to work on each assignment, then were given a survey about the assignments. Students were asked to report which assignment would take the longest amount of time to complete in its entirety and which assignment was more difficult. Results indicated that students completed significantly more problems on the experimental assignment than on the control assignment, however, there were no differences between the groups on 3 x 2 problems completed and accuracy rates on 3 x 2 problems. More students reported that the experimental assignment would take less time and effort to complete, despite the fact that it had six more problems than the control assignment.

Given that ease of problem completion can serve as reinforcement (Skinner et al., 1996), it is possible that interspersing easy problems into more difficult problems on an assignment can serve as reinforcement, which increases the probability of students engaging in the behavior of working on the assignment. This is the theoretical basis of interspersal as a modification to academic interventions.

### **Interspersal**

Interspersal is a modification that can be applied to multiple interventions. In addition to applying interspersal procedures to interventions, interspersal can be used as a modification to homework assignments or assessments. When using interspersal as a modification to assignments and assessments, there are two procedures from which to choose: additive and substitutive. Additive interspersal includes adding the easier items into the more difficult items, which increases the total amount of problems to be completed. Substitutive interspersal includes removing some difficult problems and replacing them with easier problems, thus maintaining the amount of problems to be completed (Cates, 2005).

Dunlap and Koegel (1980) examined the effects of interspersing varied tasks versus a control group of consistent task delivery on student response in students with autism. Effects were measured by the percent of correct responses to provided stimuli. Visual analyses show more consistent, less variable, upward trending data in the interspersal condition, as opposed to

the control group of no interspersed stimuli. Additionally, results show that student nonresponses to stimuli drastically reduced in the interspersal condition. These results support the underlying theory that interspersal can be reinforcing for students, thus motivating them to increase performance levels.

Wildmon and colleagues (1998) examined the effects of adding easier problems to math homework assignments with college students. The control assignment consisted of eight target problems. The interspersal assignment included the eight target problems, plus an additional three easy problems, resulting in more problems to be completed. Results show that while accuracy was not different between the interspersal assignment and the control assignment, problems completed increased and student preference was higher for the interspersal assignment. A follow-up study was conducted with high school students (Wildmon et al., 1999) and similar results were found.

Cates and colleagues (1999) examined the effects of interspersing more simple problems into an assignment on student preference. In the first study of this article, students were presented with two assignments. The first assignment included 15  $3 \times 2$  multiplication problems. The second assignment included 18  $3 \times 2$  multiplication problems and an additional six single-digit multiplication problems. After students completed the assignments, they were given a survey to determine which assignment students thought was most difficult, which was more time consuming, which would take the most effort, and which they would prefer to complete in the future. Students in the interspersal group ( $M = 12.48$ ) completed more problems than the control group ( $M = 9.11$ ). However, there were no differences between groups on the number of  $3 \times 2$  problems completed or percentage of accurate responses. Students reported favoring the interspersal assignment on all survey questions.

The second study in the article (Cates et al., 1999) followed up two weeks following the initial study. All procedures were the same, apart from the assignments. The control assignment remained the same, but the interspersed problems were removed from the experimental

assignment, leaving 18  $3 \times 2$  multiplication problems. In this study, the results indicated no significant differences between groups on problems completed or percentage of correct problems. Additionally, more students reported favoring the control assignment; however, differences were not statistically significant. The third study examined interspersal ratios; therefore, it is reported in the following section.

Cates and Skinner (2000) examined interspersal procedures that increased student preference for assignments, even when assignments consisted of more problems. All participants received remedial math services in a rural high school. Students completed a worksheet with multiplication problems. One side of the worksheet consisted of control problems –  $3 \times 2$  multiplication problems. The opposite side of the worksheet had one single-digit multiplication problem interspersed after every third  $3 \times 2$  multiplication problem. However, there were 0, 20, or 40 percent additional  $3 \times 2$  problems included, depending on group assignment. Following completion of the time allotted for worksheet completion, students were asked to identify which assignment they anticipated would take the most time and effort to complete, the most difficult assignment, and which assignment they would prefer to complete in the future. Results show that students reported that students reported the control assignment would take more time to finish, was the most difficult, and would require the most effort to finish at statistically significant levels (nearly 70 percent of students). Students also reported preferring all three experimental assignments to the control assignment (range: 65 – 69 percent).

Meadows and Skinner (2005) argued that much of the research on additive interspersal to increase accurate student responding on and preference for interspersal assignments has limited validity, due to a lack of alignment with curricula and consequences, or incentives, for responding. This study examined the effects of interspersal on increased accurate responding on curricula-aligned assignments for seventh grade students. On the interspersal assignment, following every third target item a simpler problem was interspersed, resulting in eight total interspersed items. Once students had completed the assignments, they were given a survey to

report assignment difficulty levels and preferences for assignments. Results indicate students completed significantly more problems on the interspersal assignment ( $M = 11.53$ ) than on the control assignment ( $M = 8.39$ ). Additionally, 85% of the participants preferred the interspersed assignment. These results support previous research indicating interspersal can increase student responding on assignments, as well as increase students' preference for assignments.

In an attempt to replicate early research on additive interspersal procedures with elementary-aged students, Rhymer and Cates (2006) examined the effects of two assignments on student preference and response rate. One assignment used an explicit timing procedure in which students were told they would have one minute to complete as many problems as they could. The six problems on this assignment were all target problems. The other assignment used an additive interspersal procedure by adding two easier problems to the six target problems. Results showed a statistically significant increase in problems completed correctly for the interspersal assignment ( $p = .00$ ,  $d = 1.29$ ) but no difference in target problems completed correctly. During preference assessments, students rated the explicit timing assignment as having a higher level of difficulty and taking longer to complete. Interestingly, there was a statistically significant difference ( $p = .01$ ,  $d = .47$ ) in the time to completion between the assignments, with the interspersal assignment taking a little over 30 additional seconds to complete, on average, indicating student perspectives on length of time differed from the actual amount of time spent on the assignments.

