8-2004

The Effects of Task Demands and Interspersal Ratios on Student Accuracy in Mathematics

James Andrew Hawkins
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by James Andrew Hawkins entitled "The Effects of Task Demands and Interspersal Ratios on Student Accuracy in Mathematics." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

Christopher H. Skinner, Major Professor

We have read this dissertation and recommend its acceptance:

Robert L. Williams, William Calhoun, Thomas W. George

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

To the Graduate Council:

I am submitting herewith a dissertation written by James Andrew Hawkins entitled "The Effects of Task Demands and Interspersal Ratios on Student Accuracy in Mathematics." I have examined the final paper copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

Christopher H. Skinner, Major Professor

We have read this dissertation
and recommend its acceptance:

Robert L. Williams

Accepted for the Council:

Vice Chancellor and Dean of
Graduate Studies

The Effects of Task Demands and Interspersal Ratios on Student Accuracy in Mathematics

A Dissertation Presented for the Doctor of Philosophy Degree
The University of Tennessee, Knoxville

James Andrew Hawkins
August, 2004

Dedication

This work is dedicated to my friends and family. First, I thank my parents for their encouragement, support, and interest in my pursuit of educational and personal endeavors. I would also like to thank the Oliver family for their support. I express gratitude to my fellow graduate students who have provided help and friendship for the past five years. I also dedicate this dissertation to Renee. Thank you for the time and energy you devoted to this project. Most of all, thank you for being there for me each and every day.

Acknowledgements

I would like to express sincere appreciation to my committee members, Dr. William Calhoun, Dr. Thomas George, Dr. Christopher Skinner, and Dr. Robert Williams, all of whom invested significant time and effort in this project. I would like to thank Dr. George and Dr. Calhoun for their continued support of the students and faculty of the School Psychology program and their valuable input on this particular project. Thank you to Dr. Williams for his excellent feedback and suggestions in regards to my dissertation. His oral and written comments were extremely perceptive, helpful, and greatly enhanced the quality of the product. Finally, I would like to thank my dissertation chair, Dr. Skinner, for his guidance, encouragement, and patience. I greatly appreciate all the time and effort he generously devoted to this dissertation. I could not have asked for a better working relationship. He made a difficult process enjoyable and rewarding. He has helped me grow personally and professionally, and for that I express my gratitude.

Abstract

The primary purpose of this study is to extend research on increasing accuracy on academic assignments through use of the additive interspersal procedure. Additive interspersal is the addition of brief and/or easy problems among longer, more difficult target problems. Research has shown additive interspersal is effective in promoting student choice in regards to engaging in assignments. Only one study has found an increase in student accuracy on interspersed assignments as compared to control assignments when using additive interspersal. The current study attempted to determine if the results of that study are a statistical outlier or whether the uniqueness of that study, using assignments requiring different task demands, can increase problem accuracy.

Students (N=52) from three fifth-grade classes completed six math assignments incorporating two task demands and three ratios of interspersal. The interspersal ratios applied were no interspersal, one interspersed problem per three target problems, and one interspersal problem per one target problem. Each of these three ratios was used in two task demands. In the written (low-attention) task, students completed problems via paper and pencil. In the oral (high-attention) task, students had to compute mathematics problems in their head.

Results showed students performed more accurately on written tasks compared to oral tasks. A target to interspersal problem ratio of 3:1 on oral tasks led to a significant increase in accuracy compared to the no interspersal and 1:1 interspersal conditions. A target problem to interspersed problem ratio of 1:1 on written tasks led to a significant increase in accuracy when compared to the no interspersal condition.

The results of this study suggest the interspersal procedure can be used to increase student accuracy in math. However, the most effective ratio of interspersal to target problems is dependent on task demands. Interspersal studies have shown mixed results regarding student accuracy on assignments under the additive interspersal procedure. Currently, there is no understanding of the causal mechanisms to explain why interspersal increases accuracy in some instances but has no effect in other instances. Future theoretical research that explains the causal mechanism(s) of the interspersal procedure may allow us to maximize its impact on performance.

Table of Contents

List of Tables

Chapter 1

Introduction

Educators often spend much time instructing students in basic academic skills. Research on both academic learning time (ALT) (Fisher & Berliner, 1985) and opportunities to respond (Greenwood, Delquadri, & Hall, 1984) suggests that after students acquire basic academic skills, increasing the number of active, accurate responses they make to academic stimuli can enhance fluency, maintenance, and generalization of academic skills (Berryman, O'Brien, & Cummins, 1983). Opportunities to respond require learners to be active participants instead of merely engaging in on-task behaviors. Active responses include writing, reading aloud, reading silently, asking questions, and answering questions. ALT is described as time in which students are on-task and performing an academic skill accurately. This research base suggests two specific target behaviors: choice and quality of responses.

The first target behavior is related to choice. Regardless of how many opportunities are provided to practice skills, little skill development is likely to occur unless students choose to respond (Skinner, Wallace, & Neddenriep, 2002). The second target behavior is the quality of those responses. Skill development is not likely to be enhanced, and may actually be hindered, when students are engaged in high rates of inaccurate responding (Hargis, 1989). Thus, developing assignments that enhance the probability of students choosing to engage in active academic responding and the probability of those responses being accurate are likely to enhance skill development across students.

Researchers investigating the interspersal procedure have focused on both choice and accuracy. The interspersal procedure involves altering assignments or assessment procedures by either adding items (sometimes called the additive interspersal procedure) or replacing items with alternative items (sometimes called the substitutive interspersal procedure). Typically, these new items are briefer and easier than the items replaced.

Interspersal has been used with a variety of different populations including students with autism (Charlop, Kurtz, & Milstein, 1992; Dunlap, 1984; Harrower, 2000; Stahmer, 1999), mental retardation (Cuvo, Davis, & Gluck, 1991; Horner, Day, Sprague, & O'Brien, 1991; Neef, Iwata, & Page, 1980; Rowan & Pear, 1985), learning disabilities (Cooke, Guzaukas, Pressley, & Kerr, 1993; Cooke & Reichard, 1996; Johns, Skinner, & Nail, 2000), those in special education (Cates & Skinner, 2000), low achieving or at-risk students (Robinson & Skinner, 2002), students with behavior and emotional disorders (Skinner, Hurst, Teeple, & Meadows, 2002; Teeple, 2002), and students in general education (Dickinson & Butt, 1989; Logan & Skinner, 1998; Martin, Skinner, & Neddenriep, 2001; Roberts & Shapiro, 1996).

Interspersal has also been used across several age ranges including adults (Cuvo et al., 1991), college aged students (Billington & Skinner, 2002; Neef et al., 1980; Wildmon, Skinner, & McDade, 1998), high school students (Johns et al., 2000; Wildmon, Skinner, McCurdy, & Sims, 1999), middle school students (Browder & Shear, 1996; Cooke et al., 1993; Cooke & Reichard, 1996), and elementary students (Dickinson & Butt, 1989; Dunlap, 1984; Roberts & Shapiro, 1996).

The main purpose of this study is to extend research on increasing accuracy on academic assignments through use of the additive interspersal procedure. Research has shown additive interspersal is effective in promoting student choice in regards to engaging in assignments (Logan & Skinner, 1998; Wildmon et al., 1999). Only one study (Robinson & Skinner, 2002) has found an increase in student accuracy on interspersed assignments as compared to control assignments when using additive interspersal. The current study attempted to determine if the results of the Robinson and Skinner (2002) study are a statistical outlier or whether as was done in the Robinson and Skinner study, using assignments requiring different task demands, can increase problem accuracy.

Chapter 2

Literature Review

In this chapter, results of interspersal research are reviewed. First, studies that focus on enhancing student preference for assignments and the probability that students choose to engage in assignments will be reviewed. Next, studies that focus on enhancing response accuracy and learning rates will be discussed. This chapter will conclude with a brief summary of interspersal research reviewed and the purpose of the current study.

Interspersal Effects on Choice and Preference

Researchers investigating choice and preference have used both single-subject and group design studies. In the group design studies, students have been exposed to two assignments and then asked to choose which type of assignment they want to do next, another interspersal assignment or another control assignment.

The single-subject design research has measured student behavior while working on control and interspersal assignments. While working on these assignments, at any given moment students can choose to engage in assigned tasks or other behaviors. In these studies, choice was measured continuously using direct observation of on-task and off-task behavior. Higher rates of on-task behavior suggest students are more frequently choosing to engage in assigned work.

On-task Behavior

When interspersal is used to promote acquisition of behaviors, it is defined as the use of very simple commands that have a high probability of being followed among commands that have a lower probability of being followed, in order to increase the chance a person will engage in novel or difficult tasks without performing behaviors that are maladaptive (Horner et al., 1991). Interspersal may be used to promote the learning of behaviors or the reduction of negative behaviors.

The Horner et al. (1991) study sought to reduce aggressiveness and self-injurious behavior in three mentally retarded children during instruction and increase response rates to instructions. In study one, there were three conditions. In the first condition, the easy phase (A phase), students completed easy tasks. Easy tasks were those that the students performed correctly at least 70% of the time. Another condition, hard phase (B phase), included tasks that students performed correctly less than 33% of the time. These two phases were alternated in an A-B-A- fashion as part of a bigger A-B-A-B-C-B-C within-subject reversal design.

During the easy phases, participant one performed aggressive acts 0% of the time as opposed to 71.3% of the time during hard phases. Participant two performed aggressive or self-injurious acts 2.5% of the time during easy phases and 71.3 % during the hard phases. Participant three scored 0% and 49.8% across the same behaviors and phases. During the B-C-B-C part of the design, the three students experienced two interspersed phases (C phase) and two hard phases. In the C phase, interspersed simple requests followed approximately every third hard request or when students expressed resistance. Investigators defined interspersed requests as taking 2-3 seconds to complete as well as having a high probability of being completed.

During the hard phases, participant one expressed aggression 69.6% versus 0% during the hard plus interspersal phases. Participants two and three expressed aggression or self-injurious behaviors at 63.9% and 62.5% during hard phases and 7% and 19.5%

during hard plus interspersal phases respectively. Maladaptive behaviors for all three participants were reduced during the interspersal condition.

In addition to a reduction in the frequency of maladaptive behaviors, two of three participants significantly increased attempts to complete hard tasks during the hard task plus interspersal phases. Participant one responded within 3 seconds of task presentation in all conditions. Participant two attempted to complete 99% of trials in the easy phases and 61% in the hard phases. Participant three attempted to complete 100% and 4% during the easy and hard phases respectively. After the interspersal procedure was implemented, participant two attempted to complete 63% of trials and participant three 7% of trials during the hard phase. These results are similar to attempts to complete during hard phases before the introduction of the interspersal phases. This is contrasted with attempts of 99% and 73% on hard trials during interspersal plus hard phases for participants two and three respectively.

A study by Dickinson and Butt (1989) investigated how academic success affects on-task behavior, as measured by momentary time sampling. Three students, two with a history of high math achievement and one with a history of low math achievement, participated in the study. Two assignments were created. In assignment one, the ratio of known to unknown items was 70% to 30%. On assignment two, the ratio of known to unknown items was 50% to 50%.

