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The Effects of the Interspersal Procedure on Persistence with Computer-Delivered Multiplication Problems

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To the Graduate Council:

I am submitting herewith a dissertation written by Emily R. Kirk entitled "The Effects of the Interspersal Procedure on Persistence with Computer-Delivered Multiplication Problems." 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 School Psychology.

Christopher H. Skinner, Major Professor

We have read this dissertation and recommend its acceptance:

R. Steve McCallum, Amy L. Skinner, Richard A. Saudargas

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

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The Effects of the Interspersal Procedure on Persistence with Computer-Delivered Multiplication Problems

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

Emily Richardson Kirk
August 2010

Dedication

This document is dedicated to all my friends and family that have supported me throughout my time in graduate school and along my educational path. I wouldn't have been able to get this far without their constant support and encouragement. Particularly, my parents, Kim and Bonnie Richardson, have taught me that doing my best and trusting in God's provisions are key aspects in achieving my goals. These lessons, paired with their unending love and support, have helped me get where I am today. I believe a special dedication is necessary for my husband, Brian. Without his ongoing patience, persistence, and sacrifice, this project would never have been complete.

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Abstract

An across-subjects, post-test only design was used in two experiments to assess the impact of interspersing additional math problems (i.e., briefer problems and/or longer problems) among target math problems on students' persistence when completing computer-delivered math multiplication problems. In Experiment 1, high school students who worked only target problems completed 32% more target problems and worked 22% longer than those who had briefer problems interspersed. Problem completion rates were significantly higher for those who had briefer problems interspersed. These results suggest that altering assignments by interspersing additional, briefer discrete tasks does not always enhance, and in some instances may hinder academic responding. Stimulus preference and within-trial contrast effects provided possible explanations for these results and indicated that interspersing longer problems could, perhaps, cause students to increase persistence. Experiment 2 was designed to replicate Experiment 1 and extend this line of research by investigating the stimulus preference and within-trial contrast hypothesizes.

To increase the number of participants and allow for the evaluation of three conditions, college students served as participants for Experiment 2. In Experiment 2, no significant differences among groups (i.e., control group with only target problems, experimental group with brief problems interspersed, and experimental group with long problems interspersed) were found in the amount of time before college students quit working or in their problem completion accuracy levels. Interspersal of the long problems significantly reduced the number of target problems completed. The results failed to support stimulus preference or within-trial contrast theories.

Discussion focuses on theoretical and applied implications related to the additive interspersal procedure, the discrete task completion hypothesis, and the delay reduction hypothesis. Applied implications suggest that educators avoid interspersing longer discrete tasks and exercise caution when interspersing brief tasks.

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CHAPTER I

LITERATURE REVIEW

Teachers regularly provide students with opportunities to develop academic skills through homework or classroom independent seatwork assignments. However, if skill development is to occur, students must *choose* to work on those assignments. Even when students choose to start assignments, at any time they may choose to continue working or engage in a plethora of competing behaviors, including some behaviors that may disrupt their classmates and teachers or interrupt their learning. Therefore, identifying strategies and procedures that increase the probability of students choosing to work on academic assignments and maintain these desired behaviors can decrease incompatible disruptive behaviors and enhance learning (Myerson & Hale, 1984; Skinner, Pappas, & Davis, 2005).

Basic and applied researchers have identified variables that influence choice. Working with operant chambers, Herrnstein (1961) found that the choice behavior of laboratory pigeons (i.e., pecking keys for food) was directly proportional to relative rates of reinforcement for competing behaviors rather than absolute reinforcement for a single behavior. In other words, organisms tend to distribute their choice responses according to the relative rate at which these responses are reinforced (i.e., they match; Fantino, 2008). This principal became known as the "matching law" and has been shown to predict choice behavior with great precision across settings, tasks, and organisms (Billington, Skinner, & Cruchon, 2004).

The matching law has generalized to student choice behavior. Specifically, after providing students with a choice of two competing academic tasks, student choice behavior matched the relative rates of tangible reinforcement for those two behaviors (Mace, McCurdy, & Quigley, 1990). Subsequent studies have shown that relative reinforcer quality and immediacy, along with the relative effort required for competing behaviors, influence students' choice (Mace, Neef, Shade, & Mauro, 1994; Neef, Mace, & Shade, 1993; Neef, Mace, Shea, & Shade, 1992; Neef, Shade, & Miller, 1994). For example, Neef et al. (1992) examined the effects of reinforcer rate and reinforcer quality on how students chose to allocate their time. Three students with disabilities completed math problems in two conditions: 1) an equal-quality reinforcer condition and 2) an unequal-quality reinforcer condition. Two variable interval schedules (VI 30-s versus VI 120-s) were presented concurrently. In the equal-quality reinforcer condition, high-quality (nickels) and low-quality ("program money" in the school's token economy) items were alternated across sessions as the reinforcer for both the VI 30-s and VI 120-s sets of problems. In the unequal-quality reinforcer condition, the program money was used for the set of problems on the VI 30-s schedule and the nickels were used for the set of problems on the VI 120-s schedule. Results indicated that when the reinforcer quality was equal, the time allocated to concurrent response alternatives was approximately proportional to obtained reinforcement, as predicted by the matching law.

Additive Interspersal Procedures and the Discrete Task Completion Hypothesis

Researchers have extended the matching law to students' choice behaviors; however, in these studies, teachers and/or researchers have had to deliver high rates of tangible or social rewards contingent upon the students' behavior (e.g., Mace et al., 1990; Martens & Houk, 1989). It is often impractical for teachers to monitor each student's behaviors and deliver reinforcement contingent upon those behaviors at high rates; ideally, the assignment itself would provide high rates of reinforcement. Researchers who developed the additive interspersal procedure, which intersperses additional tasks among the target task (thus, not reducing the number of target items in the assignment; Cates, 2005), and the discrete task completion hypothesis may have found a more sustainable procedure for enhancing relative rates of reinforcement for academic work (Logan & Skinner, 1998; Skinner, 2002).

Skinner (2002) posited that when given an assignment comprised of many discrete tasks, each completed task is a reinforcing stimuli. This hypothesis, known as the *discrete task completion hypothesis,* is based on an assumed learning history and the principles of operant and classical conditioning (i.e., contiguity and contingency). The assumption is that most humans have a learning history where assignments were given and reinforcement (both positive and negative) was delivered contingent upon the assignment being completed. If a completed assignment is followed by reinforcement, then stimuli that reliably precede assignment completion should become conditioned reinforcers. Because every discrete task must be finished before the assignment is completed, each completed discrete task should become a reinforcing stimuli [see Skinner (2002) for a comprehensive description of the process]. If each completed discrete task is a reinforcer, then increasing discrete task completion rates through, for instance, additive interspersal procedures will enhance rates of reinforcement. As previous researchers working with tangible and social reinforcers demonstrated (e.g., Mace et al., 1990; Mace et al., 1994; Neef et al., 1993; Neef et al., 1992; Neef et al., 1994), increasing rates of reinforcement for desired academic behaviors should enhance the probability that students choose to do those assignments (single choice) and choose to continue their assigned work (persist under a continuous choice paradigm).

Single Choice Research

Researchers studying the additive interspersal procedure have conducted numerous studies investigating the relationship between choice behavior and relative math problem completion rates that support the discrete task completion hypothesis (e.g., Billington, Skinner, & Cruchon, 2004; Billington, Skinner, Hutchins, & Malone, 2004; Cates et al., 1999; Logan & Skinner, 1998; Skinner, Robinson, Johns, Logan, & Belfiore, 1996). For example, Skinner et al. (1996) gave college students multiplication assignments to complete. The control assignment sheet contained 16 three-digit by two-digit target problems (e.g., 478 x 56 = ___). The experimental assignment, which was the additive interspersal assignment, included six additional one-digit by one-digit problems (e.g., 6 x 7 = ___) interspersed following every third target problem. Results indicated that this procedure increased problem completion rates. Additionally, significantly more students chose an interspersal sheet for their next assignment, even though it required more effort (i.e., the additional problems).