Research has also examined interspersal as a means to increase student responding on assessments. Robinson and Skinner (2002) examined the effects of interspersing mastered math skills (based on teacher report) into a standardized math assessment on seventh grade students. Students were administered two forms of the assessment – one form with mastered problems interspersed and one form without interspersed problems. Following the completion of the assessments, students were given a survey to determine student preference of assessment form. Dependent variables included the scaled scores of the standardized assessments, as well as percentage of problems answered correctly on the assessments. Students scored significantly



higher, according to scaled scores, in the interspersal condition ( $M = 9.6$ ) on the computation portions of the assessments than in the control condition ( $M = 7.6$ ). No other subtests differed significantly between conditions. Task demands for computation portion of the assessment were hypothesized to be more difficult and requiring longer periods of attention. These results indicate that interspersing mastered problems into a standardized assessment may increase student scores in some areas. However, the validity of the scores can be called into question, given the assessment is no longer standardized when procedures vary, leaving scaled scores and normed percentiles un-interpretable.

In another facet of interspersal research, Montarello and Martens (2005) compared baseline responding to two experimental conditions: interspersal alone and interspersal with additional reinforcement. In the interspersal condition, a simpler problem was interspersed following every third target item. In the interspersal and reinforcement condition, interspersal rates remained the same. Additionally, students were able to earn a token for each problem completed. Tokens could be exchanged for candy following completion of the assignments. Sessions for each condition were ten minutes in length. Dependent variables included total digits correct, as well as digits correct per minute. All four students increased total digits correct from baseline ( $M = 275.25$ ) to the interspersal condition ( $M = 290.45$ ) and, again, to the interspersal with reinforcement condition ( $M = 307.50$ ). These results indicate that while interspersal increased students' correct responses, outcomes could be made even more favorable with the addition of a tangible reinforcer.

Clark and Rhymer (2003) were the first to conduct a comparative study comparing the effects of interspersal and explicit timing. Participants were college students; however, the target (three-digit subtraction) and interspersed (single-digit subtraction) items were elementary grade-level skills. Participants completed packets that contained an explicit timing assignment, and an interspersal assignment, as well as a survey on assignment preference. Students were given three one-minute timings to complete as many problems as possible on both assignments. The majority

of the students (14 out of 19) reported preferring the interspersal assignment. No differences were found between item completion rates, target item completion rates, or percentage of problems completed accurately. These results indicate that while interspersal may not be more effective than explicit timing in general, interspersal could potentially benefit students with little motivation to complete assignments, as most students preferred the interspersal assignment and rated it as easier to complete.

In a follow-up study to Clark and Rhymer (2003), Rhymer and Morgan (2005) compared the outcomes of interspersal and explicit timing with third grade students. Target items were 2-digit subtraction problems requiring a borrowing procedure, and interspersed items were single-digit subtraction problems. One interspersed item was placed after every third target item, which is consistent with other research in the area (Skinner, 1998). Students were given three minutes of one-minute intervals to complete as many items as possible (Rhymer & Morgan, 2005). Three data points were collected for each assignment type: control, explicit timing, and interspersal. The average problems completed are significantly higher for the interspersal assignments ( $M = 16.04$ ) than the explicit timing assignments ( $M = 13.00$ ); however, the average number of target items completed was significantly lower for the interspersal assignments ( $M = 11.56$ ) than the explicit timing assignments ( $M = 13.00$ ). No significant differences were found for percentages of problems completed accurately between groups. These results indicate that while students complete more problems under interspersal conditions, there are also more problems to complete, leaving target problems incomplete when time is held constant across conditions. The effects of an interspersal modification to an intervention on increasing student correct response rates on target items could be an future area of interest, given these results. An additional finding was that teachers tended to rate the interspersal intervention more favorably than the explicit timing intervention, indicating teachers may be more willing to implement an interspersal intervention than an explicit timing intervention, which has implications for academic consultation with teachers.

The majority of the research on the additive interspersal procedure indicates that while it does not increase learning rates, there is evidence that students prefer and are more attentive to tasks when easier problems are interspersed into more difficult problems, even when the workload is increased (Cates, 2005; Cates & Skinner, 2000). Therefore, additive interspersal may be useful for students who are difficult to motivate, as it is possible that adding the interspersed items relieves the sense of difficulty and effort for the student.

### **Interspersal Ratios**

In addition to these two versions of interspersal (additive and substitutive), multiple ratios of easy-to-difficult problems can be implemented. Roberts, Turco, and Shapiro (1991) examined the effects of five ratios of easy-to-difficult items (9:1, 4:1, 7:3, 3:5, and 1:1) on vocabulary acquisition of 42 elementary school students. In this study, interspersal was used as a modification to a traditional flash card intervention. Their results indicate that ratios with higher rates of difficult items were more effective at increasing word acquisition than higher ratios of easy problems.

In an extension of the previous study, Roberts and Shapiro (1996) examined the effects of 3 ratios of known-to-unknown interspersed items: 4:1, 1:1, and 1:4, as well as a control group. The dependent variables included vocabulary words unknown, oral reading fluency measures (pre and post-test; words read correctly per minute and errors) a comprehension measure, percentage of words learned during treatment, and correctly read words and errors (measured by curriculum-based assessment weekly). Students were assigned to group so each group would have a similar make-up of students at each level on the dependent variables. Interspersal ratios were applied to a traditional flash card intervention. Students learned a significantly higher percentage of vocabulary words in the 4:1 interspersal group than in all other groups. Similarly, the 1:1 interspersal group learned a significantly higher percentage of vocabulary words than the 1:4 and control groups. However, the 1:4 interspersal group learned more words, overall ( $M$  slope =

5.97). Inversely, on the post-test measures, the 4:1 interspersal group made greater gains in known vocabulary words from pre-test ( $M = 161.50$ ). Roberts and Shapiro (1996) hypothesized some explanations for the mixed results, such as the amount of new information presented, the demographics of the participants, as well as a novelty effect due to the computer-based nature of the treatment. Ultimately, the results indicate that all interspersal ratios produced greater results than no treatment; however, the most effective ratio cannot be determined from this study.

Roberts, Turco, and Shapiro (1991) examined the effects of interspersing on learning words. Dependent measures included words learned during intervention, as well as multiple reading measures, such as oral reading fluency and comprehension. The following ratios of known-to-unknown words were used: 9:1, 4:1, 3:2, and 1:1. Participants in the 1:1 group ( $M = 62.66$ ) and the 3:2 group ( $M = 48.65$ ) increased significantly on total words learned over the other groups. Given the students placed in groups where they were presented with more unknown words each session were given the opportunity to learn more words, it is intuitive that they would learn more words. However, when percentage of words learned was examined, there were no differences between groups, indicating all groups learned a similar percentage of unknown words. These results indicate that when more unknown items are presented in an interspersal modification, students have stronger learning rates.