The low-achieving student increased the percentage of intervals during which he was on-task from 56% during the 50% known/50% unknown assignment to 84% during the 70% known/30% unknown assignment. Results for the high-achieving students were inconsistent when the assignment changed from 70% known/30% unknown to 50%

known/50% unknown. One high-achieving student was on-task for 96% of observed intervals during the condition where 70% of items were known and 94% of observed intervals during the condition where 50% of items were known. The other high-achieving student was on task for 92% of the observed intervals during the 70% known assignment and 52% of observed intervals during the 50% known assignment.

For two students, one high-achieving and one low-achieving, more frequent on-task behavior appeared to increase with the assignment students could more successfully complete and decrease with the assignment where they were less successful. The other high-achieving student showed similar levels of on-task behavior across the two assignments.

A reversal to baseline phase was used for only one student. Therefore, results should be interpreted with caution. Evidence for the validity of the conclusion is present for the high-achieving student whose on-task performance decreased during the more difficult assignment and then returned to identical levels found during baseline when an easier assignment was reintroduced.

The previous two studies measuring on-task behavior involved substitutive interspersal. Known items were substituted in the place of unknown items. The following studies involved additive interspersal. Additional problems were added to target problems rather than replacing them.

McCurdy, Skinner, Grantham, Watson, and Hindman (2001) investigated the use of interspersal with a girl who had been referred for off-task behavior during independent seatwork. An alternating treatments design contained a control assignment of math problems the student was working on and an experimental assignment where brief problems were interspersed. The student was on-task approximately 73% of observed intervals during work on the interspersal assignment and 56% of observed intervals during work on the control assignment. The results suggested when working on the interspersal assignment, the student demonstrated higher rates of on-task behavior as compared to the control assignment.

Skinner et al. (2002) extended the previous research of McCurdy et al. (2001) by examining the effect of interspersal on on-task behavior of four emotionally disturbed students. Sixteen assignments were created (two control and two interspersal) for four different mathematical skills. Investigators, using momentary time sampling, observed the on-task behavior of students during assignments. All but one student showed a higher percentage of intervals on-task during intespersal assignments as compared to control assignments.

Choice of Assignments

Research on interspersal has shown on-task behavior is higher during assignments involving interspersal than assignments without interspersal. Interspersal assignments appear to increase student attention when compared to control assignments, but does it also influence student choice of assignments? Researchers have used additive interspersal to investigate whether interpsersal is powerful enough to influence student choice of assignments.

A study by Logan and Skinner (1998) is an excellent example of the impact of interspersal on student choice, interspersal improving student completion rates, and how additive interspersal can maintain the integrity of the curriculum. Thirty 6^{th} grade students had 8 minutes to work on math problems. The problems consisted of four-digit by one-digit multiplication. In the control assignments, students were presented 25 of these multiplication problems. In the experimental condition, students were presented 25 similar problems and 9 interspersed one-digit plus one-digit problems. Rate of problem completion was higher under the experimental or interspersed problem condition. Students were then presented a third assignment in which they could choose an assignment similar to either the control or experimental assignments. Significantly more students chose to compete the experimental assignment containing interspersed problems. The interspersed assignment, of course, contained more items. Logan and Skinner (1998) concluded that interspersing additional problems that take less time to complete than target problems can improve student preference for assignments without compromising the integrity of the curriculum.

Wildmon et al. (1999) presented 76 students with a control assignment containing eight 2-digit x 2-digit + 2-digit x 2-digit multiplication problems and an experimental assignment containing eight 2-digit x 2-digit + 2-digit x 2-digit and three 4-digit + 4-digit problems. Students were then asked which assignment they would choose for homework. The majority of students chose the assignment containing the interspersed problems.

Johns at al. (2000) used computers to present two mathematics assignments to four students with learning disabilities. The control assignment contained two-digit x one-digit multiplication problems while the experimental condition contained similar problems plus interspersed one-digit x one-digit multiplication problems. Students chose to spend more time working on the interspersal assignment as compared to the control assignment. Similar findings of student preference for mathematics assignments containing interspersed problems over control assignments were found by numerous researchers (Skinner, Robinson, Johns, Logan, & Belfiore, 1996; Wildmon et al., 1998; Billington & Skinner, 2002).

Teeple (2002) investigated choice behavior for grammar assignments. Students were to copy paragraphs and insert periods to make grammatically correct sentences. Students were presented a control assignment containing fifteen multi-sentence paragraphs and an experimental assignment containing fifteen multi-sentence paragraphs and eight single-sentence paragraphs. When given a choice, students preferred the assignment containing the interspersed sentences. Meadows (2002) also examined student choice in regards to language arts assignments and found students preferred assignments containing interspersed items over control assignments.

Martin (1998) investigated student choice in reading assignments. Seventh graders read passages aloud. In the control condition, students read a passage that was written at the seventh grade level. In the experimental condition, they read a similar passage with an interspersed 16-word paragraph written at a first grade level. When asked which passage they preferred, students indicated they did not prefer one passage over the other. This is the only study involving additive interspersal in which students did not prefer the interspersed assignment. There are no studies in which students preferred the control assignment over the experimental assignment.

The majority of studies that have investigated choice of assignments have involved additive interspersal. However, some substitutive interspersal studies, which have focused primarily on accuracy and learning rates, have also examined preference or choice (Neef et al., 1980; Cooke et al., 1993; Dunlap, 1984; Cooke & Reichard, 1996). These studies lend support to the overwhelming data showing students prefer to engage in assignments containing interspersal problems over control assignments. The Cooke and Reichard (1996) study was the only substitutive interspersal study where preferences for assignments were mixed.

Causal Mechanisms

When given a choice of two behaviors and consequences that are equivalent (e.g., rate, immediacy, and quality of reinforcement), organisms will choose to exert less effort (Tustin & Morgan, 1986). Thus, in assignments involving substitutive interspersal, it is not surprising students will prefer these assignments over control assignments. In the few substitutive studies that investigated preference, students said they preferred the interspersal assignment because it was easier. High effort problems are being replaced with low effort problems (which students have already mastered), leading to a "watering down" of the curriculum. This does not occur in additive interspersal where easier, briefer problems are added to target problems rather than replacing them.

Students overwhelmingly prefer interspersal assignments over control assignments despite the interspersal assignments containing more problems. Some researchers have found interspersal is so powerful that students will choose assignments where they have to complete more target problems.

Cates and Skinner (2000) investigated student preference for interspersal assignments using three experimental assignments and three control assignments. The control assignments consisted of 15 three-digit by two-digit math problems. The first experimental problem set contained interspersed items but no additional target items. The second experimental problem set contained interspersed problems and 18 total target problems or 20% more than in the control condition. The last experimental problem set contained interspersed problems and 21 target problems or 40% more target problems than the control. Results showed interspersal was capable of influencing students to prefer homework assignments with 20% and 40% more target problems.

Another study by Cates, Skinner, Watkins, Rhymer, McNeill, and McCurdy (1999) suggested 20% more target problems may be the upper limit for the number of additional problems that can be included on an assignment and still have students select that assignment over a control assignment. Further support for the 20% criteria level was found by Meadows (2002).

How does additive interspersal influence choice of assignments? Researchers have looked at several variables including novelty, level of difficulty, and time to complete tasks.

One potential explanation for students preferring interspersal assignments is the novelty of the interspersed problems. Skinner et al. (1996) ruled out novelty effects with two experiments. Students worked on a three-digit by two-digit multiplication assignment and an identical assignment with one-digit by one-digit multiplication problems interspersed. After completing both assignments, students rated their preference for control and interspersal assignments across the dimensions of time to complete, effort to complete, and level of difficulty. In the next experiment, students completed three assignments. Two of the three assignments were those from experiment one. The new assignment contained interspersed problems requiring three-digit by two-digit division with whole number answers. After completing all three assignments, students ranked the assignments across the same dimensions as experiment one. Students rated the one-digit by one-digit interspersal assignment as taking less time, less effort, and being less difficult than the other two assignments. Rankings of the one-digit by one-digit interspersal assignment were nearly identical in both experiments. In experiments one and two, problem completion rate was highest in the one-digit by one-digit interspersal assignment.

Investigators researching student preference for interspersal versus control assignments have also looked at student evaluations regarding both the difficulty of interspersal assignments as well as the amount of effort required to complete interspersal versus control assignments. Martin et al. (2001) found no differences in student ratings of effort required by interspersed assignments as compared to control assignments. Meadows (2002) also found no difference in student rankings of interspersal versus control assignments across the dimensions of difficulty and effort.

A number of researchers have found students rated interspersal assignments as less difficult and requiring less effort than control assignments (Billington & Skinner, 2002; Wildmon et al., 1998; Cates et. al, 1999; Cates & Skinner, 2000). The mixed results make it important to look for variables that may affect student ratings. In this case, studies where students rated interspersal assignments as less difficult and requiring less effort were in mathematics, while those that found no difference between interspersal and control assignments across these two variables were in reading and English.

Additive interspersal requires the addition of problems, albeit less time-consuming problems as compared to target problems, to be interspersed among the target problems. Therefore, a control condition may have 15 target problems while the experimental or interspersal assignment would include 15 target problems and possibly five interspersed problems. Perceived time to complete an assignment may be influenced by adding more problems. Student evaluation of time to complete interspersed assignments versus control assignments has yielded mixed results.

Martin et al. (2001) found students reported the control assignment as taking less time to complete than the interspersed assignment, although this did not affect their selecting the control assignment when asked for a preference. Meadows (2002) found no difference on student evaluation of time regarding assignments. Skinner et al. (1996) and Cates and Skinner (2000) found students rated the interspersal assignment as taking less time.

Reinforcement is most often offered as the reason for why interspersal, both substitutive and additive, works to increase accuracy and task completion as well as to promote choosing to engage in assignments. In substitutive interspersal studies, Neef, Iwata, and Page (1977) and Neef et al. (1980) found the interspersal procedure produced greater accuracy and task acquisition than either baseline conditions or high-density social reinforcement.

Neef et al. (1977) suggest the importance of attention in the interspersal procedure. They claim the inclusion of known items increased student attention for work on unknown items. With more focused attention, students were able to increase their performance on the unknown items and were then reinforced for correct responses during learning. In substitutive interspersal, reinforcement is seen as being contingent on getting items correct.

Reinforcement and attention are also explanations for why additive interspersal is successful in promoting students choosing more effort by engaging in interspersal over control assignments. However, in additive interspersal, reinforcement is seen as contingent on completing problems. Reinforcement does not follow sustained attention as in substitutive interspersal. Rather, in additive interspersal, problem completion leads to increased attention.

An example of reinforcement contributing to attention is present in a study by Robinson and Skinner (2002). Interspersal increased the rate of reinforcement relative to the non-interspersal condition. This increased reinforcement led to increased student attention and performance on tasks that required high levels of attention as reflected in the evaluation of student performance on a high-attention task (Mental Computation subtest requiring calculation without the use of paper and pencil) versus a low-attention task (Multiplication subtest allowing use of pencil and paper).