These findings not only apply to multiplication problems but also have been replicated with word problems (Wildmon, Skinner, McCurdy, & Sims, 1999; Wildmon, Skinner, & McDade, 1998; Wildmon, Skinner, Watson, & Garrett, 2004). Wildmon et al. (1998) gave college students a control assignment that contained eight two-digit by two-digit plus two-digit by two-digit (e.g., 56 x 49 + 47 x 54) target mathematics word problems and an experimental assignment with three additional four-digit plus four-digit mathematics word problems interspersed. After spending the same amount of time on both the control and experimental assignments, significantly more students ranked the experimental assignment as being less difficult and requiring less effort to complete. When given a choice between the two assignments for homework, significantly more students preferred, or chose, the experimental assignment. Researchers replicated these findings in high school students and middle school students with learning disabilities (Wildmon et al., 1999; Wildmon et al., 2004).

Other researchers found similar results when they applied the additive interspersal technique to language arts assignments (Meadows & Skinner, 2005; Teeple & Skinner, 2004). Teeple and Skinner (2004) gave students with emotional disorders in grades 7 through 12 grammar assignments that required students to copy sentences and paragraphs and add punctuation at the end of the sentences. The control assignment contained multisentence paragraphs (target tasks). The experimental assignments contained similar target tasks and additional interspersed brief one-sentence paragraphs. After the students had completed both assignments, they were asked to rank them and then choose a new assignment for homework. As with the mathematics research, there were no significant differences in the amount of time or effort to complete either assignment; however, significantly more students chose the interspersal assignment for homework.

In most studies of the additive interspersal procedure, the experimental assignments have required more effort to complete because they contained additional brief tasks. However, in some studies, researchers found that the additive interspersal procedure could cause students to choose to work on assignments that contained more target tasks as well as the brief interspersed tasks (Cates & Skinner, 2000; Cates et al., 1999; Meadows & Skinner, 2005). For example, Cates and Skinner (2000) asked high school students in remedial mathematics classes to complete six different assignments. Three of the assignments were control assignments with only target (three-digit by two-digit) multiplication problems. The other three were experimental assignments, with additional one-digit by one-digit problems interspersed after every third target problem, and either 0% more, 20% more, or 40% more target problems. For each student, a control and experimental assignment were paired together, and after each set of control and experimental pairings, students were asked to report which of the two required the most time and effort to finish, which was more difficult, and to choose a new assignment for homework. With all three assignment pairs, significantly more students chose the additive interspersal assignment for homework, even if it had 20% or 40% more of the target problems. One method of increasing the probability of students choosing higher effort behavior is to provide higher rates of reinforcement for that behavior relative to competing behavior (Friman & Poling, 1995). Consequently, these studies support the discrete task completion hypothesis while demonstrating that additional reinforcement can encourage students to choose to complete more target problems.

Repeated Choice

Johns, Skinner, and Nail (2000) used procedures similar to past researchers (e.g., Mace et al., 1990; Mace et al., 1994; Neef et al., 1993; Neef et al., 1992; Neef et al., 1994) who provided a repeated choice of academic tasks and tangible reinforcers to investigate the effects of the additive interspersal procedure. Johns et al. (2000) delivered multiplication problems to high school students with learning disabilities using a computer. The math problems (two-digit by one-digit or one-digit by one-digit) were delivered to the students on a computer screen in a flashcard format with two problems appearing simultaneously on the screen. Students chose either the problem on the left or the right, worked the chosen problem using scrap paper, and then entered the response. Immediate accuracy feedback was provided after each problem. In the experimental condition, the one-digit by one-digit problems appeared as an option after the students had completed three two-digit by one-digit problems. The control condition contained only two-digit by one-digit problems. Results indicated that the students preferred the additive interspersal assignments, just as they did in earlier studies where researchers delivered tangible reinforcers (e.g., nickels in cups) contingent upon students' choice behaviors (e.g., Mace et al., 1990).

On-task and Attention

The additive interspersal procedure has been shown to increase students' on-task behavior (McCurdy, Skinner, Grantham, Watson, & Hindman, 2001; Skinner, Hurst, Teeple, & Meadows, 2002). For example, McCurdy et al. (2001) used the additive interspersal procedure with a fourth-grade general-education student to increase her on-task behavior, defined as having her head oriented toward her work, social interaction with the teacher regarding the assignment, or having her hand raised. The student was given either a control assignment (i.e., the math worksheet from her teacher) or an experimental assignment (i.e., the math worksheet from her teacher that had been altered to include an easier problem interspersed after every third target problem). The student's mean level of on-task behavior during control assignments was 55.5%

but was 72.25% during the experimental assignments. On-task behavior was also increased during the experimental assignments when a similar study was done with students with emotional/behavioral disorders (EBD; Skinner et al., 2002). These studies provide evidence that the additive interspersal procedure can enhance students' on-task behavior.

One reason researchers measure on-task behaviors is an assumed positive correlation between on-task behavior and attention (Lentz, 1988; Skinner, 2004). Researchers have conducted studies that suggest the additive interspersal procedure can enhance attention (Hawkins, Skinner, & Oliver, 2005; Robinson & Skinner, 2002). Robinson and Skinner (2002) applied the additive interspersal procedure to standardized mathematics subtests with different task demands. At-risk seventh-grade students were administered both a control and experimental version of the Mental Computation and Multiplication subtests of *KeyMath-Revised* (KM-R; Connolly, 1988). The Mental Computation subtest required students to compute responses without using paper and pencil. Thus, it differed from the traditional pencil-and-paper studies because students were required to sustain their attention and maintain their progress through the problem in their working memory. The experimental version contained briefer problems interspersed among the subtest's target items (addition, subtraction, multiplication, and division problems of increasing difficulty). The items were either presented verbally or visually on an easel. The Multiplication subtest contained problems that required a variety of multiplication skills (e.g., decimals, fractions, two-digit by one-digit problems); the experimental test interspersed one-digit by one-digit problems among the target problems. The problems were presented in a worksheet format, and students could use paper and pencils to work the problems.

Robinson and Skinner's (2002) results indicated that the interspersal procedure enhanced the academic performance on the Mental Computation subtest but not the Multiplication subtest. In a subsequent study, Hawkins et al. (2005) found similar results with fifth-grade students. Specifically, when high attention problems (e.g., 6 x 3 + 8 -14 + 29 = ___) were read aloud and students could not use paper and pencil to solve the problems, response accuracy was enhanced when brief problems (e.g., 27 – 16 = ___) were interspersed. However, no effect was found when students could work all problems using paper and pencil. These results suggest that the additive interspersal procedures may enhance students' attention to tasks and, consequently, their learning.

Persistence

Montarello and Martens (2005) extended research on the interspersal procedure by examining its effects on persistence, or task endurance, which Binder (1996) defined as the ability to maintain high rates of work completion over longer intervals. They also wanted to increase the reinforcement strength of the interspersal procedure by providing exchangeable tokens each time a brief task was completed. In their study, Montarello and Martens (2005) used an alternating treatments design with four low achieving fifth-grade students and a preference assessment to determine tangible reinforcers. Then, they gave the students a stack of worksheets composed of three-digit by three-digit addition problems with or without one-digit problems interspersed. The worksheets were either white (all target three-digit by three-digit problems), blue (target problems with brief one-digit by one-digit problems interspersed after every third target problem), or yellow (formatted like the blue worksheets, but the student earned a token from the experimenter after the completion of each brief problem). In each condition, the student was told to complete as many or as few math problems as he or she wished for 10 minutes; however, in the tangible reward condition, the student was aware that he/she could earn reinforcement for completing math problems. The students' total number of digits correct was used to evaluate the interspersal procedure (i.e., endurance was measured using digits correct per minute). Results indicated that the total digits correct per session were highest during the interspersal plus tangible reinforcement condition followed by the interspersal and then the control condition for three of the four students.

Montarello and Martens (2005) set out to study persistence; however, several limitations arise within their study: 1) their measure of persistence, which was accurate rates of responding, was artificially inflated due to the inclusion of brief problems, 2) problem completion rates within the conditions were not measured, and 3) their sessions were only 10 minutes in length. Montarello and Martens' dependent variable was digits correct per minute; thus, it appears that the interspersal procedure increased students' rates of accurate work. However, because additional interspersed problems were briefer and easier than target problems, it is not clear if the interspersal procedure increased their rate of accurate work on the target problems. Rather, including the brief problems may have accounted for the increase in digits correct per minute.

Although Montarello and Martens (2005) indicated that the interspersal procedure enhanced persistence because it enhanced rates of work, they did not measure rates of work within-trials. Therefore, it is not clear if their rates of work differed across conditions or if differences in work rates were caused by students quitting prior to the 10 minutes expiring. It is possible that students worked more rapidly on the control assignments, but quit before the 10 minutes expired, which reduced their digits correct per minute.