Cooke, Guzaukas, Pressley, and Kerr (1993) compared new-to-maintenance problems interspersal ratios of 3:7 to 1:0, so 30% new problems to 100% new problems, on the acquisition of correctly spelled words. Interspersal was used as a modification to a traditional flash card intervention in this study. Results indicated no differences between the groups on learned words and accuracy; however, maintenance results show students in the interspersal condition scored higher on measures of maintenance. Given the students were practicing maintenance problems, as well as new problems, these results are not surprising. A second experiment in this publication examined the same groups of interspersal versus no interspersal on single-digit multiplication digits correct per minute. Results show students in all conditions showed excellent growth on the

dependent variable, with all students showing greater growth in the experimental condition, according to visual analyses. These results support the use of interspersal to promote skill growth and maintenance of known items in the areas of spelling and multiplication.

Roberts and Shapiro (1996) examined the effects of three known-to-unknown interspersal ratios (4:5, 1:1, and 1:5), as well as a control group, on increasing known vocabulary words using a flashcard intervention. All groups, including the control group, showed significant gains on the dependent variable between pre-test and post-test, so results should be interpreted with caution, as it is possible maturation or outside variable could be responsible for differences. Both the 1:1 and the 1:5 group increased known words significantly faster than the 4:5 group. Additionally, the 1:5 group gained significantly more known words than the 1:1 group. This supports other research where findings indicate lower rates of easy problems interspersed into more difficult problems are more effective at increasing learning rates.

Hawkins, Skinner, and Oliver (2005) examined the effects of three interspersal ratios (0, 1:1, and 1:3;  $N=52$ ) on increasing accuracy of target skills. Difficult problems included multi-digit addition and subtraction problems that included regrouping or borrowing procedures. Easy problems did not require regrouping or borrowing procedures. Results showed that students in the 1:3 ratio group ( $M=64.85$ ,  $SD=3.55$ ) increased their accuracy significantly from the no interspersal group ( $M=59.62$ ,  $SD=3.75$ ). The 1:1 interspersal group ( $M=62.93$ ,  $SD=3.59$ ) did not significantly differ from the no interspersal group, indicating that there is an effectiveness curve wherein interspersal ceases to produce desired effects.

Cooke and Reichard (1996) examined the effects of three ratios of easy-to-difficult problems (7:3, 1:1, and 3:7) on multiplication and division fact acquisition of six sixth graders. The participants were receiving special education services for learning disabilities and emotional-behavioral disabilities. Interspersal was used as a modification to a traditional flash card intervention. Results showed that the 3:7 interspersal ratio was the most effective at increasing known problem accuracy for the majority of the students.

A third study report by Cates and colleagues (1999) utilized a completely different set of participants to examine three control assignments and three experimental assignments. All control assignments included 15  $3 \times 2$  multiplication problems. The experimental assignments included 20, 40 or 60 percent additional  $3 \times 2$  items, with every third problem being a single-digit multiplication problem. All other procedures were similar to the first two studies. In all ratios, students completed more problems on the experimental assignments than on the control assignments. In the 20 and 40 percent groups, students also completed more  $3 \times 2$  problems than the control groups. Students in the 20 percent interspersal group reported the experimental assignment was less difficult and required less effort than the control assignment. Students in this condition also reported they would choose the experimental assignment over the control assignment.

Cates and Erkfritz (2007) examined the effects of multiple ratios of interspersed items (1:1, 2:1, 4:1, and no interspersal) on student response rates and preference. Similar results to other interspersal studies – students completed more total problems under interspersal conditions but completed more target items under non-interspersal conditions. Additionally, students in the 1:1 and 2:1 interspersal conditions rated the interspersal assignment as easier, less time consuming, and preferable to the control assignment, indicating a ratio of four target items to 1 interspersal item may be too thin of a reinforcement schedule to be effective at increasing student response rates and preferences.

A more recent, unpublished thesis by Hou (2010) compared the effects of one interspersal ratio (1:1) utilizing ET to untimed practice of problems with the same interspersal ratio (1:1). The dependent variable in this study was digits correct per minute on addition and subtraction problems. Participants included five students with mild/moderate disabilities who were all receiving math services in special education, according to their Individualized Education Plans. Visual analyses were used to determine the effectiveness of the two interventions. Results differed across students, but the ET with interspersal condition was typically more effective than

the untimed with interspersal condition, though the differences do not appear to be significant. Given the interspersal ratios were the same for both conditions, this study ultimately examined the effects of timed versus untimed practice, despite its claim to study interspersal ratios.

It is intuitive that the research on interspersal techniques would be conflicting, given so many procedural options for its implementation. While there is little research examining the effects of interspersal modifications being used to increase the intensity, and thus the effects, of an intervention, the bulk of interspersal research examines student preference for interspersed assignments. Many of the above interspersal studies examine interspersal as a modification to flash card interventions on acquiring new skills, such as sight words.

Very little quality research has been conducted to examine the effects of interspersal on increasing skill fluency. Given the underlying theory behind interspersal is that interspersing easier problems into more difficult problems serves as reinforcement, its effects on increasing fluency should be examined. Additionally, as the majority of comparative interspersal ratio studies have shown stronger effects for interspersal when lower rates of easy problems are added to more difficult problems (fewer than fifty percent easy problems), future research should focus on examining the ideal ratio of easy-to-difficult problems within that range.

## CHAPTER III

### METHODOLOGY

#### **Participants and Setting**

Participants consisted of 56 fourth grade students in general education classrooms in central Oklahoma. Inclusion in the study required potential participants to complete a preliminary worksheet of all multiplication problems with multipliers from 0 to 9 with 80 percent accuracy. Participants ranged in age from 9 to 11 years old. Of the participants, 31 were male and 28 were female. Thirty-eight participants (68 %) were Caucasian, 6 were Native American (11 %), 4 were Hispanic (7 %), 7 were African American (13 %), and 1 was Asian American (2 %). Participants were randomly assigned to one of 4 groups, identified by percentage of easy problems: 0 % easy problems, 10 % easy problems, 20 % easy problems, and 40 % easy problems. Of the initial 62 participants, six participants were removed from analyses due to excessive missing data, resulting in 56 participants. The criterion for exclusion based on missing data was three or more missing data points.

This study was part of Math Two-A-Days, a systems-wide math fluency intervention study. This study was covered under the scope of IRB approval for Math Two-A-Days. Graduate



students in school psychology implemented the daily intervention, while the principal investigator and classroom teachers collected measures of the dependent variables.