A specific example of how interspersal affects completion rates is evident in Skinner et al. (1996). By interspersing six problems in addition to 16 target problems on one assignment, as opposed to just 16 target problems in the control assignment, mean problem completion rates were 13.5 problems during interspersal compared to 9.9 problems in the control assignment when time to complete assignments was held constant. By adding items that take less time to complete, student completion rates and therefore reinforcement can be increased, thus making it more likely students will choose the assignment for which they receive higher rates of reinforcement.

Cooke et al. (1993) found when three students were asked why they chose the interpsersal assignment over the control assignment, they said the interspersal assignment was easier. Since this study used substitutive interspersal, and it is believed students are reinforced based on correct responses, this finding is logical.

For additive interspersal studies, students often rate interspersal assignments as easier than control experiments, but this does not mean this is the reason why students choose interspersal over control assignments. Many studies (Martin, 1998; Meadows, 2002; Skinner, Fletcher, Wildmon, & Belfiore, 1996) suggest interspersing items that take little time to complete may be more important than interspersing easier items when getting students to prefer interspersal assignments over control assignments.

There are two models/hypotheses most cited for explaining how students are reinforced under the additive interspersal procedure, Matching Law (Herrnstein, 1961) and Discrete Task Completion Hypothesis (Skinner, 2002). Matching Law is a mathematical model that predicts student choice of engaging in behaviors/academic activities based on relative rates of reinforcement (Skinner, 2002). By changing the schedule of reinforcement, teachers should be able to alter both the likelihood of a student engaging in an assignment and student preference of assignments. Johns et al. (2000) provide support for the utility of the Matching Law in interspersal assignments by measuring the amount of time students allocated to interspersal and control assignments presented on a computer.

The Discrete Task Completion Hypothesis (Skinner, 2002) maintains that in assignments that have many discrete tasks, each completed task may serve as a conditioned reinforcer. Each problem serves as a discriminative stimulus for the next problem in the assignment (chain). This process continues until the final problem, the terminal discriminative stimuli, is completed. Completion of that stimuli leads to discriminative reinforcement based on completing the assignment. This hypothesis depends on the assumption that problem completion has been reinforced previously in the student's learning history. Discrete tasks are often found in the form of math assignments. An example of an academic task that is not a discrete task is reading. This may explain why the findings of the Martin (1996) and Martin et al. (2002) studies involving reading were different from the other interspersal studies that primarily involved math problems.

An application of the Discrete Task Completion Hypothesis in conjunction with Matching Law is visible in Skinner et al. (1999). The authors examined whether Matching Law accurately predicted students choosing assignments based on discrete task completion rates. There were four different assignments including four-digit by one-digit multiplication, four-digit by two-digit multiplication, four-digit by three-digit multiplication, and four-digit by four-digit multiplication. Control assignments involved no interspersed problems while experimental assignments were interspersed with one-digit by one-digit multiplication problems. Each control assignment was paired with its experimental interspersal assignment. Because of this comparison, relative rates of task completion were measured. The Matching Law successfully predicted that as target problem length increased (4 by 1 to 4 by 4) and the discrepancy between problem completion rates increased across control and experimental pairings (4 by 1 to 4 by 4), the proportion of students choosing the experimental assignments increased according to the linear mathematical model offered by Matching Law.

Response Accuracy and Learning Rates

Students choosing to respond is a good start to the process of learning. Choosing to do work is necessary for skill development (Greenwood et al., 1984). Students are often given independent seatwork assignments that allow them to practice responding.

During these assignments, there is no immediate feedback or error correction. Thus, students may be practicing errors. Therefore, it is important to also develop assignment alteration procedures that enhance accuracy of those responses and further enhance learning rates.

Studies involving additive interspersal have focused primarily on choice. However, researchers have also investigated whether additive interspersal increases accuracy on target problems. Only one additive interspersal experiment procedure has shown an increase in student accuracy on the interspersal assignment in comparison to control assignment (Robinson & Skinner, 2002). In this study, accuracy increased when students worked on problems they had to compute mentally (high-attention task) without aid of pencil and paper. An increase in accuracy on interspersal assignments was not present when the assignment required computation of written problems (low-attention task).

Thirty students with a history of low math achievement were administered subtests from the Key Math Revised Test. The two subtests administered were Mental Computation and Multiplication. Both subtests had equivalent forms so that interspersal assignments could be constructed easily by adding problems to one of the alternate forms of each subtest. On the Mental Computation subtests, items are presented either orally, or visually on an easel. In this condition, students are prohibited from using pencil and paper to solve problems. The Multiplication subtest contained problems written on a sheet, which students were to solve with the aid of a pencil.

Student accuracy on the interspersal assignment of the Mental Computation subtest was higher than accuracy on the control assignment of the same subtest. This result is significant as it is the first evidence of an increase in accuracy with the use of additive interspersal. There was no difference in accuracy on the interspersal and control assignments on the Multiplication subtest.

The authors suggested reinforcement and different task demands best explain the increase in accuracy on the interspersal assignment versus control assignment on the Mental Computation subtest. Reinforcement is offered as an explanation because the characteristics of the interspersed problems, easy and brief, allow for the completion of a greater number of problems in less time. Reinforcement rates for problem completion are higher under the interspersal condition as reinforcement occurs more frequently. Increased rate of reinforcement is a plausible explanation as to why students choose to engage in interspersal assignments over control assignments, however, it does not clearly explain an increase in accuracy or why there was no gain in accuracy on the interspersal assignment over the control assignment on the Multiplication subtest. Different task demands, in this case mental computation versus computation with pencil and paper, may affect attention, which in turn may increase academic performance. The Multiplication subtest was not timed, while students received only 15 seconds to complete each problem in the Mental Computation subtest. The researchers posit the faster pacing and oral computation present in the Mental Computation subtest required a higher level of sustained attention compared to the untimed, written problems. This higher level of attention may contribute to increased accuracy.

During independent seatwork, educators want high rates of accurate academic responding because this increases learning rates. Academic Learning Time is described as time in which students are on-task and performing an academic skill accurately (Fisher &

Berliner, 1985). The goal of altering assignments through interspersal is to increase learning rates. Studies involving substitutive interspersal have focused on measuring learning. Many researchers have suggested interspersal increases learning (Cooke et al., 1993; Cooke & Reichard, 1996; Roberts & Shapiro, 1996). However, a close inspection of the results shows this conclusion to be misleading.

Researchers using substitutive interspersal are interested in increasing learning through experimentally altering instructional ratios of known (interspersed, known items) to unknown (target items) material. Much of the research in this area has centered around the work of Gickling and Thompson (1985) and Gickling and Havertape (1981).

Roberts, Turco, and Shapiro (1991) explored changing ratios of known and unknown words while investigating learning of vocabulary words via drill techniques. Experimenters used four conditions; 90% known to 10% unknown, 80% known to 20% unknown, 60% known to 40% unknown, and 50% known to 50% unknown. Unfortunately, the researchers did not provide a condition in which there were more unknown words than known words. Cooke and Reichard (1996) noted each student was assigned to only one of the four conditions, and idiosyncratic possibilities were not assessed. Results showed students learned more words in the 60% known to 40% unknown and 50% known to 50% unknown conditions.

However, researchers did not equate the number of words that students could learn across all conditions. Therefore, students in the 60% known words condition had many more words to learn (88) than in the 80% known condition (44). When the researchers equated the number of words learned from pre-test to post-test eight weeks later by factoring the proportion of known to unknowns, it was found students in the 90% known and 80% known conditions learned a greater proportion of unknown words.

The authors concluded the 90% known and 80% known ratios were most beneficial because they provided the most learning. However, two problems arise. First, researchers are determining words learned by a post-test eight weeks later. An individual is more likely to remember a greater number of words when given a list of 10% new words than 80% new words. Second, the researchers are not measuring learning by total words learned, but rather proportion of words learned.

Roberts and Shapiro (1996) conducted a somewhat similar study to the one previously discussed hoping to account for flaws they identified from their 1991 study. Roberts and Shapiro used 20 words per learning trial and changed the instructional ratios to 80% known to 20% unknown, 50% known to 50% unknown, and 20% known to 80% unknown. Results were very similar to the Roberts et al. (1991) study. Students learned more words under the 20% known to 80% unknown condition, but learned a greater percentage of the unknown words under the 80% known compared to the 20% known condition.

Roberts and Shapiro (1996) claimed Gickling's ratio of 80% known to 20% unknown items was the most beneficial in promoting learning. Again, the researchers stuck to their faulty line of reasoning. Students in the 20% known/80% unknown condition learned 35.1% of unknown words while those in the 80% known/20% unknown condition learned 65.73% of unknown words. During each trial in the 20% known/80% unknown condition, students were presented with four known words and 16 unknown words. The inverse proportion was true under 80% known/20% unknown condition.

Roberts and Shapiro (1996) made this conclusion despite presenting a graph that showed the mean number of cumulative words learned over 28 sessions. The highest slope was found in the 20% known/ 80% unknown condition, followed by 50% known/50% unknown and 80% known/20% unknown condition. Students learned twice as many words under the 20% known condition as compared to the 80% known condition.

An analogy as to how you can have a smaller percentage of words learned yet learn more is as follows. On a spelling test with twenty problems, a student may get nine correct for a score of 45%. On a spelling test with ten words, which can be ten words common to the twenty words test, a student can get seven correct for a score of 70%. The student's score is higher on the latter, but they have learned more words on the former.

It is also easy to see why substitutive interspersal is seen as watering down the curriculum. Potential tasks to be learned are being replaced with tasks already learned. In order to equate the number of tasks learned, more trials will be needed.

Cooke et al. (1993) also explored instructional ratios in a three experiment study. In the first experiment, four students worked on activities involving spelling acquisition and maintenance by using flash cards to present a word and then having the student spell it without looking at the word. The two different conditions were 30% acquisition (unknown)/70% maintenance (known) and 100% acquisition (unknown). After each session, student accuracy was measured. There was no difference in student performance in terms of words spelled correctly between the two conditions. Similarly, follow-up measures showed no difference in accuracy between the two conditions. Students learned more words per minute under the all acquisition task since all words were new, as opposed to the condition in which 30% of the words were novel.

Experiment two was similar to number one with the difference being the flashcards contained one-digit by one-digit multiplication tasks. Researchers found greater fluency of multiplication facts occurred during the 30% unknown/ 70% known condition. There were no significant differences in student performance on follow-up maintenance tests.

The third experiment involved the same 30% unknown /70% known and 100% unknown conditions with the use of reading probes. Students read a passage, worked with a peer-tutor on flashcards involving known and unknown words, and then re-read the same passage. Variables of student performance measured were number of words read per minute, number of words mastered per two-minute session, and number of correct words previously learned as measured by follow-up tests. Fluency in terms of correct words per minute was not changed as a result of the drills for either of the two conditions. More words were learned per session during the 100% unknown condition and it follows that students learning rates were greater in this condition. Maintenance, as measured by follow up tests of previously mastered words from earlier passages was very high for both conditions.