A final limitation of the Montarello and Martens (2005) study is that they only measured rates of accurate responding (their measure of persistence) over 10 minute sessions. Often educators are not concerned with maintaining students' academic behavior over brief intervals; instead, they are concerned that students continue to choose to respond (persist) when given assignments that require much more time to complete (e.g., 1 hour).

Summary and Purpose

After assigning academic work, the first challenge for educators is to influence students to choose to work on the assignment rather than engage in a plethora of other behaviors. Researchers using single choice procedures have suggested that altering assignments by interspersing additional brief tasks can increase rates of reinforcement for that task and the probability that students will choose to begin the assigned work (see Skinner, 2002). Further, interspersing additional brief tasks can cause students to choose to work assignments with more target tasks, thus enhancing their opportunities to respond and consequently their skills (e.g., Cates & Skinner, 2000; Meadows & Skinner, 2005).

Once students begin working, they are faced with a continuous choice situation where at any moment in time they may choose to stop working and engage in competing behaviors. Researchers who measured on-task behavior have found evidence that the interspersal procedure can increase the probability that they will maintain their academic behaviors (Skinner et al., 2002; Teeple & Skinner, 2004). Additionally, researchers found evidence that students' attention while working on assignments may be enhanced by the additive interspersal procedure, which in turn should enhance their learning (Robinson & Skinner, 2002; Hawkins et al., 2005).

Another challenge educators face arises when students are asked to persist over long periods of time. Specifically, after beginning and working on an assignment for a period of time, students may choose to quit and engage in other behaviors. If a completed task is a conditioned reinforcer, then enhancing rates of reinforcement via the additive interspersal procedure should enhance students' persistence, which can be conceptualized as the amount of work completed or time spent working before quitting.

Past researchers have not evaluated how the additive interspersal procedure affects persistence, defined as time before quitting. Thus, the purpose of the current study is to extend previous research by evaluating the effects of the additive interspersal procedures on persistence as students work computer-delivered math computation problems over a 1-hour period.

CHAPTER II

EXPERIMENT 1

Altering assignments by interspersing additional briefer tasks hinders persistence

Students may start working on assignments, but at any moment choose to stop working and engage in competing behaviors. Thus, persistence can be conceptualized as responding under a continuous choice context. Because working on academic assignments is related to learning, identifying and controlling variables that influence persistence and/or choice may allow educators to enhance learning and decrease competing undesired behaviors (Skinner et al., 2005). Response effort and reinforcement have been shown to influence students' choice behavior. If all other variables are held constant, students tend to choose to engage in behaviors that require less effort (Billington, Skinner, & Cruchon, 2004; Billington, Skinner, Hutchins, & Malone, 2004; Friman & Poling, 1995). Educators can increase the probability of students choosing to engage in higher-effort behaviors by enhancing reinforcement a) rate, b) immediacy, and c) quality (Mace et al., 1990; Mace et al., 1994; Martens & Houk, 1989; Martens, Lochner, & Kelly, 1992; Neef et al., 1993; Neef, Mace, Shea, & Shade, 1992; Neef et al., 1994).

Studying choice behavior, researchers have found evidence for the discrete task completion hypothesis, which suggests that when working on an assignment comprised of many discrete tasks, each completed task is a reinforcing stimulus (Skinner, 2002). If a completed task is a reinforcer, then anything that increases discrete task completion rates will increase rates of reinforcement, which should increase the probability of students choosing to engage in the assigned work (e.g., Martens & Houk, 1989). One way to increase discrete task completion rates is the additive interspersal procedure, which involves interspersing additional briefer discrete tasks among assignments that contain more time-consuming discrete tasks (Cates et al., 1999; Logan & Skinner, 1998; Skinner, 2002).

Logan and Skinner (1998) asked sixth-grade students to work on two different paper-and-pencil mathematics assignments: a control assignment and an additive interspersal assignment. The control assignment contained 25 target multiplication problems (four-digit by one-digit). The additive interspersal assignment contained 25 similar target problems with nine additional brief addition problems (one-digit plus one-digit problems) interspersed following every third target problem. After working on both assignments for 8 minutes, students were allowed to choose an assignment for homework. Based solely on the principle of least effort, the students should have chosen the control assignment, as it contained nine fewer problems (i.e., the brief problems). However, significantly more students chose the experimental assignment. These results were supported with subsequent studies conducted across tasks and participants (e.g., Johns et al., 2000; McCurdy et al., 2001; Skinner et al., 1996; Teeple & Skinner, 2004; Wildmon et al., 1999; Wildmon, Skinner, & McDade, 1998; Wildmon et al., 2004). Also, researchers found that interspersing additional brief tasks could cause students to choose to work assignments that required much more effort to complete (e.g., 40% more long target problems) than the control assignment (Billington, Skinner, & Cruchon, 2004; Cates & Skinner, 2000; Cates et al., 1999; Meadows & Skinner, 2005).

Skinner (2002) analyzed relative problem completion rate and assignment choice data across studies. In each study, discrete task completion rates were higher on the experimental (additive interspersal) assignment than the control assignment (target problems only), and as the difference in relative task completion rates increased, so did the percentage of students choosing the experimental assignment. This relationship was comparable to that found by Myers and Myers (1977) who conducted a similar analysis of multiple laboratory studies (pigeons' bar pressing) and relative rates of food reinforcement. Thus, a completed discrete task appeared to function as a reinforcer.

If a completed discrete task is a reinforcer, interspersing briefer tasks may enhance rates of reinforcement and students' persistence when working on assignments (McCurdy et al., 2001). However, research on stimulus preference suggests that the opposite may occur. Fisher et al. (1992) compared preference for stimuli when preference was assessed for each stimulus in isolation and when preference was assessed with multiple stimuli presented concurrently. Preference for some stimuli was weaker when preference was assessed with other more preferred stimuli. These findings have implications for using the additive interspersal procedure. Because the briefer tasks require less effort to complete than target tasks, brief tasks may be preferred (Billington, Skinner, Hutchins, & Malone, 2004). Thus, altering assignments by interspersing additional briefer tasks may introduce a contrast effect that reduces the quality of the target-item stimuli (e.g., the longer math problems). Because target tasks make up the majority of the assigned work on interspersal assignments, decreasing students' preference for these tasks may reduce their persistence when working on interspersal assignments.

Montarello and Martens (2005) attempted to study the effects of the interspersal procedure on persistence. Using an alternating-treatments design and a preference assessment to determine tangible reinforcers, they applied the additive interspersal procedure as well as tangible reinforcement to multiplication worksheets for four low achieving fifth-grade students. They gave the students a stack of worksheets composed of three-digit by three-digit addition problems with or without one-digit problems interspersed. The worksheets were a) white with all target three-digit by three-digit problems, b) blue with target problems and brief one-digit by one-digit problems interspersed after every third target problem, or c) yellow and formatted like the blue worksheets, but the student earned a token from the experimenter after the completion of each brief problem. In each condition, the student was told to complete as many or as few math problems as he or she wished for 10 minutes; however, in the tangible reward condition, the student was aware that he/she could earn reinforcement for completing math problems. The students' total digits correct were used to evaluate the interspersal procedure and measure persistence. Results indicated that the total digits correct per session were highest during the interspersal plus tangible reinforcement condition followed by the interspersal and then the control condition for three of the four students.

Although Montarello and Martens (2005) set out to study persistence, their dependent variable was digits correct per minute. With this form of measurement, the additional brief problems could have accounted for the increase in digits correct per minute. In addition, Montarello and Martens (2005) did not actually measure persistence over time, for students only had 10 minutes to complete the trials. Finally, because students may have quit working before 10 minutes expired, the data on rate of work is compromised. For example, students may have worked faster on the control assignments, but quit working after 5 minutes.

Purpose

Researchers have not investigated the effects of the additive interspersal procedure on persistence, defined as time worked before quitting. Previous research on choice suggests that interspersing additional brief tasks could enhance persistence by enhancing rates of reinforcement. Alternatively, stimuli preference research suggests that interspersing briefer tasks may make the target tasks less preferred or more aversive, which could reduce persistence. The current experiment was designed to extend this line of research by evaluating the effect of the additive interspersal procedure on persistence as students worked computer-delivered math computation problems.