## **Materials**

Participants were provided with experimenter-constructed worksheets, developed through Microsoft Excel, each morning during the study. Multiplication problems in different ratios of easy to difficult, according to assigned group, were randomly ordered into nine rows of eight problems each for a total of 72 problems per worksheet. Difficult and easy problems were randomly selected from a set of problems. Easy problems were evenly spaced throughout the worksheets in differing ratios according to group, with the exception of the 40 % interspersal group. The worksheets for this condition followed the pattern of two difficult-one easy-one difficult-one easy. Participants were provided with a folder at the beginning of the week, which included all of the intervention worksheets for the entire week. Additional worksheets were available and dispersed in the event that a participant completed a worksheet prior to the end of the timing period.

A multiplication worksheet that included each possible problem with multipliers from 0 to 9 was administered to determine accuracy. An inclusion criterion in the study was to complete the worksheet with 80 % accuracy. This assessment was administered prior to the start of the intervention. Students scoring below 80 % on the inclusion assessment were given an accuracy intervention during the duration of the study.

Multiplication probes generated using Microsoft Excel were used to collect baseline and each data point throughout the study. Eleven assessment probes each (one for each data collection) were created for difficult multiplication problems (those including multipliers of 6, 7, 8, and 9) and for mixed multiplication problems (multipliers of 0 through 9). One set of each assessment probe was used as the baseline measure, with the alternate sets used to collect data on the dependent variables every third session throughout the duration of the study.

## **Experimental Design and Analysis**

This study used a longitudinal randomized design. This design increases power by collecting datum points across time for each subject, while allowing analyses across groups (Shadish, Cook, & Campbell, 2002). The study used a stratified random sample to ensure equal initial levels of multiplication fluency in each of the four groups. All of the groups received an ET with interspersal intervention, with the independent variable being the manipulation of the interspersal ratios.

Data were analyzed using Growth Curve Modeling, a model using Hierarchical Linear Modeling (HLM), to compare differences between groups. These analyses allow for comparison of groups at different time points during the study, as well as to analyze trends in the data. Using HLM, time points are nested within students, in order to account for the variance between dependent measure scores that is due to participants (Raudenbush & Bryk, 2002).

**Independent variable.** The independent variable was the ratio of easy problems interspersed into a worksheet of difficult problems. Group one, the 0 % interspersal percentage, received daily timed practice on a worksheet with no easy problems. Group two, the 10 % interspersal percentage, received daily timed practice on a worksheet with five easy problems. Group three, the 20 % interspersal percentage, received timed daily practice on a worksheet with ten easy problems. Group four, the 40 % interspersal percentage, received timed daily practice on a worksheet with 20 easy problems. Each group received timed practice on two worksheets for two minutes each, per day, for a cumulative four minutes per day.

**Dependent variables.** Digits correct per minute (DCPM) on the difficult and mixed problems assessment probes were used as the dependent variables for the study. A digit was counted correct if it was the correct numeral written in the correct column (Deno & Mirkin, 1977). For example, if a subject provided the answer “24” for the problem “6 x 4 =,” the answer was scored as two digits correct. If the subject provided the answer “22” to the same problem,

then the answer was scored as one digit correct because only the “2” in the tens column was correct. If the subject provided the answer “31” to the same problem, the answer was scored as 0 digits correct because neither column received a correct number. DCPM was used as it is an objective measure of student performance on multiplication facts (Deno, 2003) and enables the experimenter to calculate learning rates.

## **Procedures**

**Interspersal Intervention.** Participants practiced the interspersal intervention once each school day during the study in their general education classrooms. Graduate students in a local school psychology program administered the daily interspersal intervention. Participants practiced the interspersal intervention once daily during the study in their general education classrooms. The intervention consisted of two 2-minute timings of the prepared worksheets for any given day. Procedural integrity of administered directions was collected for 44 % percent of the intervention sessions.

Due to the hypothesized function of the independent variable, external reinforcement was controlled by removing any evident external reinforcement, such as goal setting, self-graphing, and teacher/researcher praise and encouragement.

**Collection of the Dependent Variables.** The dependent variables were assessed before intervention as the baseline and following every third day of intervention during the intervention phase. These data were gathered using timed 1-minute assessment probes. The researcher and classroom teachers timed participants for one minute on each assessment probe. The assessment probes were then collected and scored. The score of DCPM from the difficult and mixed problems assessment probes were used in analyses. A new, randomized version of each assessment probe was administered for each data collection session, with the order of the probes selected randomly for each data collection period. If the difficult problem probes were classified as assessment A and the mixed problem probes classified as assessment B, the sequence of probe

administration was as follows: AB, BA, BA, AB, BA, AB, BA, AB, AB, BA, AB. Procedural integrity of administered directions was collected for 48 % percent of the assessment sessions.

### **Inter-scorer Agreement and Procedural Integrity**

Inter-scorer agreement was assessed by comparing initial scorer and independent scorer DCPM counts for 31 percent of all assessment probes. Agreement was calculated by dividing the number of agreed digits by the number of digits disagreed upon and multiplying by 100. Inter-scorer agreement ranged from 88 % to 100 % (M = 99.34 %).

Procedural integrity of assessment sessions was collected by a second experimenter, using a checklist of the assessment protocol. Percentage of integrity of integrity was calculated by dividing the number of steps completed by the total number of steps and multiplying by 100. Procedural integrity was assessed for 48 % of the assessment sessions. Procedural integrity ranged from 100 % to 100 % (M = 100 %).

Procedural integrity of intervention sessions was measured by a second experimenter, using a checklist of the intervention protocol. Percentage of integrity was calculated by dividing the number of steps completed by the total number of steps and multiplying by 100. Procedural integrity was assessed for 44 % percent of the intervention sessions. Procedural integrity ranged from 100 % to 100 % (M = 100 %).