In order to further examine the impact of different instructional ratios on student learning, Cooke and Reichard (1996) conducted a study using three different instructional ratios; 70% known and 30% unknown, 50% known and 50% unknown, 30% known and 70% unknown. Investigators examined student acquisition and generalization of multiplication and division facts. Again, a flashcard procedure was used and known and unknown items were determined by a teacher-administered pre-test. Students were then given a generalization probe in which they answered problems written on a sheet instead of responding to items on flashcards.

In terms of the mastering of multiplication and division facts, the six students varied as to under which condition they performed best. Four students performed best under the condition of 30% known and 70% unknown while two students performed best under the 50% known and 50% unknown condition. No students performed best under the 70% known and 30% unknown condition. In fact, the 70% known and 30% unknown condition produced the least mastery for all six students. In terms of maintenance or generalization, all three conditions were the best in terms of producing generalization for different students.

The previous two studies refute the Shapiro and Roberts (1996) conclusion that the optimal instruction ratio for learning is around 80% known to 20% unknown. Students scored highest on the mean number of acquisition facts mastered per session under the lowest ratio of known to unknown items. This suggests substitutive interspersal is not preferable to additive interspersal because substituting known items for target items reduces the amount of information that can be learned when time is held constant.

Summary and Purpose

Researchers found students preferred assignments involving additive interspersal over assignments without interspersal. Students were also more likely to engage in on-task behavior during interspersal assignments compared to control assignments. This was likely attributable to the brief nature of the interspersed problems leading to higher rates of problem completion that is reinforcing. Additionally, because additive interspersal problems are brief, they do not decrease opportunities to respond to target items. Only one study involving additive interspersal found an increase in accuracy on assigned target tasks. The most likely explanation was the additional reinforcement caused higher levels of sustained attention.

The main purpose of the current study was to extend research on increasing accuracy on academic assignments through use of the additive interspersal procedure. Robinson and Skinner (2002) are the only researchers to have found an increase in student accuracy on interspersed assignments as compared to control assignments. This study attempted to determine if the results of the Robinson and Skinner (2002) study were a statistical outlier or whether the uniqueness of that study, using assignments requiring different task demands, could increase problem accuracy.

Although the design of the current study was greatly influenced by the Robinson and Skinner (2002) study, it was not a strict replication. This study was designed to account for possible methodological flaws in the Robinson and Skinner study as well as introduce different instructional (interspersal) ratios into the assignments.

This study sought to improve on the Robinson and Skinner (2002) study by equating the two different assignments so as to rule out extraneous variables that may arise due to the different nature of the assignments. By ruling out extraneous variables, we hoped to measure the impact of task demands, which is the variable that was unique to the Robinson and Skinner study.

Problems in the Robinson and Skinner (2002) study that were changed were as follows. First, item difficulty was equated across all assigments. In the Robinson and

Skinner study, the Multiplication subtest selected consisted only of multiplication problems, while the Mental Computation subtest had multiplication, division, addition, and subtraction problems.

Second, in the current study, there was consistency in the assignments where problems were presented orally. In the Mental Computation subtest used by Robinson and Skinner (2002), six of the 18 problems were presented orally while the other 12 problems were presented visually on an easel. In the current study, all of the high-attention problems were presented orally.

Lastly, in the Robinson and Skinner (2002) study, students had different amounts of time to complete problems. Items on the Multiplication subtest were not subject to a time limit, while students had 15 seconds to complete each target problem on the Mental Computation subtest. In the current study, students had 20 seconds to complete each target problem. High-attention and low-attention tasks were determined by the manner in which the material was presented, not by the imposition of a timed condition versus an untimed condition.

Three ratios of interspersal were added in order to examine whether different schedules of interspersal affect problem accuracy. One high-attention (oral) and one low-attention (written) assignment contained nine target problems with no problems interspersed, serving as a control condition. Another high-attention and low-attention assignment consisted of nine target problems and three interspersed problems. An interspersed problem was presented after the presentation of three target problems for an interspersal ratio of 3:1. Finally, one high-attention and one low-attention assignment consisted of nine target problems and nine interspersed problems. Each target problem was followed by an interspersed problem for an interspersal ratio of 1:1. Therefore, students completed the same number of high-attention and low-attention problems, methodology not used in the Robinson and Skinner (2002) study.

Chapter 3

Methodology

Participants and Setting

All students from four fifth-grade general education classrooms in a rural elementary school in the southeastern United States were given the opportunity to participate in the current study. Approximately 85% of students were eligible for a free and/or reduced lunch. Thirty-one percent of students were Hispanic, 61% were Caucasian and eight percent were African-American. The school contained kindergarten through fifth-grade classrooms. There were two alternative classrooms serving students with behavior problems, developmental disorders, and physical impairments.

In soliciting participants, the primary experimenter first met with the principal, described the study, and received permission to request the cooperation of all four fifth-grade teachers. Each teacher agreed to allow the primary researcher to conduct this study in her classroom. Next, formal permission to conduct this study was obtained from the school system and University of Tennessee Institutional Review Board.

Subsequently, each of the four teachers distributed parental consent forms to each student in their classroom. Every student who returned an informed consent form was also given an assent form prior to the beginning of the study. These students were informed they could cease participation at any time during the study without repercussions. Students were also informed their participation would have no bearing on their grades in class.

The final pool of participants included 70 students. Forty-five students were Caucasian, 21 were Hispanic, and four were African-American. Fifteen of the 21

Hispanic students spoke Spanish as their primary and native language. Fifty-two students from three classrooms were used in the actual experiment. The other 18 students, all in the same class, participated in the piloting of test items.

Administrations of experimental procedures were run in classrooms for half of the participants. The other administrations occurred in the cafeteria. The classrooms had individual desks, which allowed the investigator to arrange student seating in an attempt to minimize potential cheating and distractions. The cafeteria had tables with individual seats affixed to the table. Students were seated every other chair in order to reduce the possibility of cheating.

Materials

In the current study, each student completed six assignments. The first step in designing all possible assignments was to develop six control assignments. In order to equate problems across control assignments, six initial assignments (assignment A, B, C, D, E, and F) with nine multi-step mathematics computation problems (i.e., target problems) were constructed (Appendix A).

Specific rules were constructed regarding the types of target problems used in the study. First, each problem consisted of three mathematical computations or operations that involved either addition or subtraction. Therefore, in each problem there were four numbers preceding the equals sign. In each problem, the four numbers consisted of three one-digit numbers and one two-digit number. Furthermore, a single specific order of two-digit, one-digit, one-digit, one-digit, =, was used for every problem. In each problem, the three computations or operations required one of three skills (carrying, borrowing, neither carrying nor borrowing). In each problem, two computations did not involve carrying or borrowing while a third computation involved either carrying or borrowing. Each of the nine target problems per assignment were different in terms of the operations and skills used as well as the order they were arranged. The nine different combinations of computations and skills used on the assignments are presented in Table 1.

The problems used in the study were decided upon as a result of piloting several problem types and finding a difficulty level appropriate for fifth graders. This arrangement consisted of each skill (carrying, borrowing, neither carrying nor borrowing) appeared in each position (first, second, third) in the equation an equal number of times. Students performed five operations involving carrying and four operations involving borrowing. Students performed 13 addition operations and 14 subtraction operations during work on the target problems on each assignment. The inequity in the number of addition/subtraction and borrowing/carrying operations was a function of having an odd number of problems on each assignment. On the briefer, easier interspersed problems, students either added or subtracted two one-digit numbers that did not involve carrying or borrowing.

The numbers zero and one were not used in any of the problems and never occurred as a correct answer following an operation. The number two was not used in any operations, but could occur in the final answer (e.g., 47+5=52). Additionally, no identical two-digit numbers (e.g., 77) were used in any of the problems. There were no duplicate problems among the 54 total target problems to be attempted by the students.

Each control assignment was modified to develop two interspersal assignments (1:1 ratio and a 3:1 ratio) by adding brief one-digit plus or minus one-digit problems

Table 1

Problem Types

	Two-Digit		One-Digit		One-Digit		One-Digit	
1.		+	N	-	N	+	C	=
2.		-	N	+	N	-	B	=
3.		+	N	-	N	-	B	=
4.		+	C	+	N	-	N	=
5.		-	B	-	N	+	N	=
6.		+	C	-	N	+	N	=
7.		-	N	+	C	-	N	=
8.		+	N	+	C	-	N	=
9.		-	N	-	B	+	N	=

Note. N = neither borrowing or carrying, B = borrowing, C = carrying with one-digit answers. For the 1:1 ratio interspersal assignments, the first problem was a target problem, the next an interspersed problem, with this pattern continuing for a total of 18 problems. For the 3:1 ratio, the first three problems were target problems, followed by one interspersed problem with this pattern continuing for a total of 12 problems. Thus, a total of 18 assignments including six control, six 1:1 interspersal, and six 3:1 interspersal assignments were constructed for this study. Other materials used in the current study included a stopwatch and paper and pencils.

Experimental Design

The current study used a 3 x 2 within-subjects repeated measures ANOVA to test main and interaction effects of interspersal ratios and task demands (written-low attention, oral-high attention) on students' mathematics computation accuracy. Interspersal ratios included no interspersal, 3 target problems:1 interspersed problem and 1 target problem:1 interspersed problem. Task demands included high-attention tasks where students were required to solve problems without the aid of paper and pencil and low-attention tasks where students were allowed to use paper and pencil to solve similar problems.

Independent variables. The two independent variables manipulated in this study were ratio of interspersal and task demands (attention). Interspersed problems were included at three different ratios. Assignments either contained no interspersed problems, a 3:1 ratio of target problems to interspersed problems, or a 1:1 ratio of target problems to interspersed problems.

Two different procedures were used for presenting and solving mathematics problems. In the low-attention condition, problems were printed on 8 ½" by 11" paper and students were allowed to solve the problems using a pencil. In the high-attention condition, the experimenter read the problems and students were only allowed to use pencils to record their answer. Under both conditions, students were given 20 seconds to complete target problems and 4 seconds to complete interspersed problems.

Dependent measures. Three dependent measures were used in this study. The primary dependent variable was accuracy on target problems. Problem accuracy was calculated by dividing the number of target problems correct by the total number of target problems. Problem accuracy on brief problems and total problem accuracy (interspersed problems plus target problems on 1:1 ratio and 3:1 ratio assignments) was calculated in the same manner.

Data Analysis Procedures

A within-subjects 3 x 2 repeated measures ANOVA was used to test for differences in target problem accuracy across interspersal ratios (0, 3:1, 1:1) and attention conditions (high and low). The terms task demands and attention were used interchangeably as written assignments were considered low-attention whereas oral assignments were considered high-attention. Main effects, interaction effects, and post hoc analysis were examined using Scheffe's Multiple Comparison Test (See Table 2). All differences were considered significant at the $p < .05$ level.

Counterbalancing and Randomization of Assignments

After obtaining the final pool of participants, each of the three classrooms was split up and members were randomly assigned to one of two groups (Group A or Group B). Counterbalancing was used so group size varied by no more than one student. The

Table 2

3 X 2 ANOVA

	Interspersal Ratio		
	0	3:1	1:1
Low Attention	% correct	% correct	% correct
High Attention	% correct	% correct	% correct

division of the three classes into six groups allowed for easier management of the students and permitted different orders of presentation to control for sequence effects.