Method

Participants

All students (61) from three high school math classes (i.e., two Algebra II classes and one Trigonometry class) in a public Kindergarten through 12^{th}-grade school located in a rural town in the Southeastern U.S. were recruited for this study. There were 693 students in the school, 237 in grades 9 – 12. Caucasians account for the majority (i.e., 685) of the students. Approximately 41% of the students were eligible for free or reduced lunch. All 40 Caucasian students whose parents provided informed consent and who were present on the day the procedures were run agreed to participate. These participants included 17 males and 23 females ranging from 15 – 18 years of age. None of the students were receiving special education service for mathematics difficulties. The students were either sophomores (47.5%) or juniors (52.5%).

Setting and Materials

All procedures were run in the students' math classroom. The students' desks were arranged in rows facing the teacher's desk and board at the front of the room. Laptop personal computers (20) were set up on the desks, each with a flash drive that contained one of two experimenter-constructed math persistence programs. Participants were given paper and pencils to work their math computation problems and each participant was given a puzzle pack, which contained sudoku, crossword, and word search puzzles on 8.5" by 11" sheets of paper.

Procedures

Students entered the classroom for their regularly scheduled math class. Those with parental consent sat at desks with a computer. The other students sat at desks in the back of the room and completed work assigned by the teacher. Computers were removed from the desk of any student who did not have a signed parental consent form. Assent was solicited and obtained from each of the students with signed parental consent forms.

Half of the computers contained a flash drive with a control computer program and half with the experimental program. These programs were randomly assigned to computers that were randomly placed on desks. Both programs presented multiplication computation problems one at a time. After using the keyboard to type in their answer, another problem would appear on the screen. The control program presented only target, three-digit by two-digit, problems. To ensure students had to carry following each multiplication operation, all digits were greater than or equal to four (e.g., 798 x 58). On the experimental program, every third three-digit by two-digit problem was followed by a two-digit by one-digit multiplication problem (e.g., 60 x 3). The single-digit factor and the digit in the one's place of the two-digit factor were always less than 4. Thus, no carrying was required. For each problem type, the computer randomly generated digits for each problem following these rules, which were designed to maximize the time difference required to complete the two types of problems (see Billington, Skinner, Hutchins, & Malone, 2004).

After students were seated, their math teacher administered procedures. Students were told to remain quiet throughout the entire 1-hour period. After responding to demographic items, students were told that after they clicked the *Start* button on their computer screens, their computer would deliver math problems one at a time. Students were provided scrap paper and told they could use it and a pencil or pen to work the problems and then use the keyboard to provide the answer. After providing their answer, they were instructed to press enter and a new problem would appear on their screens.

The students were told that they must begin working math problems, but they were also informed that they could quit at any time and work quietly from their puzzle packs for the rest of the period. Students were told that they could quit by clicking the *Stop* button on the bottom right corner of the screen. After 1 hour, students were asked to stop working on either the math problems or the puzzle packs, materials were collected, and computers were re-set for the next math class.

Two additional researchers independently recorded the primary experimenter's and teacher's behavior using a procedural integrity checklist (see Appendix A). Both researchers recorded 100% integrity across the three experimental sessions.

Designs, Dependent Variables, and Data Analysis

A between-subjects design was used to evaluate the effects of interspersing additional brief problems on students' persistence. No pre-test was given; hence, the random assignment of participants was necessary to control for threats to internal validity.

A MANOVA was used to test for significant differences across groups on two measures of persistence: the number of target (three-digit by two-digit) problems completed and the number of seconds before students quit working. A one-way ANOVA was used to test for differences on total problem completion rates, which were measured as problems completed per minute spent working. The computer program saved all data on the flash drives. All differences were considered significant at the $p < 0.05$ level. Effect sizes were calculated for each comparison by dividing mean differences by the pooled standard deviation and then interpreted based on criteria defined by Cohen (1988): 0.2 = small, 0.5 = medium, and 0.8 = large.

Results

Table 1 displays the mean and standard deviation across dependent variables for the control and experimental groups. A MANOVA with groups (i.e., control and experimental) serving as the independent variable and target problems completed and number of seconds worked before quitting serving as the dependent variable revealed a significant difference $F(37,2) = 188.86$, $p = .000$. Students working on the control assignments worked approximately 22% longer (M = 2475.22s, SD 831.77) than those working on the experimental assignment (M = 2032.35s, SD = 608.34). This difference neared significant levels, F (38,1) = 3.74, p = .06, and the effect size was moderate, ES = 0.61. Also, students working on the control assignment

Table 1

Experimental and Control Group Summary Statistics for each Dependent Variable in Experiment 1.

	Control Group			Experimental Group		
	N	*M*	*SD*	*N*	*M*	*SD*
Seconds Worked per Problem	19	78.29	33.41	21	60.21*	21.79
Seconds Worked before Quitting	19	2475.22	831.77	21	2032.35	608.34
Number of Target Problems Completed	19	35.16*	13.74	21	26.57	14.07
% Correct on Completed Target Problems	19	52.85	36.68	21	56.99	25.46

* Significant difference at $p < .05$ level (2-tailed).

completed approximately 32% more three-digit by two-digit target problems (*M* = 35.16, *SD* = 13.74) than those working on the experimental assignment (*M* = 26.57, *SD* = 14.07). This difference approached significant levels, $F(38,1) = 3.79$, $p = .06$, and the effect size was moderate, *ES* = 0.62. These findings suggest that interspersing brief problems hindered as opposed to enhanced persistence. Appendix B displays the output from the MANOVA.

Although students in the experimental group had slightly higher accuracy levels on completed target problems (*M* = 56.99% correct, *SD* = 25.46) than those in the control group (*M* = 52.85% correct, *SD* = 36.68), these differences were not significant and the effect size was very small, *ES* = .15.

A one-way ANOVA with rate (seconds per problem) serving as a dependent variable and groups (i.e., control and experimental) serving as the independent variable revealed that students working on the experimental assignment worked significantly [$F(38,1) = 4.42$, $p < .05$] fewer seconds per problem (*M* = 60.21 s/problem, *SD* = 21.79) than those working on the control group (*M* = 78.29 s/problem, *SD* = 33.41). The effect size was moderate, ES = .65. These findings suggest that interspersing the briefer problems enhance problem completion rates. Appendix C shows the output from the ANOVA.

Discussion

The current findings suggest that the additive interspersal procedure may reduce, as opposed to enhance, students' persistence. These results have applied and theoretical implications. Researchers who developed the discrete tasks completion hypothesis have posited that completed tasks become conditioned reinforcers because most people have been reinforced for assignment completion. As each completed discrete task is a stimulus that often preceded reinforcement delivered contingent upon assignment completion, previous research on contiguity and contingency suggests each completed task should become a conditioned reinforcer (see Skinner, 2002). In the current experiment, if a completed discrete task was a reinforcer, those working on the experimental assignment were exposed to a richer schedule of reinforcement (their problem completion rates were higher) than those working on the control assignments. This richer schedule of reinforcement should have caused them to persist longer. However, results indicated the opposite, as those working on control assignments showed greater persistence. Thus, the current experiment shows that, under some conditions, the additive interspersal procedure may actually hinder desired academic responding (in the current experiment, persistent responding). These findings suggest several directions for future research.

Previous researchers investigating the additive interspersal procedure exposed each participant to both control and interspersal assignments that were on printed page(s) so that students were aware that the assignment contained a limited number of discrete tasks. The delay reduction hypothesis suggests that in such situations these completed discrete tasks may serve as discriminative stimuli indicating that time to reinforcement, typically delivered contingent upon assignment completion, has decreased (Fantino, 1969; Fantino, 1981; Staddon, Chelaru, & Higa, 2002). However, in the current experiment, the assignment was continuous as the computer delivered one math problem after another *with no terminal problem*. Thus, each completed problem may not have served as a stimulus that signaled that students were closer to finishing the assignment. Because previous reinforcement following assignment completion is the causal mechanism which accounts for each discrete task being a reinforcer (see Skinner, 2002), the failure to present students with a discrete assignment may have reduced or even eliminated the reinforcing quality of a completed problem. Researchers should attempt to determine if effects of the additive interspersal procedure can be accounted for by the discrete task completion hypothesis or Fantino's (1969) delay reduction hypothesis. Also, researchers should evaluate the effects of the additive interspersal procedure on persistence across discrete and continuous assignments.