## CHAPTER IV

### FINDINGS

Data for the current study were analyzed using a form of the generalized linear model called growth curve modeling, or hierarchical linear modeling (HLM; Raudenbush & Bryk, 2002) with restricted maximum likelihood estimators. This form of analysis is used to analyze growth rate differences between individuals and examine treatment differences between groups across data points. HLM is able to control for violations of independence, allows the examination of individual participants' growth across time points, and allows the modeling of slope and level differences in relation to selected predictors by considering observation points (level-1) as nested within individual students (level-2). Using HLM, time points are nested within students, in order to account for the variance between dependent measure scores that is due to participants (Raudenbush & Bryk, 2002). Observation points in this study included the initial measurement time point, as well as ten additional data points collected across the time of the study (11 observations per student). The final two-level model was defined as:

Level-1 Model:  $SCORE_{it} = \pi_{0j} + \pi_{1j}*(LINCEN_{mj}) + \pi_{2j}*(QUADCEN_{mj}) + e_{mj}$

Level-2 Model:  $\pi_{0j} = \beta_{00} + \beta_{01}*(D2_j) + \beta_{02}*(D3_j) + \beta_{03}*(D4_j) + u_{0j}$

$$\pi_{1j} = \beta_{10} + \beta_{11}*(D2_j) + \beta_{12}*(D3_j) + \beta_{13}*(D4_j)$$

$$\pi_{2j} = \beta_{20} + \beta_{21}*(D2_j) + \beta_{22}*(D3_j) + \beta_{23}*(D4_j)$$

$$\pi_{0j} = \beta_{00} + \beta_{01}*(D1_j) + \beta_{02}*(D3_j) + \beta_{03}*(D4_j) + u_{0j}$$

$$\pi_{1j} = \beta_{10} + \beta_{11}*(D1_j) + \beta_{12}*(D3_j) + \beta_{13}*(D4_j)$$

$$\pi_{2j} = \beta_{20} + \beta_{21}*(D1_j) + \beta_{22}*(D3_j) + \beta_{23}*(D4_j)$$

$$\pi_{0j} = \beta_{00} + \beta_{01}*(D1_j) + \beta_{02}*(D2_j) + \beta_{03}*(D4_j) + u_{0j}$$

$$\pi_{1j} = \beta_{10} + \beta_{11}*(D1_j) + \beta_{12}*(D2_j) + \beta_{13}*(D4_j)$$

$$\pi_{2j} = \beta_{20} + \beta_{21}*(D1_j) + \beta_{22}*(D2_j) + \beta_{23}*(D4_j)$$

$$\pi_{0j} = \beta_{00} + \beta_{01}*(D1_j) + \beta_{02}*(D2_j) + \beta_{03}*(D3_j) + u_{0j}$$

$$\pi_{1j} = \beta_{10} + \beta_{11}*(D1_j) + \beta_{12}*(D2_j) + \beta_{13}*(D3_j)$$

$$\pi_{2j} = \beta_{20} + \beta_{21}*(D1_j) + \beta_{22}*(D2_j) + \beta_{23}*(D3_j)$$

where  $SCORE_{mij}$  represents an individual student's fluency score  $j$  at each time point  $m$ .

Additional models were run for all pairwise group contrasts. Group assignment was dummy coded so that the 10 % interspersal group was coded as D1, the 20 % interspersal group as D2, the 40 % interspersal group as D3, and the 0 % group as D4. The parameter  $\pi_{0j}$ , the intercept, was centered at the final data point. This allowed for significance testing of final datum point performance across groups.  $\pi_{1j}$  defines the growth trend, or slope, over time.  $\beta_{11}$ ,  $\beta_{12}$ ,  $\beta_{13}$ , and  $\beta_{14}$  represent the time constant group membership dummy codes that permit contrasts of student trajectories across experimental groups at the linear level.  $\beta_{21}$ ,  $\beta_{22}$ ,  $\beta_{23}$ , and  $\beta_{24}$  represent the group membership dummy codes that allow contrasts of student trajectories across groups as quadratic functions. Two unconditional models were first tested to examine whether a linear or quadratic trend best explained the pattern of results. It was found that a quadratic model was significant,  $t(530) = 3.44$ ,  $p < .001$ , and was a more accurate representation of growth than a model with a linear term,  $t(530) = 0.43$ ,  $p = .67$ . Group differences were modeled at Level-2 for both  $\pi_{0j}$  and  $\pi_{1j}$ , allowing for comparisons of final data point performance and slopes.

Descriptive data from the four groups are presented in Table 1 and Figure 1 for average initial datum point and final datum point scores. Mean performance and variance were roughly equivalent at baseline across groups. For the initial measurement period there were no missing data. For the final measurement period, there were five missing datum points: 1 from D2, 3 from D3, and 1 from D4. Across the 9 measurement points in between, there were 17 missing datum points distributed across groups: 5 from D1, 6 from D2, 5 from D3, and 1 from D4.

Table 1.

*Descriptive Statistics Across Phases and Groups*

Group	Initial			Final			Difference Score
	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>	
D1 (10%)	14	22.93	16.07	14	44.07	24.46	21.14
D2 (20%)	14	22.64	20.28	13	38.08	33.27	15.44
D3 (40%)	15	18.87	14.72	12	42.75	28.22	23.88
D4 (0%)	13	20.08	16.34	12	48.25	31.14	28.17

Figure 1.

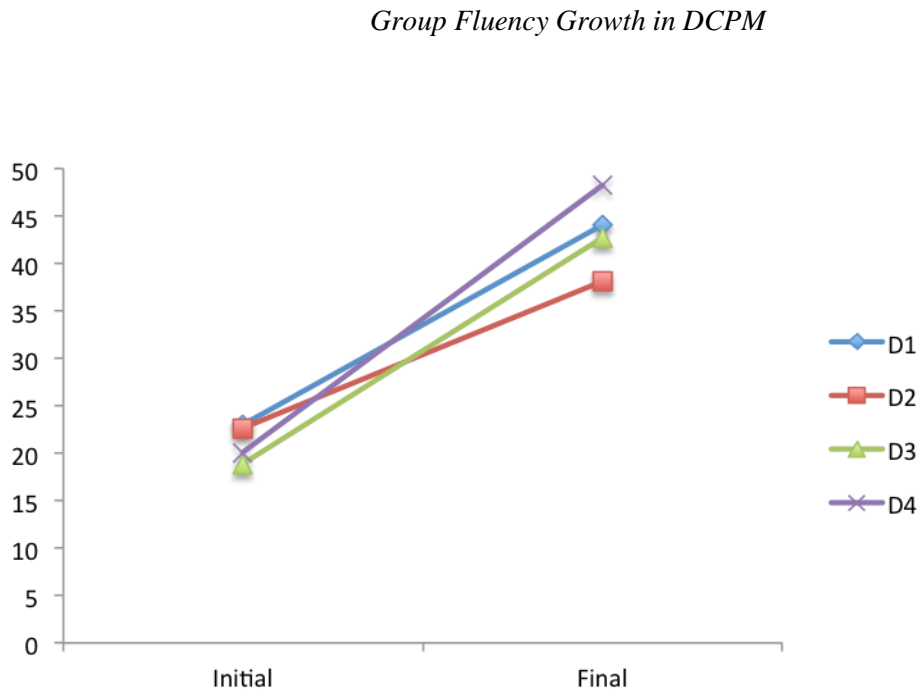


Table 2 presents final datum point performance and slope results from the final model. An alpha value of .05 was used to determine significance for all tests of statistical significance of parameters. Final datum point performance results indicate no statistically significant differences in final datum point intercepts between groups. Slope results indicate no statistically significant differences in slope between groups.