Each of the six groups attended three sessions on the same school day. During each session, each group worked on two different assignments (i.e., a low attention and a high attention) with identical interspersal ratios (e.g., both 1:1 ratios). After each of the first two sessions, a five-minute break was given before commencing with the subsequent session. Within-subjects designs are susceptible to multiple treatment interference (e.g., practice effects, treatment induction). To control for these effects, the six conditions were randomly sequenced for each group. For each group, the sequence of low and high-attention tasks was counterbalanced across sessions. Additionally, the sequence of ratios (0, 1:1, 3:1) was counterbalanced across groups. Table 3 displays the sequence for each group.

Although assignments A-F were constructed to contain equivalent long problems, counterbalancing was used to assign assignments A-F to conditions, to further control for

Table 3

Assignments Completed Each Session by Group

	Session 1	Session 2	Session 3
Group 1	0/HA –0/LA	3:1/LA –3:1/HA	1:1/LA-1:1/HA
Group 2	0/LA-0/HA	3:1/HA-3:1/LA	1:1/LA-1:1/HA
Group 3	1:1/LA-1:1/HA	0/LA-0/HA	3:1/HA-3:1/LA
Group 4	1:1/HA-1:1/LA	0/LA-0/HA	3:1/HA-3:1/LA
Group 5	3:1/HA-3:1/LA	1:1/HA-1:1/LA	0/LA-O/HA
Group 6	3:1/LA-3:1/HA	1:1/HA-1:1/LA	0/HA-O/LA

assignment difficulty. Table 4 graphically displays this assignment pattern.

General Procedures

Three sessions were needed for each group. For each classroom (two groups in each room, sessions were run on the same school day. During each session, students completed two assignments (see table 3). The experimenter introduced himself to students in each class and explained that he would be working with them on some math problems. The teacher was asked not to inform students of the purpose of the study. Each administration followed the same procedure. The experimenter and group of students either stayed in the classroom or walked to the cafeteria. Students were asked to sit at individualized desks or seats spaced apart in order to reduce opportunities to cheat.

Table 4

Counterbalancing Assignments

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
A L-0	H-3:1	H-1:1	H-0	L-3:1	L-1:1
B L-1:1	L-0	H-3:1	H-1:1	H-0	L-3:1
C L-3:1	L-1:1	L-0	H-3:1	H-1:1	H-0
D H-0	L-3:1	L-1:1	L-0	H-3:1	H-1:1
E H-1:1	H-O	L-3:1	L-1:1	L-0	H-3:1
F H-3:1	H-1:1	H-0	L-3:1	L-1:1	L-0

Assignments were handed to each student in the correct order based on the sequences in Table 3. Additionally, each student was assigned a code in order to track performance on each of the six assignments. Students were provided pencils to write their answers. Directions were read to the students and they were asked not to share what they had done with the other members of their class or the other fifth grade classes. Finally, students were told that this activity would not affect their grades in their regular math class.

In this study there were six conditions under which students performed math problems. The six conditions come from a two by three model consisting of two tasks by three interspersal ratios. One task was considered low-attention (written). Students were given 8 ½" by 11" paper that contained the problems and spaces for answers to the problem. Students were told to complete the problems in order without skipping. Two sample problems were given at the beginning of the first low-attention problem set. The experimenter reviewed the sample problems with students to ensure they understood the task. The total time allotted for completion of the problems was 20 seconds per target problem and 4 seconds for the interspersed problems. Twenty seconds was found to be optimal in allowing students sufficient time to complete each problem. The experimenter started the stopwatch and said, “begin” to signal the start of work on the assignment. The experimenter stopped the stopwatch when the designated time to complete the assignment had expired.

The second task was considered a high-attention task (oral). Students were given a piece of paper with only spaces to write down answers. Each problem was read aloud to students who were to complete the problem in their head and then record the answer on the answer sheet provided. Two sample problems were given at the beginning of the first high-attention problem set. The experimenter reviewed the sample problem with students to ensure they understood the task. Students were again given 20 seconds per target problem and 4 seconds per interspersed problem. Students were required to wait for the examiner to read each subsequent problem. Problems were not repeated.

For the two different types of tasks, students worked on three different assignments. Interspersed problems, those briefer and easier than target problems, were included at three different ratios in the presentation of problems. One condition was characterized by the complete absence of interspersed items. Therefore, all problems presented were target problems. During the second condition, brief problems were interspersed at a 1:1 ratio so that every other problem was a non-target or interspersed problem. The third condition provided a 3:1 ratio of target problems to interspersed problems. For every presentation of three target problems there was presentation of one interspersed problem.

The specifics regarding the number of problems and time allowed for the administration of each condition are presented as follows.

1. Low-attention task (written) and no interspersal- total of nine problems and 3 minutes to complete the problem set.

2. Low-attention task (written) and 1:1 interspersal ratio- total of eighteen problems and 3 minutes and 36 seconds to complete the problem set.

3. Low-attention task (written) and 3:1 interspersal ratio- total of twelve problems and 3 minutes and 12 seconds to complete the problem set.

4. High-attention task (oral) and no interspersal- total of nine problems and 3 minutes to complete the problem set.

5. High-attention task (oral) and 1:1 interspersal ratio- total of eighteen problems and 3 minutes and 36 seconds to complete the problem set.

6. High-attention task (oral) and 3:1 interspersal ratio- total of twelve problems and 3 minutes and 12 seconds to complete the problem set.

Scoring

An answer key was developed for each problem set. Before grading the answer sheets, the experimenter made a copy of each answer sheet. The experimenter then marked all of the problems with pen so that errors would be clearly marked and counted.

Interscorer Agreement

Interscorer agreement was obtained by having another graduate student independently score twenty percent of the total problems sets. The accuracy percentage obtained by the graduate student was compared to that of the principal investigator. The formula used to determine agreement was found by taking the total number of agreements and dividing that number by the number of agreements plus disagreements. This fraction was then multiplied by 100 in order to yield a score in percentage form. This same procedure was used in order to obtain agreement on accuracy of interspersed problems as well as the total problems (target plus interspersed problems). Interobserver agreement was 96.2% on target problems and 97.1% on total problems. It appears most scoring discrepancies were due to difficulties interpreting handwriting. Interobserver agreement was predicted to be high because scorers were working off of a previously made answer key that was checked for accuracy by the investigator and the graduate student.

Procedural Integrity

Procedural integrity was determined by use of a checklist (Appendix B) to make sure proper steps were taken in the administration. The checklist was created by the principal investigator and completed by an independent observer for each session. The checklist consisted of a number of important procedural steps. Integrity was determined to be 100%.

Chapter 4

Results

This chapter summarizes the results of data analysis procedures. Although counterbalancing was used to control for sequence effects and assignment difficulty, analyses were conducted to evaluate these possible threats to internal validity. Next, main effects are presented, followed by interaction effects.

Order

In the current study, six groups of students worked on six different assignments. Thus, the possible combinations of assignment sequence were 720. Because assignments were administered in a group format, all possible sequences could not be used. Therefore, a mixed-design ANOVA with ratio of interspersal and task demands (attention) serving as the within-subjects variables and order of assignment presentation as the between-subjects variable was used to determine if order of assignment presentation led to significant differences in accuracy. The main effect of order was not significant, F (5, 46) = .76, p = .58.

Three by Two ANOVA

A repeated measures ANOVA with ratio of interspersal and task demands (attention) serving as the within-subjects variables was used to determine the effects of ratios of interspersal and task demands (attention) on student accuracy on target problems. Table 5 provides mean and standard deviation data for percent of target problems answered correctly under each of the six conditions.

Table 5

Percent Target Problems Correct, Means and Standard Deviations Across Conditions (N = 52)

	Ratio of Interspersal					
Attention	0		3		1	
	M	*SD*	*M*	*SD*	*M*	*SD*
Written	70.09_{a}	30.13	$72.86_{a,b}$	27.95	74.57_{b}	27.34
Oral	49.15_{c}	28.38	56.84_{d}	27.63	51.28_{c}	29.94

Note. Means in the same row that do not share a subscript differ at $p < .05$. Means without a subscript do not differ from other means in their row. Means in the same column that do not share a subscript differ at $p < .05$.

Main effect of attention or task demands. ANOVA summary results for the main effect of attention are displayed in Table 6. The main effect of attention was significant, $F(1, 51) = 56.00$, $p < .05$, with students having higher accuracy on the low-attention written task ($M = 72.51$, $SD = 3.76$) than on the high-attention oral task ($M = 52.42$, $SD = 3.75$). These findings are only important because they suggest researchers were successful in developing assignments to meet their goals. In the current study, the specific problems across task demands were similar (i.e., same number of steps and the same operations). However, researchers attempted to construct tasks in a manner that obtaining accurate answers under the oral condition would require more attention than

Table 6

Main Effect of Attention or Task Demands

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Attention	254.885	1	254.885	56.003	.000
Error	232.115	51	4.551		

under the written condition. Although attention was not directly measured, the lower levels of accuracy on low-attention assignments suggests researchers were successful developing tasks that required different levels of cognitive attention.

Main effect of ratio. ANOVA summary results for the main effect of ratio are shown in Table 7. The main effect of ratio was significant, F (2, 102) = 5.25, $p < .05$. Post hoc analysis using Scheffe's Multiple Comparisons Test of the main effect of ratio revealed students had significantly higher accuracy rates on assignments when a briefer, easier problem was interspersed after every third target problem (M = 64.85, SD = 3.55) compared to no interspersal (M = 59.62, SD = 3.75). There were no significant differences in accuracy between assignments without interspersal and assignments with an easy, brief problem interspersed every other problem (M = 62.93, SD = 3.59). There also were no significant differences in accuracy on assignments with an easy problem interspersed every other problem and assignments with easy problems interspersed every third problem. Although these data suggest that a 3:1 ratio of target to interspersed problems will result in higher accuracy levels than no interspersal, they must be interpreted in light of the interaction results presented next.

Table 7

Main Effect of Ratio

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Ratio	11.814	2	5.907	5.246	.007
Error	114.853	102	1.126		

Interaction effects. Table 8 summarizes ANOVA interaction results. The attention x ratio interaction effect, F (2, 102) = 3.27, was significant, $p < .05$. Post hoc comparisons using Scheffe's Multiple Comparison Test showed altering ratios of target to interspersed problems led to significant differences in accuracy on both the oral and written assignments. These results are summarized in Table 5. On the written assignments, students had significantly higher accuracy on the assignment with 1:1 interspersal ratio than they did on the assignment with no interspersal, $p < .05$. There were no significant differences on accuracy rates between the written 3:1 ratio interspersal assignment and either the control assignment (no interspersal) or the 1:1 assignment.

On the oral assignments, students performed with significantly higher accuracy on the assignment with brief, easy problems interspersed after every third target problem than they did on the assignment without interspersal and the assignment with an easy problem interspersed every other problem, $p < .05$. There was no significant difference between accuracy on the oral assignments without interspersal and with interspersal every other problem.