Researchers investigating stimulus preference have found that participants may rate a stimulus as highly preferred when it is presented in isolation but as less preferred when it is presented with other more-preferred stimuli (Fisher et al., 1992). In the current study, each participant was exposed to only one assignment type; those in the control group were exposed only to target-problem stimuli, while those in the experimental group were exposed to both target-problem and briefer-problem stimuli (Billington, Skinner, Hutchins, & Malone, 2004). Future researchers should determine if exposing students to briefer discrete problems, which may be preferred over the target tasks because they require less time and effort to complete, reduces participants' preference for the target tasks and consequently decreases their persistence. This theoretical research has applied implications as researchers may find that when working on continuous assignments with no terminal response, persistence may be enhanced by interspersing tasks that are less preferred than the target tasks (e.g., interspersing problems longer than target problems) because such procedures may enhance preference for the more prevalent target tasks.

Finally, researchers should address limitations associated with the current study. Across both persistence measures, differences were found approaching significant levels (i.e., $p = .06$). Although these differences were not statistically significant, effects size analysis suggests moderate effects. These findings suggest that future researchers should consider running similar studies with more participants. In the current experiment, students worked only one type of target math problem and that problem type was not part of their general education curricula. Researchers conducting additional studies should address this limitation by conducting similar studies using more educationally valid tasks (i.e., tasks that are part of their curricula and assignments that contain a variety of tasks). External validity would be enhanced by conducting similar studies across students (e.g., students with disabilities), tasks (e.g., Language Arts), tasks length (e.g., giving 1.5 hours for students to work), teachers, and settings (e.g., home to mimic a homework assignment). Finally, repeated-measures designs would allow researchers to investigate the applied value of all findings (e.g., sustainability of effects).

Summary

Previous researchers exposed each participant to both control and interspersal assignments and found evidence that additive interspersal procedures may enhance persistence (McCurdy et al., 2001; Skinner et al., 2002). The current across-subjects design suggests that the additive interspersal procedure can reduce persistence. These findings suggest that more research is needed that increases our understanding of how the additive interspersal procedure influences behavior. Studies designed to establish causal mechanisms related to the interspersal procedure may allow researchers to identify contexts when such procedures can be effective (e.g., continuous versus discrete assignments), alter procedures to enhance their effectiveness, and develop new procedures (e.g., interspersing a few longer tasks to enhance preference for target tasks). Because altering assignments by interspersing additional, briefer tasks is a simple, efficient, and sustainable procedure that has the potential to enhance assignment perceptions, academic responding, and learning, these future theoretical studies have clear applied value (Skinner, 2002).

CHAPTER III

EXPERIMENT 2

Altering assignment by interspersing additional briefer tasks and additional longer tasks: An investigation of persistence

Based on a series of studies on choice behavior, researchers developed the discrete task completion hypothesis, which suggests that when given an assignment comprised of many discrete tasks, each completed task is a reinforcer. If completed tasks are reinforcers, then increasing the task completion rates should increase the rates of reinforcement (Skinner, 2002). When rates of reinforcement are increased, the probability for students to engage in on-task behaviors, as opposed to any other competing activity, also may increase (Martens & Houk, 1989; Skinner et al., 2002; McCurdy et al., 2001).

If a completed discrete task is a reinforcer, interspersing additional brief tasks should increase rates of reinforcement and students' persistence. Persistence can be conceptualized as the amount of work completed or time spent working before quitting. However, in Experiment 1, Kirk, Skinner, Rowland, Roberts, and Ridge (2008) found evidence that interspersing brief tasks reduced, as opposed to enhanced, persistence.

Kirk et al. (2008) assessed the impact of interspersing additional briefer math problems (i.e., two-digit by one-digit problems) among target math problems (three-digit by two-digit problems) on high school students' persistence when completing computer-delivered problems. Computers ran either a control program that administered only the target math problems or an experimental program, which contained similar target problems but included a brief problem interspersed after every third target problem. Although they were given an hour to work, students were told they had to begin working the problems but could quit at any time to work on cognitive puzzles (i.e., sudoku, crossword, and word search puzzles). Students who worked only target problems completed 32% more target problems and worked 22% longer than those who had briefer problems interspersed. Although the interspersal procedure has been shown to enhance assignment preference (e.g., Teeple & Skinner, 2004) and on-task behavior (e.g., McCurdy et al., 2001), Kirk et al. (2008) found that this procedure may reduce persistence. Research on stimulus preference and within-trial contrast may explain these contradictory findings.

Stimulus Preference. Fisher et al. (1992) found that the rate of responding is a function of the quality of the reinforcer, and although stimuli might be highly preferred in isolation, they can be less preferred when presented with other more-preferred stimuli. Fisher et al. (1992) worked with four students who had severe or profound disabilities ranging in age from 2 years 9 months old to 10 years old. In the stimulus preference assessment, the students were exposed to 16 items, presented individually to the student 10 times over eight sessions. Preference was assessed according to whether the client approached the stimulus. During a forced-choice assessment, the same 16 stimuli were presented in pairs, with each stimulus paired once with every other stimulus for a total of 120 stimulus-pair presentations. Preference was assessed according to which of the two stimuli the student approached. Results indicated that all items identified as highly preferred by the forced-choice assessment were also identified as highly preferred by the stimulus preference assessment. However, sometimes the stimulus preference assessment identified an item as highly preferred, but the forced-choice assessment identified the stimulus as low to moderate.

The results of Kirk et al. (2008) can be examined in the same manner as Fisher et al. (1992). Specifically, preference for the target problems or reinforcing value associated with these problems was fixed when they were presented in isolation (the control program). However, students who completed the experimental program were exposed to both target and brief problems (similar to Fisher et al., 1992; forced choice condition). Previous researchers have shown that students preferred the brief problems that required less effort to complete (Billington, Skinner, & Cruchon, 2004; Billington, Skinner, Hutchins, & Malone, 2004). Often students' choice behavior is based on their preferences (Cannella, O'Reilly, & Lancioni, 2005), and more highly preferred stimuli may be higher quality reinforcers (Cannella et al., 2005; Piazza, Fisher, Hanley, Hilker, & Derby, 1996). The difference in preference across items in Kirk et al. (2008) may have reduced the preference for and/or reinforcing value of the longer, target problems within that condition and may explain why including the brief problems hindered persistence.

Within-trial Contrast. Within-trial contrast also may explain why students persisted longer on the assignments without the brief problems. Researchers investigating within-trial contrast have found that a discriminative stimulus is preferred when it follows a less appetitive event (e.g., a higher effort task; Clement, Feltus, Kaiser, & Zentall, 2000; Zentall, 2005).

Researchers investigated whether effort followed by a stimulus associated with reward affects the value of the stimulus. Using pigeons, Clement et al. (2000) examined relative preference for discriminative stimuli that followed a low ratio (FR 1) or a high ratio (FR 20) pecking requirement. At the start of each trial, a white light was shown on the center response key. On some trials, one peck turned on a simultaneous discrimination on the side keys (e.g., red or yellow hues, which represented a positive stimulus and negative stimulus respectively); on other trials, 20 pecks were required to turn on a simultaneous discrimination on the side keys (e.g., blue or green hues, again representing either a positive or negative stimulus). After this training, the pigeons were given the choice between the positive stimulus (S^+) that previously followed the FR 1 and the S^+ that previously followed the FR 20. The pigeons preferred the S^+ that had been preceded by the 20 pecks in training over the S^+ that had followed the single peck in training for 69% of trials. When given the choice between the two negative stimuli (S^-), the pigeons showed an even stronger tendency (84%) to peck the S^- that had followed the 20 pecks in training over the S^- that had been preceded by only 1 peck. Additionally, results indicated that no significant effects on preference occurred for the number of pecks that preceded choice between the two S^+ or between the two S^- stimuli; rather, the colors that had followed the greater effort in training had apparently taken on added value relative to the colors that had followed less effort.

Klein, Bhatt, and Zentall (2005) extended within-trial contrast research to humans. Thirty-two undergraduates were told to produce pairs of shapes by clicking a computer mouse, sometimes repeatedly. They had to determine which shape of each pair was correct. The participants were divided into two groups, each of which would participate in a high effort task and a low effort task. In one group, the high effort task required 20 responses (FR 20), and the high effort task required 30 responses (FR 30) for the other group; both low effort tasks required only one response (FR 1). During training, each trial began with the presentation of a blue rectangle. A pair of discriminative stimuli (i.e., other shapes) would then appear by clicking on the rectangle either once (FR 1) or multiple times (FR 20 or FR 30). The participants would then choose between the discriminative stimuli by clicking that shape one time. If the S^+ was chosen, the word *correct* would appear. If the S^- was chosen, the word *wrong* appeared. As with the pigeon studies, the low-effort response discriminative stimuli were different from the high-effort response discriminative stimuli.