Table 2.

*Growth Curve Model Results of Group Final Performance and Slope Comparisons*

Model Parameters	Comparisons	Coefficient	SE	t	df	p
$\beta_{00}$		41.57	5.61	7.41	52	<.001
$\beta_{12}$	10% vs. 20%	-8.71	7.94	-1.10	52	.28
$\beta_{13}$	10% vs. 40%	-1.77	7.81	-0.23	52	.82
$\beta_{14}$	10% vs. 0%	0.49	8.09	0.06	52	.95
$\beta_{00}$		32.85	5.61	5.85	52	<.001
$\beta_{23}$	20% vs. 40%	6.94	7.81	0.89	52	.38
$\beta_{24}$	20% vs. 0%	9.20	8.09	1.14	52	.26
$\beta_{00}$		39.79	5.43	7.33	52	<.001
$\beta_{34}$	40% vs. 0%	2.26	7.96	0.28	52	.78
$\beta_{10}$		0.19	0.06	3.44	530	<.001
$\beta_{12}$	10% vs. 20%	-0.09	0.08	-1.18	530	.24
$\beta_{13}$	10% vs. 40%	-0.02	0.08	-0.25	530	.81
$\beta_{14}$	10% vs. 0%	-0.12	0.08	-1.51	530	.13
$\beta_{10}$		0.10	0.06	1.77	530	.08
$\beta_{23}$	20% vs. 40%	0.07	0.08	0.96	530	.34
$\beta_{24}$	20% vs. 0%	-0.03	0.08	-0.34	530	.73
$\beta_{10}$		0.17	0.05	3.21	530	.00
$\beta_{34}$	40% vs. 0%	-0.10	0.08	-1.3	530	.20

Note. Final model summary:  $\sigma^2 = 102.64$ ,  $\tau^2 = 418.68$ .  $\tau^2$  was statistically significant,  $\chi^2(2326.96)$ ,  $p < .001$ . Model includes unstandardized coefficients.

In addition to examining differences between groups utilizing all student data, data was also analyzed examining differences between groups including only low-performing students' data. Low-performing students were defined as those participants scoring less than or equal to 20 DCPM on the initial measurement period. Descriptive data from the four groups are presented in Table 3 and Figure 2 for average initial data point and final data point scores. Mean performance and variance were roughly equivalent at baseline across groups.

Table 3.

*Descriptive Statistics Across Phases and Groups – Low-Performing Students*

Group	Initial			Final			Difference Score
	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>	
D1 (10%)	8	12.50	5.63	8	29.13	17.56	16.63
D2 (20%)	8	10.00	5.37	7	15.86	14.94	5.86
D3 (40%)	10	10.90	6.47	8	30.63	26.43	19.73
D4 (0%)	8	10.13	5.72	8	38.13	29.90	28.00

Figure 2.

*Low-Performance Group Fluency Growth in DCPM*

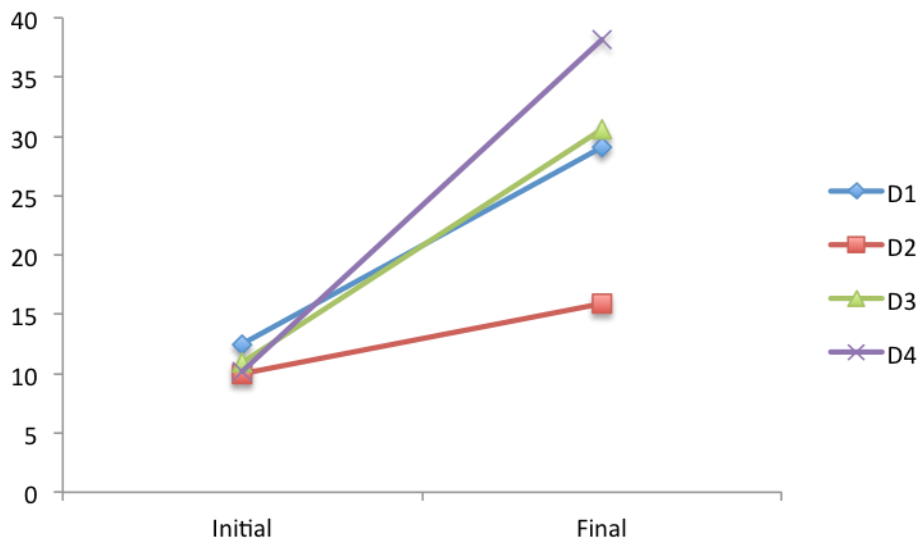


Table 4 presents final datum point performance and slope results from the final model. An alpha value of .05 was used to determine significance for all tests of statistical significance of parameters. Low-performing students in the 40 % interspersal group performed an average of 16.91 DCPM better than students in the 20 % interspersal group. The difference was statistically significant,  $t(30) = 2.88, p = 0.01$ . Low-performing students in the 0 % interspersal group

performed an average of 12.43 DCPM better than students in the 20 % interspersal group. The difference was statistically significant,  $t(30) = 2.01, p = 0.05$ . Slope results indicate no statistically significant differences in slope between groups.

Table 4.