Table 8

Interaction Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Attention* Ratio	714.625	2	357.312	3.27	.042
Error	11137.227	102	109.188		

These results suggest that for the low-attention assignments (written assignments) altering assignments by interspersing briefer, easier problems following every third target problem did not improve accuracy. However, altering written assignments by interspersing briefer and easier problems every other target problem did enhance accuracy. In contrast, on the oral assignment, interspersing a briefer and easier problem after every third target problem did enhance accuracy over the control assignment, but interspersing every other problem did not enhance accuracy over the control assignment.

Accuracy on Interspersed Problems versus Target Problems

Two independent samples *t*-tests were performed in order to measure student accuracy on interspersed versus target problems under the low-attention and high-attention condition. The results of the independent samples *t*-test in the low-attention or written condition were significant t (258) = 9.00, $p < .05$. Students were significantly more accurate on interspersed problems (M = 98.08, SD = 7.00) than target problems (M = 72.51, SD = 28.38). The results of the independent samples *t*-test in the high-attention or oral condition were significant t (258) = 15.57, $p < .05$. Students were significantly more accurate on interspersed problems (*M* = 97.32, *SD* = 7.82) than target problems (*M* = 54.42, *SD* = 28.66).

Summary of Results

Results show students performed more accurately on written tasks compared to oral tasks. This finding was important only in that it suggested that experimenters were successful in their assignment construction goals. Although a main effect for ratio was found, interaction effects make interpreting this finding inappropriate. Instead, this finding can be accounted for by significant interactions. A target to interspersal problem ratio of 3:1 on oral tasks led to a significant increase in accuracy compared to the no interspersal and 1:1 interspersal conditions. A target problem to interspersed problem ratio of 1:1 on written tasks led to a significant increase in accuracy when compared to the no interspersal condition.

Chapter 5

Discussion

In this chapter, findings will be discussed in relation to past research. Applied and theoretical implications of these findings will be discussed along with limitations of the current study and directions for future research.

Relating Findings to Previous Research

Previous research on the effects of interspersal procedures and student preference or choice is consistent. In fact, Skinner's (2002) meta-analysis found a clear linear relationship between relative problem completion rates (manipulated via interspersing easy, brief mathematics problems) and the probability of students choosing or preferring one assignment over another. In each of these studies, interspersal ratios were three target problems to one interspersed problem.

Skinner and Robinson (2002) are the only researchers to have found enhanced accuracy on target mathematics problems using additive interspersal. In this study, written mathematics tasks were interspersed at a 2:1 ratio and cognitive (non-written) tasks were interspersed at a 3:1 or 2:1 ratio. Results showed an increase in accuracy on target tasks for the cognitive tasks only. The researchers suggested these inconsistent findings might have been caused by differential tasks demands. More specifically, they suggested reinforcement occasioned by completing discrete tasks might have enhanced students' sustained attention, which caused the increase in accuracy on the cognitive tasks. These cognitive tasks appeared to require high levels of attention to complete accurately. The purpose of the current study was to extend this research by examining the effects of different ratios (as opposed to merely 3:1) and task demands on target problem accuracy.

Written assignments. In the current study, the written tasks could be considered low-attention because students worked at their own pace and all problems were written on paper. Students could work the math problems directly on the assignment. Because the problems were written, students could easily refer to any problem on the assignment at any time. Additionally, they could refer back to their written work as they progressed through the separate operations of each problem. However, on the oral tasks, students had to perform operations without being able to refer to previously written computations or answers. In the current study, students performed more accurately on written tasks than oral tasks. This finding suggests that the written problems required less cognitive effort or sustained attention to complete accurately than the oral problems.

With respect to the written assignments, the current results showed a 3:1 ratio did not enhance accuracy on target mathematics problems as compared to the control assignment. This result confirms previous findings of numerous researchers who used approximately a 3:1 ratio on written mathematics assignments (Billington & Skinner, 2002; Cates et al., 1999; Johns et.al., 2000; Logan & Skinner (1998); Robinson & Skinner, 2002; Skinner, Fletcher et al., 1996; Skinner, Robinson et al., 1996; Skinner et al, 1997; Wildmon et al., 1998; Wildmon et al., 1999).

The current results extended research on written mathematics assignments by examining the effect of a 1:1 ratio on accuracy. Results showed this thicker ratio of interspersed problems to target problems did enhance accuracy on the written assignments. Future researchers should continue to investigate the effects of different ratios of interspersal on student accuracy.

Oral assignments. Only Robinson and Skinner (2002) examined the impact of interspersal on target mathematics performance where students could not use paper and pencil methods to compute answers to problems. These researchers found improved accuracy on the cognitive subtest of the Key Math (Connolly, 1988) when they interspersed problems at a mixed ratio (2:1 or 3:1). The current findings on the oral assignments support this previous research, as student accuracy levels were higher on the 3:1 assignment relative to the control assignment. The current study extends this research by showing that interspersing at a 1:1 ratio did not result in increased accuracy on target problems during the oral tasks.

Applied Implications

From an applied perspective, interspersing brief, easy problems can enhance students' perceptions of written mathematics assignments (Cates & Skinner, 2000; Logan & Skinner, 1998) and their persistence or on-task levels when working on assignments (Skinner et al., 2002; McCurdy, 2001). However, researchers have cautioned against adding too many additional non-target tasks. The primary concern is adding too many interspersed problems may reduce time available and opportunities to practice target problems. Researchers found that at a 3:1 ratio, interspersing these additional problems did not significantly reduce student problem completion rates on target problems. However, because responding accurately, not mere responding or completing problems is needed to enhance learning, a higher ratio may still be beneficial if it enhances accuracy.

Oral tasks. From an applied perspective, the results of the oral task were most encouraging. Interspersing at a 3:1 ratio enhanced assignment accuracy compared to the control assignment, but at a 1:1 ratio, the interspersal procedure did not enhance accuracy over the control (no interspersal) condition. This suggests educators can enhance accuracy on teacher delivered tasks that are presented orally by merely adding a briefer and easier task after every third difficult task. Additionally, interspersing these tasks following every three target tasks allows teachers to provide students with more opportunities to respond to target items than a 1:1 ratio because the time spent responding to interspersed items is decreased.

Thus, the current study has clear implications for teachers who deliver tasks verbally. For example, teachers often deliver items verbally to the entire class during recitation sessions (i.e., teacher asks questions and students are called upon to respond). The current study suggests the quality of those responses (i.e., accuracy) may be enhanced when an additional brief and easy question is interspersed following every third difficult question. Applied researchers should conduct studies to assess the generalizability of these findings. Additionally, they should extend these findings by determining if such procedures are acceptable to students. For example, researchers should determine if students prefer recitations sessions with briefer and easier tasks interspersed among more difficult target tasks.

Written tasks. The applied implications of the current study are less clear for written independent seatwork assignments. The current study suggests interspersing at a 3:1 ratio does not enhance accuracy on written mathematics assignments. However, such increases could be obtained if briefer and easier problems were interspersed at a 1:1 ratio.

While this suggests written independent seatwork or homework assignments should be altered by interspersing a brief, easy problem every other problem, there are some concerns with using such procedures. Specifically, interspersing at such a high ratio would significantly increase the time and effort required to complete assignments. This may make assignments less acceptable to students (Cates & Skinner, 2000).

Additionally, interspersing at such a high ratio may make assignments less acceptable to teachers because it could reduce target problem learning rates or skill development (Cooke et al., 1993; Cooke & Reichard, 1996; Roberts & Shapiro, 1996: Roberts et al., 1991). For example, assume there are 10 minutes allotted for students to practice newly learned mathematics behaviors (target problems). Interspersing at a 3:1 ratio may require 1 minute to complete interspersed problems, thus leaving 9 minutes to practice target problems. At a 1:1 ratio, students would have only 7 minutes to practice target tasks. This reduction in time to complete target problems would reduce opportunities to respond (Greenwood, Delquadri, & Hall, 1984) and perhaps learning rates (Fisher & Berliner, 1985). Future researchers should conduct studies to determine if interspersing at such a high ratio a) reduces opportunities to respond to target task, b) alters students perceptions of assignments, and c) reduces levels of on-task behavior or persistence when working on assignments because they are longer.

Theoretical Implications

Skinner (2002) posited that when given assignments with many discrete tasks, a completed discrete task may be a reinforcing stimuli. Robinson and Skinner (2002) suggested that reinforcement for working on assignments may enhance attention, thus causing students to perform more accurately on assignments that require high levels of sustained attention. If this were the case, then in the current study the highest rates of reinforcement occurred on the 1:1 ratio condition and the highest levels of sustained attention occurred on the oral assignments. Thus, we would expect interspersing additional brief, easy problems at a ratio of 1:1 would enhance accuracy on the oral assignments, but perhaps not on the written assignments. The current results showed the opposite. In the current study, the 1:1 ratio enhanced accuracy on the low-attention written tasks, but not on the high-attention oral tasks. The current results not only failed to support the Robinson and Skinner (2002) theoretical explanation for differential effects of interspersal across tasks, but also suggests this theory is inaccurate.

One possible explanation as to why students were more accurate on the 3:1 oral assignments than the 1:1 oral assignments is that as the number of intersperal problems in relation to target problems increased, it was more difficult for students to maintain their attention. The fact that student accuracy was lower on the 1:1 assignment (18 total problems) than on the 3:1 assignment (12 total problems) suggests there may be a threshold point at which students may not be able to sustain attention as well. Adding an interspersal problem for every target problem significantly increased the length of the assignment as well as the length of time students needed to maintain attention. The assignment applying the 3:1 ratio may have given students enough reinforcement to keep their attention during the task while the 1:1 assignment may have demanded too much cognitive effort to sustain attention. This explanation as to why students had higher accuracy on the 3:1 assignment than on the 1:1 assignment is supported by accuracy means from the written task.

It is important to note this study did not directly test whether a completed task is a reinforcer. While the interspersal procedure may enhance discrete task completion rates and consequently rates of reinforcement, this reinforcement is not delivered contingent upon accuracy. Perhaps if students were provided additional immediate reinforcement contingent upon accurate responding (e.g., computer delivered feedback or points) the interspersal procedure might result in a more consistent increase in level of accuracy. Regardless, the current study does suggest that Robinson and Skinner's (2002) more complex causal hypothesis (i.e., interspersal increases discrete task completion rates and rates or reinforcement which enhance sustained attention which causes an increase in accuracy on tasks requiring higher levels of attention) is inaccurate.

Robinson and Skinner's (2002) discrete task completion as a reinforcer hypothesis focuses on the relative briefness of the interspersed problems (relative to target problems). Other research investigating the interspersal procedure focused on the relative ease of interspersed problems relative to target problems (Neef, Iwata, & Page, 1977; Neef, Iwata, & Page, 1980). This alternative hypothesis suggests students may perceive interspersal assignments as easier than assignments without interspersal. In the current study, while working on problems, several students said phrases like, "I like these easy ones" or "we need more easy problems." In addition, students may believe they are more successful at interspersal assignments because interspersed problems are easier than target problems. In the current study, students correctly answered 98.08% of written interspersed problems and 97.32% of oral interspersed problems. Students' perceptions that interspersal assignments are easier and that they are more successful on these problems may influence effort or attention on target problems found on assignments involving interspersal. The current study does not support this hypothesis either. Following this theory, that is based on interspersal ease, as opposed to brevity, the 1:1 condition should be superior across all conditions for accuracy, followed by 3:1 and no interspersal.