After training, the participants were told they were entering a new phase of the experiment that would not produce feedback. Like the training sessions, the participants had to click on the rectangle once (FR 1) for half of the trials and multiple times (FR 20 or FR 30) for the other half. The participants then received a choice between a high-effort S^+ and the low-effort S^+ (for 50% of the trials) or they had a choice between the high-effort S^- and the low-effort S^- (for 50% of the trials); however, these responses did not include feedback. After the testing, the participants filled out questionnaires that asked them to rank the shapes in order of preference from most preferred to least preferred. Participants preferred the shapes that followed the high-effort response in training, which revealed that the within-trial contrast effect is, indeed, effective for humans.

Within-trial contrast research suggests that any relatively aversive preceding event should lead to a greater preference for the stimuli that follow. Researchers have confirmed the importance of a relatively aversive event, or the expectation of such an event, as the source of such contrast (Clement et al., 2000; Clement & Zentall, 2002; DiGian, Friedrich, & Zentall, 2004). Zentall and Singer (2007) indicate that discrepancies in human behavior have been explained through theories in social psychology such as cognitive dissonance (Festinger, 1957), self-concept (Bem, 1967), social norms (Tedeschi, Schlenker, & Bonoma, 1971), and justification of effort (Aronson & Mills, 1959). The cognitive dissonance theory (Festinger, 1957) suggests that humans will try to reduce the dissonance produced when an outcome from high effort is not better than that from low effort. For instance, if a student receives an A in both an organic chemistry course (which is presumably difficult) and in a physical education course (which is presumably easier), he or she would likely value the A in organic chemistry more, even though the grade was the same in each (Klein et al., 2005). Giving more value to rewards that are difficult to obtain can be explained by cognitive dissonance as humans justify their effort to obtain such rewards by giving more value to the outcome with higher effort (Klein et al., 2005; Zentall, 2005; Zentall & Singer, 2007).

The within-trial contrast effect suggests that a stimulus should be less preferred when it follows a low effort response and more preferred if it follows a high effort response (Zentall, 2005). In the Kirk et al. (2008) study, the target problems (stimuli) for students who received the control assignment were always followed by similar target problems (stimuli). Thus, there was no contrast. However, the students in the experimental group received both high effort (target) and low effort (brief interspersed) problems and the low effort problems were always followed by the higher effort target problem stimuli. Based on the contrast effect, the across problem sequence of one event (finishing a low effort problem) followed by another event (a target problem stimuli), should have reduced students' preference for the target problem stimuli because the event immediately preceding it required less effort. Since the assignment was primarily comprised of high effort problems, this decrease in preference for these problems may have caused students who received the experimental assignment to quit working problems earlier (i.e., reduced their persistence).

Summary and Purpose

The Kirk et al. (2008) findings may be explained by research on stimulus preference and contrast effects, which suggests that interspersing the additional brief problems may have reduced student preference for the target problems or made these stimuli more aversive (Fisher et al., 1992; Zentall, 2005). Either mechanism may have caused students who received the interspersal assignment to persist less than those who received the control assignment. If these theories are correct, then introducing even higher-effort problems may result in higher-quality reinforcement. Thus, the primary purpose of Experiment 2 was to determine if interspersing longer problems enhanced persistence.

Methods

Participants

The participants were one hundred and thirty-nine undergraduate psychology students at a university in the Southeastern United States. Students enrolled in the Psychology 110 class were able to sign up to participate in research studies such as this one in return for extra credit points to be added to their final grade. The participants included 41 males and 98 females ranging from 17 to 35 years old; over 90% of participants were 18 or 19 years old. Most (72.7%) participants were freshman, although some were upperclassmen (21.6% sophomores, 2.2%

juniors, 3.6% seniors). One hundred and nine students were Caucasian, 16 were African American, eight were Asian or Pacific Islander, three were Hispanic, one was Native American, and two were Other (i.e., Caucasian/African American, Caucasian/Native American).

Setting and Materials

All procedures were run in a classroom at the university. The classroom had been equipped with 24 laptop computers, which were arranged on the desks in rows. A flash drive that contained one of three experimenter-constructed math persistence programs was connected to each computer. Beside each computer was paper to work math computation problems and a puzzle pack, which contained sudoku, crossword, and word search puzzles on 8.5" by 11" sheets of paper; pencils were provided as needed. Participants were allowed to choose their own computer/desk.

Procedures

Each participant entered the computer lab at the time he or she had scheduled. Individuals from the psychology department had the opportunity to sign up to participate in one of eight sessions. After the students were seated in the room, informed consent forms were distributed to potential participants. The principal investigator read the informed consent forms and answered any questions about the study. Willing participants signed the forms, which were then collected before beginning the study. A co-investigator made copies of the signed forms while the other investigator ran the study. At the end of the session, copies of the informed consent were returned to the participants.

One-third of the computers contained a flash drive with a control program and the other computers had flash drives with an experimental program (one-third with the brief experimental and one-third with the long experimental). These programs were randomly assigned to computers. All three programs presented multiplication computation problems one at a time. After using the keyboard to type in the answer, another problem would appear on the screen. The control program presented only target, two-digit by two-digit, problems. To ensure students had to carry following each multiplication operation, all digits were greater than or equal to four (e.g., 98 x 54). On the brief experimental program, every third two-digit by two-digit problem was followed by a two-digit by one-digit multiplication problem (e.g., 67 x 5). The single-digit factor as well as the two-digit factor were always greater than or equal to four. For the long experimental program, every third two-digit by two-digit problem was followed by a four-digit by two-digit multiplication problem that also required the students to carry numbers (e.g., 9987 x 45). Students never received identical digit factors (e.g., 44 x 3, 67 x 88, or 5989 x 55) and the two-digit by two-digit problems never multiplied a number with itself (e.g., 57 x 57). In every condition, students received the same two-digit by two-digit problems in the same order; however, in the brief or long experimental conditions, these target problems were interspersed with other problems, which were identical for every flash drive in each condition.

After participants were seated, the principle investigator administered the procedures. Participants were told to remain quiet throughout the entire 1-hour period. Students were then informed that they would respond to demographic items, which would be delivered through the computer program and that the computer would deliver math problems one at a time once they had clicked the *Start* button on their computer screen. Each individual was given scrap paper and told they could use it and a pen or pencil to work the problems and then use the keyboard to provide the answer. After providing their answer, they were instructed to press enter and a new problem would appear on the screen.

The participants were told that they must begin working math problems, but they were also informed that they could quit at any time and work quietly from their puzzle packs for the remaining portion of the hour. Participants were told that they could quit by clicking the *Stop* button on the bottom right corner of the screen. The participants were allowed to ask questions before beginning their work to be sure that they understood the directions. After 1 hour, the group was asked to stop working on either the math problems or the puzzle packs and materials were collected.

The co-researcher independently recorded the primary experimenter's behavior using a procedural integrity checklist (see Appendix E). The researcher recorded 100% integrity across all experimental sessions.

Design, Dependent Variable, and Data Analysis Procedures

A true experimental, across subjects, post-test only design was used to test for differences in persistence across the three groups. Since students were randomly assigned to one of three groups, this study was a true experimental design. Because no pre-test was provided, the random assignment of participants to groups was necessary to control for threats to internal validity.

A MANOVA was used to test for significant differences across groups on two measures of persistence, the number of target (two-digit by two-digit) problems completed and the number of seconds before students quit working. The computer program saved data for these calculations on the flash drives. A MANOVA as well as one-way ANOVAs (examining percent correct of target problems, target problem completion rates, rate of the number of seconds to complete a problem) were used to test for significant differences across groups. All differences were considered significant at the $p = .05$ level.

Results

Table 2 displays the mean and standard deviation across dependent variables for the control and experimental groups. A MANOVA with groups (i.e., control, brief experimental, long experimental) serving as the independent variable and target problems completed and number of seconds worked before quitting serving as the dependent variables indicated significant difference, $F(4,272) = 9.697$, $p = .000$. Table 2 shows that the control group spent less total time on working ($M = 1685.17$ seconds) than either the brief experimental group ($M = 1936.17$ seconds) or the long experimental group ($M = 1885.04$ seconds). However, tests of between-subject effects indicated no significant difference for the total number of seconds worked, $F(2, 135) = .656$, $p = .520$.