*Growth Curve Model Results of Low-Performing Group Final Performance and Slope Comparisons*

Model Parameters	Comparisons	Coefficient	SE	t	df	p
$\beta_{00}$		26.00	4.38	5.94	30	<.001
$\beta_{12}$	10% vs. 20%	-10.30	6.19	-1.66	30	.11
$\beta_{13}$	10% vs. 40%	6.61	5.88	1.13	30	.27
$\beta_{14}$	10% vs. 0%	2.13	6.19	0.34	30	.73
$\beta_{00}$		15.70	4.38	3.59	30	.00
$\beta_{23}$	20% vs. 40%	16.91	5.87	2.88	30	.01
$\beta_{24}$	20% vs. 0%	12.43	6.18	2.01	30	.05
$\beta_{00}$		32.61	3.92	8.32	30	<.001
$\beta_{34}$	40% vs. 0%	-4.49	5.87	-0.76	30	.45
$\beta_{10}$		0.03	0.06	0.53	317	.60
$\beta_{12}$	10% vs. 20%	0.04	0.09	0.46	317	.65
$\beta_{13}$	10% vs. 40%	0.14	0.09	1.68	317	.09
$\beta_{14}$	10% vs. 0%	0.02	0.09	0.23	317	.82
$\beta_{10}$		0.08	0.06	1.19	317	.23
$\beta_{23}$	20% vs. 40%	0.10	0.09	1.20	317	.23
$\beta_{24}$	20% vs. 0%	-0.02	0.09	-0.23	317	.82
$\beta_{10}$		0.18	0.06	3.13	317	.00
$\beta_{34}$	40% vs. 0%	-0.12	0.08	-1.45	317	.15

Note. Final model summary:  $\sigma^2 = 75.72, \tau^2 = 136.59$ .  $\tau^2$  was statistically significant,  $\chi^2(600.98), p < .001$ . Model includes unstandardized coefficients.

In summary, analysis of final measurement performance of low-performing students revealed a statistically significant difference between 0 % interspersal and 20 % interspersal group performance. The 0 % group performed on average 12.43 DCPM higher at the final datum point than the 20 % group. A statistically significant difference was also found between 40 % interspersal and 20 % interspersal group performance for low-performing students. The 40 % group performed on average 16.91 DCPM higher at the final datum point than the 20 % group.

Analyses of slope indicated no statistically significant differences in growth trajectories between groups in analyses of all data and analyses of low-performing students' data.

## CHAPTER V

### DISCUSSION

Several methods of increasing student learning outcomes have been discussed in the literature, such as increasing learning trials or opportunities to respond (Albers & Greer, 1991; Skinner et al., 2008; Skinner et al., 1997). While increasing instructional time, through increasing learning trials or opportunities to respond to instructional material, is often a suggestion for intensifying support services (Skinner et al., 1997), instructional time is set within a school day; therefore, it is imperative to examine more efficient practices to increase student learning outcomes.

The purpose of the current study was to answer the following questions: 1) Do interspersal procedures increase multiplication fluency more efficiently than non-interspersal procedures, and 2) Is there an optimal ratio of easy-to-difficult problems within interspersal procedures? To answer these questions, this study examined the differences between four interspersal ratios (0 %, 10 %, 20 %, and 40 %), identified by percentage of easy problems within

the daily intervention problem sets, to increase students' performance on multiplication fact fluency. Fluency, defined as a student's rate of performance within a given time, can be increased using repeated practice and the addition of reinforcement (Albers & Greer, 1991; Haring & Eaton, 1978; Van Houten & Hill, & Parsons, 1975). The current study utilized both of these components. Repeated practice was utilized through the daily ET intervention, which allowed four minutes of repeated practice of multiplication facts each day during the course of the study. An additional component to the ET intervention was interspersal, which was hypothesized to act as reinforcement for students. Students, in their respective experimental groups, were exposed to fixed ratio schedules of reinforcement during each daily intervention period.

Given the theoretical reinforcing function of interspersal, it was hypothesized that at least one interspersal group would be more effective at increasing fluency levels than the no interspersal group. Results were analyzed using HLM. No statistically significant differences were found between groups for neither final datum point nor trend. However, all groups increased fluent responding to facts by an average of 22.16 DCPM during the course of the study (132 instructional minutes). This equates to an increase of .17 digits correct per instructional minute when all groups are combined. Table 5 examines average growth from initial to final measurement point for each group, as well as the mean growth for groups combined.

Table 5.

*Rate of Improvement in DCPM from Initial to Final Measurement Points*

Group	Difference Score	Rate of Improvement
10%	21.14	0.16
20%	15.43	0.12
40%	23.88	0.18
0%	28.17	0.21
Combined	22.16	0.17

Another hypothesis, based on previous research in the area of interspersal, was that interspersal ratios with higher rates of difficult problems would be more effective than ratios with lower rates of difficult items. This was true for the no interspersal group; however, the group in which the participants had only 60 % difficult problems, the least opportunities to respond to target problems, had the next highest rate of improvement from initial to final datum points. Following this group, the hypothesized effect occurred, as the group that received 90 % difficult problems performed better than the group that had 80 % difficult problems. While none of these differences were statistically significant, it is an interesting trend.

In addition to examining differences between groups including all participant data, groups were examined including only low-performing participants' data, or those performing at or below 20 DCPM at the initial observation point. While the first hypothesis was null – no interspersal groups performed better than the 0 % interspersal group – the second hypothesis was partially supported. Some groups with more opportunities to respond to the difficult problems performed better than those with fewer opportunities to respond. A statistically significant difference between the 0 % group and the 20 % group at the final datum point was found. The 10 % interspersal group, while not statistically significant, also performed higher than the 20 % group. However, a statistically significant difference was also found between the 40 % group and the 20 % group, supporting the reverse of this hypothesis as the 40 % group had the most interspersed easy problems of all the groups. Both the no interspersal and the 40 % interspersal groups performed significantly higher during the final measurement period than the 20 % interspersal group. These results mirror the results utilizing all participant data, with the addition of statistically significant differences.

Likewise, all groups increased fluent responding to facts by an average of 17.55 DCPM during the course of the study (132 instructional minutes). This equates to an increase of .21 digits correct per instructional minute when all groups are combined. Table 6 examines average

growth from initial to final measurement point for each group, as well as the mean growth for groups combined.

Table 6.

*Rate of Improvement in DCPM from Initial to Final Measurement Points – Low Performing Students*

Group	Difference Score	Rate of Improvement
10%	16.63	0.13
20%	5.86	0.04
40%	19.73	0.15
0%	28.00	0.21
Combined	17.55	0.13

*Implications for Practice*

There is a need for effective modifications to interventions in order to intensify services when students do not respond appropriately to instruction. Interspersal is one way to theoretically increase rates of reinforcement by placing students on a fixed ratio (FR) schedule of reinforcement higher than FR0 (no interspersal). This modification uses little-to-no additional resources on top of ET, as the only change is the sequencing of the math facts within the repeated practice probe. ET with interspersal is a change in materials, rather than a modification to intervention procedures.