The current results suggest the need for further research to identify the causal mechanism(s) responsible for the effects of the interspersal procedure on accuracy. One possible explanation of the current findings is related to sustained attention. Perhaps making assignments significantly longer caused students to become bored or fatigued. Some students groaned or complained when given the 1:1 assignments or said, "yes, a short one" when working on one of the other two types of assignments.

Limitations and Additional Future Research

Measuring attention. In this study, level of sustained attention was used as the main hypothesis to explain results showing students performed more or less accurately on problems under different task (attention) demands. However, attention was not directly assessed. Accuracy was used as an indirect measure of attention. Without a direct assessment of attention, it remains unclear if the differences found can be attributed directly to different task demands.

Pacing. One possible limitation of this study is the manner in which problems were presented to students. On the written, or low-attention task, students were able to work at their own pace. They were given 20 seconds per target problem and 4 seconds per interspersed problem, but were not paced by the investigator. That is, on the no interspersal written assignment, students were given 3 minutes to work on the assignment and on the 3:1 interspersal written assignment students were given 3 minutes and 12 seconds to complete the assignment. On the written tasks, students may have taken more or less time than allotted per problem. Students may not have been able to finish a problem in 20 seconds, but could continue to work on the problem until they obtained an answer. On the other hand, for the oral, or high-attention task, students had to wait for the investigator to present the problem. For this task, students may not have been able to solve a problem in the allotted 20 seconds, but were then forced to re-direct attention as the next problem was read.

The relative success of interspersal may be affected by the ability each person has to control the pace at which he work. During written interspersal assignments, students may have experienced a higher rate of reinforcement than they did when working on the oral task. On the written task, some students may have finished problems more quickly than they were allowed to on the oral task. On the oral task, even when a student solved a problem quickly, they had to wait for the researcher to present the next problem before they could continue solving problems. Although the overall amount of reinforcement may have been the same for the oral and written assignments, the rate or reinforcement was controlled on the oral task but not on the written task.

The procedure of not timing each individual problem on the written assignment may have increased the expected difference between student accuracy on the low-attention and high-attention tasks. Higher rates of reinforcement may have led to higher accuracy on the written task than on the oral task. On the other hand, it may be argued that the presentation of each individual problem on the oral assignments benefited students by holding their attention, and may have increased their accuracy because of the amount of attention they devoted to the problem. While self-pacing on the written assignments, students may have raced to complete the work or been focused on other issues not relevant to the problems at hand. During the presentation of the oral problems, students directed their eyes towards the examiner and wrote down answers at approximately the same time whereas when they worked on written assignments, it was difficult to see if each student appeared to be on-task or attentive toward the assignment.

Researchers may want to use computers to look at the role of attention and reinforcement in the effect of interspersal on accuracy. Computers can provide the time it takes for a student to complete a problem as well as the length of the interval between the completion of one problem and the beginning of the next problem. By tracking the time it takes for each discrete problem, it may be possible to determine under what conditions attention is easily or not easily maintained. Regarding reinforcement, computers can be used to provide immediate feedback on accuracy. This immediate feedback may better help determine if students are reinforced for accuracy or completion of items.

Repeated trials. Another possible limitation of the study is students completed only one assignment under each of the six conditions, thereby providing a small sample of behaviors. Different results may have been obtained if students repeated numerous assignments under each condition. This may be especially true for the oral assignments, as this type of task appeared relatively novel to students. Students are asked to perform mental computations in their head during class, but rarely those that require successive computations. Researchers may want to increase the number of trials under each condition to assess if the impact of interspersal on accuracy is increased or diminished over repeated trials.

Ratios. Future investigators using the additive interspersal procedure may want to manipulate the ratios at which items are interspersed. This study used a 3:1 and 1:1 ratio for both the written and oral tasks. The Robinson and Skinner (2002) study used a 2:1 ratio for the written tasks and varied interspersal on the oral tasks (one interspersed problem every 2-3 target problems). This study and the one by Robinson and Skinner found an increase in accuracy on the oral subtests. By increasing the number of target problems per one interspersal item, researchers may discover ratios that are more effective for promoting accuracy. Findings on changes in accuracy as interspersal ratios increase/decrease may also provide insight into the validity of the reinforcement and attention theories most often used to explain the success of interspersal. On written tasks, researchers may want to thin the reinforcement schedule by increasing or decreasing the number of target problems per interspersed problem. Students increased accuracy on written assignments when items were interspersed on a 1:1 ratio as compared to no interspersal. Students did not show an increase in accuracy on assignments containing a 3:1 ratio as compared to no interspersal. Finally on the written tasks, students did not show a significant difference in accuracy between the 3:1 and 1:1 ratios. Researchers may want to replicate the 2:1 and 3:1 rations as well as explore increased ratios. Researchers may also want to try interspersing two brief, easy problems per one target problem (1:2 ratio)

Researchers may also want to investigate the efficacy of different interspersal ratios when initial performance levels (base-rates) are varied. For example, will a 1:1 or 3:1 interspersal ratio increase accuracy more when a student is performing accurately on 30% of target problems versus 75% of target problems?

On the cognitive task of the Robinson and Skinner (2002) study, items were not interspersed on a fixed schedule. Researchers may want to develop assignments where items are interspersed at random times during an assignment. Perhaps this method might have an effect on increasing attention. In a fixed ratio assignment, students can predict when the next interspersed item will occur, perhaps affecting attention.

Generalizability

Problem variability. Another limitation of the current study is related to test variability. As assignments were created to be equivalent, all problems were theoretically the same level of difficulty. Interspersal may be more effective when target problems are easier or more difficult than the ones in this study. Interspersal may also be more effective when problems on the same assignment are of varying difficulty. Attention may differ when problems are varied as opposed to identical in design.

Length of assignments. Further research should be done to determine if results found at each interspersal ratio hold true on assignments that vary in length from the ones in the current study. In the current study, students were more accurate on oral assignments that involved interspersal at a 3:1 ratio as compared to oral assignments under the remaining conditions. There were 12 problems on the 3:1 ratio oral assignments in this study. Will students continue to perform more accurately on the 3:1 assignments compared to the assignments on the other oral conditions when the number of problems in each condition is multiplied say threefold?

ADHD population. The overwhelming majority of studies involving additive interspersal have worked with a population of general education students. To this point, no studies have included students with ADD/ADHD. This specific group appears to hold the most potential for evaluating the notion that interspersal helps maintain attention. Accuracy may be tested with any population, but will be relevant to the ability of the students solving the problems. Learning disabled students would need to work on problems at their level just as gifted would work on problems at the level of their skills. Interspersal should serve to increase accuracy for both groups on problems appropriate to them. The accuracy of ADD/ADHD children may not be so closely connected to their ability to solve problems, but rather their ability to concentrate while solving problems. Therefore, researchers may be able to evaluate the attention component of interspersal. This may be especially valuable in a replication of differential task demands employed by this study and Robinson and Skinner (2002).

Other subject areas. The discrete task completion hypothesis (Skinner, 2002) can be used to explain why interspersal has been successfully implemented with mathematics and not with other subject areas. Mathematics assignments are made up of discrete tasks that provide a higher rate of discrete task completion than more continuous assignments such as reading a passage (Martin, 1998). However, the findings of increased accuracy on oral tasks involving interspersal in this study and the Robinson and Skinner (2002) study, as well as increased accuracy on written assignments at a 1:1 interspersal ratio in this study, may call for more interspersal studies involving subjects such as history, science, reading, and writing. Teachers often ask students to respond to questions orally in class. Perhaps teachers may be able to intersperse brief questions that elicit brief responses when conducting recitation sessions where students are predominately asked to respond to lengthy questions. Perhaps the interspersal of several brief questions will serve to increase student attention in class. In regards to written tasks, teachers may have to increase the rate of interspersal as often as the 1:1 ratios in the present study. Certainly, teachers will need to evaluate time constraints and develop the skills to intersperse items in these subject areas. However, the brief nature of interspersed questions and promotion of accuracy may ameliorate these concerns.

Acquisition. Prior to the current study and the Robinson and Skinner (2002) study, studies using additive interspersal have focused primarily on increasing the chances students will choose to engage in an assignment. Accuracy was measured in these studies, but was not the dependent variable of most interest to the researchers. With the findings of increased accuracy in this and the Robinson and Skinner study, more researchers may design studies to investigate accuracy. All of the additive interspersal assignments to date have included academic skills that were already in the students' repertoire. Students were not working on recently acquired skills. In the current study, the students had been adding and subtracting since the end of their first grade year. They were more accurate on the 3:1 interspersal oral assignment and 1:1 written assignment than the other assignments. However, they did not learn a new skill. Researchers may want to determine if interspersal can increase accuracy when learning new information and/or skills. For example, if students are learning to spell or read new words from a wordlist, can interspersal of brief words that are part of the larger word to be learned increase accuracy and acquisition? Is interpersal successful only when a skill has been acquired or can it facilitate acquisition after the skill has been introduced?

Summary and Conclusion

The results of this study suggest the interspersal procedure can be used to increase student accuracy in math. However, the most effective ratio of interspersal to target problems is dependent on task demands. Student accuracy on written tasks requiring relatively lower levels of attention increased as the ratio of interspersal to target problems increased from 0 to 3:1 to 1:1. On the other hand, student accuracy on oral tasks requiring relatively higher levels of attention were higher on assignments with a 3:1 ratio than on both no interspersal and 1:1 ratio assignments.

The applied implications of using the interspersal method seem clearer than the theoretical implications. Interspersal studies have shown mixed results regarding student accuracy on assignments under the additive interspersal procedure. Currently, there is no understanding of the causal mechanisms to explain why interspersal increases accuracy in some instances but has no effect in other instances. Therefore, we cannot anticipate conditions or ratios under which interspersal will be effective or most effective. Future theoretical research that explains the causal mechanism(s) of the interspersal procedure may allow us to maximize its impact on performance. On the positive side, the interspersal procedure has never decreased accuracy or influenced students to prefer a control condition. Results to the contrary may be especially vital in helping explain the mechanisms behind the efficacy of interspersal.

References

References

Berryman, D., O'Brien, P., & Cummins, R.(1983). The development of fluency, stimulus generalization and response maintenance of student academic engaged time in a special school: An educational mainstream preparation procedure validated against normative peer data. *Educational Psychology, 3,* 43-61.

Billington, E.J., & Skinner, C.H. (2002). Getting students to do more work: Evidence of the effectiveness of the interspersal procedure. *Journal of Behavioral Education, 11,* 105-116.

Browder, D.M., & Shear, S.M. (1996). Interspersal of known items in a treatment package to teach sight words to student with behavior disorders. *Journal of Special Education, 29,* 400-413.