A significant difference was found for the target number of problems complete, $F(2, 135) = 4.301$, $p = .015$. Pairwise comparisons with Bonferroni corrections showed that the number of target problems completed by the control group ($M = 48.61$) and the number of target problems completed by the brief experimental group ($M = 48.84$) were significantly larger than the long experimental group ($M = 32.37$; $p = .042$ and $p = .038$, respectively). Effect sizes were moderate

Table 2

Experimental and Control Group Summary Statistics for each Dependent Variables in Experiment 2.

	Control Group			Experimental Groups					
				Brief			Long		
	N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*
Number of Target Problems Completed	44	48.61	39.54	44	48.84	30.76	51	32.37	23.95
Number of Seconds Worked before Quitting	44	1685.17	1153.27	44	1936.17	1022.48	51	1885.04	1095.19

for the control group (*ES* = .50) and for the brief experimental group (*ES* = .60). No significant differences on target problems completed were found across the control group and the brief experimental group (p = 1.0) and mean differences were less than one-third of a problem. Appendix F shows the output from the MANOVA.

Table 3 displays the means and standard deviations of the number of target problems completed and the percent correct for target problems across groups. The experimental group with the long problems had the lowest accuracy level (*M* = 27.08% correct), followed by the control group (*M* = 38.45% correct) and the experimental group with the brief problems (*M* = 39.64% correct). A one-way ANOVA with percent correct of target problems serving as the dependent variable and groups (i.e., control and both experimental) served as the independent variable revealed an insignificant effect for group, $F(2, 135) = 1.408$, $p = .248$. Effect sizes were moderate between both the control and long experimental (*ES* = .39) and between the brief experimental and long experimental (*ES* = .51). Appendix G shows the output from this ANOVA.

Table 4 displays the means and standard deviations for each group (i.e., control, brief experimental, long experimental) for 1) the total number of problems completed (i.e., total, target, brief, long), 2) the number of seconds worked for each problem type (i.e., total, target, brief, long), and 3) the rate (seconds per problem for each problem type). Table 4 shows that the brief experimental group spent the least time to complete target problems (*M* = 39.44 seconds per target problem) followed by the control group (*M* = 40.51 seconds per target problem) and

Table 3

Experimental and Control Group Summary Statistics for Number of Target Problems Completed and Percent of Target Problems Correct in Experiment 2.

	Control Group			Experimental Groups					
				Brief			Long		
	N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*
Number of Target Problems Completed	44	48.61	39.54	44	48.84	30.76	51	32.37	23.95
Percent Correct of Completed Target Problems	44	38.45	35.55	44	39.64	27.18	51	27.08	21.38

Table 4

Experimental and Control Group Summary Statistics for the Number of Problems Completed, Number of Seconds Worked, and Rate (Seconds per Problem) in Experiment 2.

	Control Group			Experimental Groups					
				Brief			Long		
	N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*
Total Number of Problems Completed	44	48.61	39.54	44	64.80	41.00	51	44.29	31.46
Number of Target Problems Completed	44	48.61	39.54	44	48.84	30.76	51	32.37	23.95
Number of Brief Problems Completed	44	0	0	44	15.95	10.25	51	0	0
Number of Long Problems Completed	44	0	0	44	0	0	51	10.59	7.89
Total Seconds Worked before Quitting	44	1685.17	1153.27	44	1936.17	1022.48	51	1885.04	1095.19
Total Seconds Worked on Target Problems	44	1684.48	1152.77	44	1698.26	892.88	51	1186.77	710.74
Total Seconds Worked on Brief Problems	44	0	0	44	237.00	135.55	51	0	0
Total Seconds Worked on Long Problems	44	0	0	44	0	0	51	697.49	408.52
Number of Seconds to Complete a Problem	44	40.52	16.70	44	33.83	11.09	51	54.97	40.30s
Number of Seconds to Complete a Target Problem	44	40.51	16.70	44	39.44	13.42	51	49.91	45.83
Number of Seconds to Complete a Brief Problem	44	0	0	44	16.44	5.12	51	0	0
Number of Seconds to Complete a Long Problem	44	0	0	44	0	0	51	71.64	29.96

the long experimental group (*M* = 49.91 seconds per target problem). An ANOVA revealed no significant differences on the target problem completion rates (seconds per problem) across groups. The effect size was small between each group (*ES* = .31 between the brief experimental group and long experimental group, *ES* = .27 between the control group and long experimental group, and *ES* = .25 between the control group and brief experimental group). Appendix H contains the output for the rate of seconds per problem for the target problems in each group.

Table 5 displays the means and standard deviations for the total problem completion rates (i.e., the number of seconds spent working each problem) across groups. Table 5 shows that the brief experimental group spent the least amount of averaged time working on each problem (*M* = 33.84 seconds per problem) followed by the control group (*M* = 40.52 seconds per problem) and the long experimental group (*M* = 54.97 seconds per problem). A one-way ANOVA with rate (seconds per problem) serving as the dependent variable and groups (problem type) serving as the independent variable revealed a significant difference $F(2, 135) = 7.73$, $p = .001$. Pairwise comparisons with Bonferroni corrections showed that the brief experimental group and the control group spent significantly less time working each problem than the long experimental group, $p = .001$ and $p = .030$ respectively. The effect size between the control group and brief experimental group was moderate (*ES* = .47) and was also moderate between the control group and long experimental group (*ES* = .47); however, effect size was larger between the brief experimental and the long experimental groups (*ES* = .71). Appendix I shows the output from this ANOVA. A summary of the results from Experiment 2 is presented in Appendix J.

Table 5

Experimental and Control Group Summary Statistics for Number of Problems Completed and Rate of Seconds Spent Working each Problem for Experiment 2.

	Control Group			Experimental Groups					
				Brief			Long		
	N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*
Total Number of Problems Completed	44	48.61	39.54	44	64.80	41.00	51	44.29	31.46
Rate (Seconds per Problem)	44	40.52	16.70	44	33.84	11.09	51	54.97*	40.30

* The long group was significantly greater than the control and brief.

Discussion

The current findings suggest that interspersing longer or shorter problems among target problems did not affect the amount of time that students worked on problems (persistence) or their accuracy level on target problems. Interspersing the longer problems did reduce the number of target problems completed; however, interspersing the brief problems had no affect on the number of target problems completed. Finally, relative to the control assignment, interspersing the long problems did decrease total problem completion rates. The results of this experiment have theoretical and applied implications.

Theoretical Implications

The results of Experiment 2 failed to support several theories. First, no significant differences in total time working emerged across the three groups. Thus, the current findings failed to support Experiment 1, which showed that interspersing the additional brief problems reduced time spent working. Because interspersing the additional long problems did not enhance time spent working, the current findings failed to support stimulus preference (e.g., Fisher et al., 1992) or within-trial contrast (e.g, Clement et al., 2000; Zentall, 2005) theories, which offered plausible explanation for the findings from Experiment 1.

Not only did the current experiment fail to confirm the results of the first experiment, but these findings also failed to support the discrete task completion hypothesis (Skinner, 2002). If each completed problem was a reinforcing stimulus, then rates of reinforcement were higher under the control and brief experimental assignment relative to the long experimental assignment. As a thicker schedule of reinforcement should have enhanced persistence, (Martens

& Houk, 1989; Skinner et al., 2002; McCurdy et al., 2001) the failure to find differences in time spent working across groups suggests that each discrete task did not serve as a reinforcing stimulus.

In the current experiment, no differences on target problem accuracy levels across the three groups were found. These findings are consistent with previous researchers who found that interspersing brief problems did not enhance target problem accuracy when students completed written mathematics tasks but did enhance target problem accuracy when students were read problems and had to complete them without paper and pencil (Hawkins et al., 2005; Robinson & Skinner, 2002). In these previous studies, researchers suggested that problem difficulty or the levels of sustained attention required to complete the problems may have accounted for the increase in accuracy when the interspersal procedure was applied in some studies, but not others (Hawkins et al., 2005; Robinson & Skinner, 2002). In Experiment 2, students work problems on scrap paper using paper and pencil; therefore, tasks did not require high levels of sustained attention. However, accuracy levels were very low, which suggests that problems were difficult. These results suggest that problem difficulty is not a moderator variable that can be used to explain why the interspersal procedure enhances accuracy in some cases but not others. Consequently, these findings suggest that future researchers investigating whether interspersing brief tasks enhances accuracy on target tasks should focus on levels of sustained attention required to complete target tasks as a plausible moderator variable (Robinson & Skinner, 2002).