The results of the current study lead to limited implications for practice, as few differences were found between groups. However, this study validated ET as an effective intervention. All groups improved performance on multiplication fact fluency across the course of the study, indicating ET is an effective tool for increasing student learning outcomes. Visual analyses of raw data indicate that no interspersal is the most effective use of ET; however, for low-performing students statistically significant differences were found between the 40 % and the 20 % interspersal groups, indicating some interspersal ratios are more effective than others when working with low-performing students. While comparisons were made between all students and



low-performing students, all students included in the current study were typically achieving students in general education classroom placements. Therefore, results may not generalize to students being served in special education placements.

#### *Limitations and Future Research*

There are several limitations to the current study. One limitation is that, while a breadth of interspersal ratios (0 %, 10 %, 20 %, and 40 %) were examined, there were several ratios that were not examined. Ratios lower than 50 % were chosen for this study based on results in previous research that indicated higher interspersal ratios were less effective than lower ratios. However, there is a possibility that more comprehensive results and differential comparisons would have been found had those and other ratios been included for examination.

Another limitation involves the participants and target problems. Participants were limited to fourth grade students in general education classroom placements, and target problems were limited to difficult multiplication problems. Therefore, results may not generalize to students in other grades or educational placements, or to other math skills, such as addition or subtraction.

Additionally, this study had limited power, particularly when examining differences between groups utilizing only low-performing students' data. As it stands, several comparisons within these analyses approached significance, while only two reached significant levels. Had there been more subjects or datum points collected within this subgroup of participants, more results may have reached statistical significance.

Future research should aim to correct for these limitations and generalize to other populations, such as students in special education placements or receiving math remediation services, and skills, such as addition or subtraction. Additionally, interspersal could be used as a modification to accuracy or generalization building interventions, as well. In addition, the results examining the second hypothesis lead to interesting discussion points and opportunities for future research.

There are two theorized functions leading to the obtained results: one variable is opportunities to respond, while the other is level of reinforcement. Increasing both variables should theoretically lead to increased student performance. When including both variables, it can be expected that one of two things will happen: one will take over as being more important than the other, or there will be an interaction between the two variables. Results of this study indicate an interaction between the two variables occurred.

Table 7 examines the groups, in order of most-to-least effective, as well as descriptors of their levels of opportunities to respond and levels of reinforcement. As can be seen, the group with the most opportunities to respond and least levels of reinforcement performed the best, while the group with the least opportunities to respond and highest levels of reinforcement performed the next best. When examining data of low-performing students, both of these groups performed significantly better at the final observation point than the group with the lowest mid-level opportunities to respond and the highest mid-level reinforcement ratio.

Table 7.

*Comparison of Effects, Opportunities to Respond, and Levels of Reinforcement*

Group	Opportunities to Respond	Level of Reinforcement
0%	Highest	Lowest
40%	Lowest	Highest
10%	Second	Third
20%	Third	Second

These results indicate high levels of either opportunities to respond or reinforcement are more likely to lead to increased student outcomes, while mid-level rates may have diminished returns, particularly when working with low-performing students. Again, the generalization of these results is limited; however, this interaction is an area to be developed for future research.

*Summary*

Previous research indicates a need for more efficient instructional strategies in the area of mathematics. Some strategies include increasing opportunities to respond and learning trials,

increasing reinforcement, and increasing academic instructional time (Albers & Greer, 1991; Skinner, 2008; Skinner et al., 1997; Van Houten, Hill, & Parsons, 1975). Since instructional time is fixed within a school day, supporting efficient interventions and modifications is imperative.

Interspersal is one proposed modification to increase accurate and fluent student responding to instructional material. Interspersal involves placing easier problems into a problem set of more difficult problems. These easy problems theoretically serve as reinforcement. Varying ratios of difficult-to-easy problems have been examined, with results supporting interspersal ratios with lower rates of easy problems as being more effective than ratios with higher rates of easy problems (Roberts, Turco, & Shapiro, 1991; Roberts & Shapiro, 1996; Skinner & Oliver, 2005).

The current study aimed to examine the differences between four interspersal ratios: 0 %, 10 %, 20 %, and 40 % easy problems. Participants included students in the fourth grade in general education classroom placements in a suburban school in the Midwest. Participants completed four minutes of repeated practice of the target problems (difficult multiplication problems), with differing interspersal ratios based on group assignment. Following the third day of intervention, each participant was given a time one-minute assessment of difficult problems. Assessments were scored by DCPM, and results were analyzed using HLM.

Findings indicate no statistically significant differences between groups at final measurement period or between growth trends. However, all groups increased fluent responding by a combined average of 22.16 DCPM during the course of the study, which equates to an increase of .17 digits correct per instructional minute. Subgroup analyses with data including only low-performing students' data indicate a difference at the final measurement point between the no interspersal group and the 20 % interspersal group, as well as between the 40 % interspersal group and the 20 % interspersal group. These findings indicate an interesting interaction between opportunities to respond and levels of reinforcement, with high levels of either variable being preferable to, or more effective than, lower levels of both.

Implications for practice are limited, given the limitations to the study; however, this study supported ET as an effective intervention, as all groups increased fluent responding across the study. Results indicate ET without interspersal is the most effective for all students. However, subgroup analyses indicate some interspersal ratios may be more effective than others when working with low-performing students, as the 40 % interspersal group performed significantly higher than the 20 % interspersal group at the final data collection period.

Limitations include the range of interspersal ratios examined, the range of participants and target problems, and overall low power of the study. The inclusion of additional interspersal ratios may have led to a more comprehensive examination of interspersal effects. Likewise, participants were limited to fourth grade students in general education placements, and the target skill was limited to multiplication fact fluency. Therefore, these results may not generalize to other students or mathematics skills. Finally, the overall low power of the study may have limited the statistically significant findings. As several *p*-values approached significance, the inclusion of more participants or additional data collection points may have led to additional statistically significant comparisons between groups.

Future research should focus on continuing to support efficient instructional strategies and modification for increasing student learning outcomes. An interesting finding of this study was the theorized interaction between opportunities to respond and levels of reinforcement. This interaction should be targeted in future research in order to examine experimentally whether the interaction holds true or not. While limited conclusions can be drawn from the results of this study, there may be a place for interspersal research within the larger framework of the instructional hierarchy. Within the interspersal research, focus should include correcting for the limitations of this study, as well as applying to more generalized participants, settings, and skills. For example, statistically significant results were found only in subgroup analyses using low-performing students' data. This indicates that interspersal may be more appropriately examined using low-performing students as participants. As students targeted for receiving intervention

services tend to be students who are not making adequate growth, these results support that there may be a place for interspersal modifications with this population.

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