Cates, G.L., & Skinner, C.H. (2000). Getting remedial mathematics students to prefer homework with 40% more problems? An investigation of the strength of the interspersal procedure. *Psychology in the Schools, 37,* 339-347.

Cates, G.L., Skinne, C.H., Watkins, C.E., Rhymer, K.N., McNeill, S.L., & McCurdy, M. (1999). Effects of interspersing additional brief math problems on student performance and perception of math assignments: Getting students to prefer to do more work. *Journal of Behavioral Education, 9,* 177-192.

Charlop, M.H., Kurtz, P.F., & Milstein, J.P. (1992). Too much reinforcement, too little behavior: Assessing task interspersal procedures in conjunction with different reinforcement schedules with autistic children. *Journal of Applied Behavior Analysis, 25,* 795-808.

Connolly, A.J. (1988). *Key MathRevised: A Diagnostic Inventory of Essential*

Mathematics. Circle Pines, MN: American Guidance Services, Inc.

Cooke, N.L., Guzaukas, R., Pressley, J., & Kerr, K. (1993). Effects of using a ratio of new items to review items during drill and practice: Three experiments. *Education and Treatment of Children, 16,* 213-234.

Cooke, N.L., & Reichard, S.M. (1996). The effects of different interspersal drill ratios on acquisition and generalization of multiplication and division facts. *Education and Treatment of Children, 19,* 124-142.

Cuvo, A.J., Davis, P.K., & Gluck, T.C. (1991). Cumulative and interspersal task sequencing in self-paced training for people with mild handicaps. *Mental Retardation, 29,* 335-342.

Dickinson, D.J., & Butt, J.A. (1989). The effects of success and failure on the on-task behavior of high achieving students. *Education and Treatment of Children, 12,* 243-252.

Dunlap, G. (1984). The influence of task variation and maintenance tasks on the learning and affect of autistic children. *Journal of Experimental Child Psychology, 37,* 41-64.

Fisher, C.W., & Berliner, D.C. (Eds.). (1985). *Perspectives on instructional time.* New York: Longman.

Gickling, E., & Havertape, J. (1981). *Curriculum-based assessment*. Minneapolis, MN: National School Psychology Inservice Training Network.

Gickling, E.E., & Thompson, V.P. (1985). A personal view of curriculum-based assessment. *Exceptional Children, 52,* 205-218.

Greenwood, C.R, Delquadri, J.C. , & Hall, R.V. (1984). Opportunity to respond and student academic performance. In U.L. Heward, T.E. Heron, D.S. Hill, & J. Trap-Porter (Eds.), *Focus on behavior analysis in education* (pp.58-88). Columbus, OH: Charles E. Merrill.

Hargis, C.H. (1989). *Teaching low achieving and disadvantaged students.* Springfield, IL: Charles C. Thomas.

Harrower, J.K. (2000). A comparison of prompt delivery procedures for increasing spontaneous speech among children with autism. *Dissertation Abstracts International, 60,* 12-A.

Herrnstein, R.J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior, 4,* 267-272.

Horner, R.H., Day, H.M., Sprague, J.R., O'Brien, M., & Heathfield, L.T. (1991). Interspersal requests: A non-aversive procedure for reducing aggression and self-injury during instruction. *Journal of Applied Behavior Analysis, 24,* 265-278.

Johns, G.A., Skinner, C.H., & Nail, G.L. (2000). Effects of interspersing briefer mathematics problems on assignment choice in students with learning disabilities. *Journal of Behavioral Education, 10,* 95-106.

Logan, P., & Skinner, C.H. (1998). Improving students' perceptions of a mathematics assignment by increasing problem completion rates: Is problem completion a reinforcing event. *School Psychology Quarterly, 13,* 322-331.

Martin, J.J. (1998). The effects of interspersing additional mastery level reading material on reading choice, perceived effort, and reading fluency. *Dissertation Abstracts International, 58,* 12-A.

Martin, J.J., Skinner, C.H., & Neddenriep, C.E. (2001). Extending research on the interspersal procedure to perceptions of continuous reading assignments: Applied and theoretical implications of a failure to replicate. *Psychology in the Schools, 38,* 391-400.

McCurdy, M., Skinner, C.H., Grantham, K., Watson, T., & Hindman, P.M. (2001) Increasing on-task behavior in an elementary student during mathematics Seatwork by interspersing additional brief problems. *School Psychology Review, 30,* 23-32.

Meadows, S.F. (2002). Causing students to choose more language arts work: An educationally valid investigation of the interspersal procedure. *Dissertation Abstracts Intenational, 63,* 1-A.

Neef, N.A., Iwata, B.A., & Page, T.J. (1977). The effects of known-item interspersal on acquisition and retention of spelling and sight-reading words. *Journal of Applied Behavior Analysis, 10,* 738.

Neef, N.A., Iwata, B.A., & Page, T.J. (1980). The effects of interspersal training versus high-density reinforcement on spelling acquisition and retention. *Journal of Applied Behavior Analysis, 13,* 153-158.

Roberts, M.L., & Shapiro, E.S. (1996). Effects of instructional ratios on students' reading performance in a regular education program. *Journal of School Psychology, 34,* 73-91.

Roberts, M.L., Turco, T.L., & Shapiro, E.S. (1991). Differential effects of fixed instructional ratios on students' progress in reading. *Journal of Psychoeducational Assessment, 9,* 308-318.

Robinson, S.L., & Skinner, C.H. (2002). Interspersing additional easier items to enhance mathematics performance on subtests requiring different task demands. *School psychology Quarterly, 17,* 191-205.

Rowan, V.C., & Pear, J.J. (1985). A comparison of the effects of interspersal and concurrent training sequences on acquisition, retention, and generalization of picture names. *Applied Research in Mental Retardation,6,* 127-145.

Skinner, C.H. (2002). An empirical analysis of interspersal research evidence, implications and applications of the discrete task completion hypothesis. *Journal of School Psychology, 40,* 347-368.

Skinner, C.H., Fletcher, P.A., Wildmon, M., & Belfiore, P.J. (1996). Improving assignment preference through interspersing additional problems: Brief versus easy problems. *Journal of Behavioral Education, 6,* 427-436.

Skinner, C.H., Hurst, K.L., Teeple, D.F., & Meadows, S.O. (2002). Increasing on-task behavior during math independent seat-work in students with emotional disturbance by interspersing additional brief problems. *Psychology in the Schools, 39,* 647-659.

Skinner, C.H., Robinson, S.L., Johns, G.A., Logan, P., & Belfiore, P.J. (1996). Applying Herrnstein's matching law to influence students' choice to complete difficult academic tasks. *Journal of Experimental Education, 65,* 5-17.

Skinner, C.H., Wallace, M.A., & Neddenriep, C.E. (2002). Academic remediation: Educational applications of research on assignment preference and choice.

Child and Family Behavior Therapy, 24, 51-65.

Stahmer, A.C. (1999). Using pivotal response training to facilitate appropriate play in children with autistic spectrum disorders. *Child Language Teaching and Therapy, 15,* 29-40.

Teeple, D.F. (2002). Interspersing additional, brief items to influence the choice behavior of students with behavioral and emotional disabilities to complete grammar assignments. *Dissertation Abstracts International,*

Tustin, R.D., & Morgan, P. (1986). Choice of reinforcement rates and work rates with concurrent schedules. *Journal of Economic Psychology,6,* 109-141.

Wildmon, M.E., Skinner, C.H., McCurdy, M., & Sims, S. (1999). Improving secondary students' perception of the "dreaded mathematics word problem assignment" by giving them more word problems. *Psychology in the Schools, 36,* 319-325.

Wildmon, M.E., Skinner, C.H., & McDade, A. (1998). Interspersing additional brief, easy problems to increase assignment preference on mathematics reading problems. *Journal of Behavioral Education, 8,* 337-346.

Appendixes

Appendix A

Assignment A

43
+ 6
- 5
+ 9

39
- 5
+ 4
- 9

53
+ 6
- 5
- 8

87
+ 8
+ 4
- 6

56
- 7
- 6
+ 3

78
+ 9
- 4
+ 5

63
\+ 6
______

\+ 7
______

\- 4
______

98
\- 5
______

\- 8
______

\+ 4
______

49
\- 4
______

\+ 8
______

\+ 5
______

Assignment B

58	74
+ 6	- 6
+ 5	- 5
- 3	+ 4

67	43
+ 9	+ 6
- 4	+ 8
+ 7	- 5

86	39
- 8	- 3
- 5	+ 7
+ 6	+ 5

64	57
+ 9	- 4
- 8	- 9
+ 3	+ 5

79
- 4
+ 8
+ 5

Assignment C

43	68
+ 6	- 5
- 5	+ 4
+ 8	- 9
54	85
+ 5	+ 8
- 6	+ 6
- 9	- 7
94	79
- 7	+ 8
- 4	- 3
+ 6	+ 5

63
\+ 6
\+ 8
\- 4

58
\- 5
\- 8
\+ 4

38
\- 4
\+ 9
\+ 3

Assignment D

43	68
+ 6	- 5
+ 9	- 7
- 5	+ 3

89	75
- 5	+ 4
+ 9	- 5
+ 6	+ 8

57	93
- 4	+ 6
+ 3	- 5
- 8	- 9

67	34
+ 8	- 7
+ 4	- 4
- 6	+ 6

59
+ 8
- 4
+ 5

Assignment E

86
+ 7
+ 6
- 5

45
- 7
- 4
+ 5

58
+ 9
- 4
+ 6

63
+ 5
+ 8
- 4

98
- 5
- 9
+ 4

38
- 4
+ 9
+ 5

54
\+ 5
_____

\- 3
_____

\+ 7
_____

79
\- 5
_____

\+ 3
_____

\- 8
_____

73
\+ 6
_____

\- 4
_____

\- 9
_____

Assignment F

63
\+ 6
\+ 8
\- 5

79
\- 6
\- 9
\+ 4

39
\- 4
\+ 8
\+ 6

45
\+ 4
\- 6
\+ 9

58
\- 5
\+ 3
\- 7

83
\+ 6
\- 5
\- 8

76
+ 7
___
+ 5
___
- 6
___

46
- 7
___
- 6
___
+ 5
___

68
+ 9
___
- 4
___
+ 3
___

Appendix B

Procedural Integrity Checklist

1. Select students with completed consent and assent forms ____________
2. Identify proper group to test ____________
3. Assign students to seats ____________
4. Remind students of rights ____________
5. Distribute assignments to student based on code ____________
6. Identify correct problem set to be administered ____________
7. Read directions as scripted ____________
8. Provide sample problems and review ____________
9. Keep accurate time ____________
10. Collect problem set after administration ____________
11. Ask for student questions/concerns ____________

Vita

James Andrew Hawkins was born in Smithtown, New York on August 1, 1975. He was raised in Wading River, New York and graduated from Shoreham-Wading River High School in 1993. He attended The University of Michigan, Ann Arbor where he received a B.A. in psychology in 1997. James is completing requirements for a Ph.D. in Education with a concentration in School Psychology. He currently works as an intern at the University of Tennessee Office of Disability Services and the Lenoir City School System.