Applied Implications

Although the current experiment failed to support several theories, the results do have some applied implications. Many analyses from Experiment 2 resulted in no significant differences; nonetheless, several findings suggest that educators should not intersperse additional longer tasks. First, interspersing the longer problems did not enhance persistence, as results from Experiment 1 had suggested. Second, interspersing longer problems did not enhance target problem accuracy levels. Academic independent seatwork is designed to provide opportunities for students to enhance their skill via practice. The current results suggest that interspersing longer problems may reduce skill development by reducing opportunities to respond to target tasks (Skinner et al., 2005). While reducing opportunities to respond may be acceptable if those responses are more accurate, the current findings showed no significant differences in accuracy on target problems. Therefore, the results of Experiment 2 suggest that educators should not intersperse longer problems, for these procedures will not enhance persistence and may reduce target problem skill development.

In Experiment 2, the participants were expected to work problems but not given an idea of how many problems they were expected to complete (i.e., there was no end problem in the assignment). Instead, students were told that they should answer the math problems until they chose to stop. When allowed to ask questions prior to beginning the computer tasks, some students asked questions to clarify that the problems would continue with no end until they chose to quit by activating the stop function. Not only were these conditions atypical, but they also differed from previous interspersal studies as each completed problem did not serve as a discriminative stimulus that indicated that the individual was nearing completion of the assignment. This has implications related to the discrete trial completion hypothesis and the delay reduction hypothesis (Fantino, 1969; Fantino, 1981; Staddon et al., 2002).

Conclusion

The current experiment failed to support several hypotheses including the discrete task completion hypothesis, stimulus preference, and within-trial contrast. Future researchers should investigate the possibility that the delay-reduction hypothesis may explain conflicting results across studies. Experiment 2 does not support the hypothesis that interspersing additional longer problems can enhance persistence or accuracy of target responses. This study did suggest that interspersing additional longer tasks can reduce the number of target tasks completed, which can retard skill acquisition, fluency, and maintenance (Haring & Eaton, 1978). Therefore, until causal mechanisms associated with the interspersal procedure's affects on behavior (e.g., choice, accuracy, persistence) are clearly delineated, educators should not intersperse longer tasks on assignments.

CHAPTER IV

DISCUSSION

The purpose of Experiments 1 and 2 was to examine the effects of the additive interspersal procedure on persistence as students worked computer-delivered math multiplication problems within a one-hour period. Students are frequently asked to complete an assignment (e.g., homework, independent seat-work in their classrooms). Although students may begin their assigned work, they can choose to stop and engage in other activities at any time (McCurdy et al., 2001). By increasing persistence, or the amount of time spent working, educators can enhance students responding and, consequently, their learning.

Researchers investigating interspersal procedures have found that altering assignments by interspersing additional brief tasks can cause students to choose to do assignments that require more work (provide more opportunities to respond) and can increase students' levels of on-task behavior when they are working on classroom assignments (Cates & Skinner, 2000; McCurdy et al., 2001; Skinner et al., 2002). To explain these and similar findings, Skinner (2002) suggested that when working on assignments comprised of multiple discrete tasks, each discrete task is a conditioned reinforcer (i.e., the discrete task completion hypothesis). If a completed task is a reinforcer, then procedures that increase problem completion rates should enhance rates of reinforcement for working on those problems. These increased rates of reinforcement should enhance persistence. However, until now, researchers have not examined how the additive interspersal procedure affects the amount of time students spend working on an assignment before quitting.

The purpose of Experiment 1 was to examine the effects of the additive interspersal procedures on persistence when using computer-delivered math multiplication problems. Although past researchers found evidence that additive interspersal procedures might enhance persistence (McCurdy et al., 2001; Skinner et al., 2002), Experiment 1 demonstrated that this procedure could decrease persistence. The results indicated that students who had received brief problems interspersed among the target problems spent *less* time working than students who received only target problems. Several possible explanations exist for these findings, including stimulus preference and within-trial contrast effect (Clement et al., 2000; Zentall, 2005).

Stimulus preference suggests that students may rate a stimulus as highly preferred when it is presented in isolation but as less preferred when it is presented with other more-preferred stimuli (Fisher et al., 1992). In Experiment 1, a difference in preference between the brief and target problems in the experimental condition may have reduced the reinforcing value of the target problems in that condition. In other words, because students preferred the brief problem stimuli more than the target problem stimuli, including the brief problems on the experimental assignment may have decreased their preferences for the target problem stimuli (Billington, Skinner, Hutchins, & Malone, 2004). Since target problems made up the majority of the assignment, this decreased preference for the target problems may have caused them to quit working earlier.

Another explanation for the results of Experiment 1 is within-trial contrast, which suggests that a discriminative stimulus is preferred when it follows a less appetitive event (e.g., a higher effort task; Clement et al., 2000; Zentall, 2005). In the control condition, there was no contrast because all students received only target problems; however, students in the experimental group received both target and brief problems. Based on the contrast effect, students' preference for the target problems should have been reduced because the event immediately preceding it (a brief problem) required less effort. Since the assignment was primarily comprised of target problems, this decrease in preference for these problems may have caused students in the experimental condition to quit working problems earlier.

Both the stimulus-preference and within-trial contrast offer plausible explanations for the results of Experiment 1, which found that interspersing brief problems among target problems reduced students' persistence when working computer-delivered multiplication problems. Furthermore, each of these hypotheses suggests that interspersing longer problems could enhance persistence. Experiment 2 was designed to replicate Experiment 1 and extend this line of research by testing the hypothesis that interspersing longer problems would enhance persistence. In this study, both brief and long problems were interspersed among target problems in two separate experimental conditions. Results indicated no differences in the amount of time worked across groups (i.e., control, brief experimental, long experimental). Consequently, the results failed to support stimulus preference or within-trial contrast theories.

Previous researchers investigating the additive interspersal procedures have found evidence supporting the discrete trial completion hypothesis (e.g., Billington, Skinner, & Cruchon, 2004; Billington, Skinner, Hutchins, & Malone, 2004; Cates et al., 1999; Logan & Skinner, 1998; Skinner et al., 1996). However, neither Experiment 1 nor Experiment 2 supports the discrete trial completion hypothesis (Skinner, 2002). If each completed problem had been a reinforcing stimulus, then rates of reinforcement, which differed across conditions, should have caused students to persist longer when working on the assignments that resulted in a thicker schedule of reinforcement. However, in the first experiment persistence was greater on the assignment that resulted in the lower problem completion rates, and this approached significant levels. In the second experiment, problem completion rates were significantly lower on the longer experimental assignment, but no differences were found in persistence. These findings suggest that in both experiments each discrete task did not serve as a reinforcing stimulus.

Theoretical Implications

Together, Experiments 1 and 2 have implications that provide future directions for both theory and practice. In terms of theoretical implications, the first study provided some support for stimulus preference and/or within-trial contrast. However, the second study failed to support either of these theories. Therefore, researchers should continue to investigate the stimulus preference and within-trial contrast theories in other learning contexts across subjects, settings, or tasks.

Both experiments in the current investigation failed to support the discrete task completion hypothesis, which suggests that each discrete task is a conditioned reinforcer. Future researchers should investigate whether the discrete tasks are punishers rather than reinforcers. If, indeed, discrete tasks are not reinforcers, the short problems in Experiment 1 and the long problems in Experiment 2 could be viewed as punishers.

In the current experiments, completed discrete tasks were assumed to be reinforcers (as in past studies of the discrete task completion hypothesis). In Experiment 1 and Experiment 2, the interspersal procedure was evaluated in a different context than used by previous researchers (e.g., McCurdy et al., 2001; Skinner et al., 2004; Skinner et al., 1996). Almost all researchers investigating the discrete task completion hypothesis conducted their experiments using paper and pencil assignments that had a clear beginning (first problem) and end (last problem). However, the current studies involved a computer interface with problems being delivered one after another. Consequently, there was no end to the assignment. These differences in procedures may explain conflicting results across studies and suggest that the delay reduction hypothesis may influence findings on the additive interspersal procedure.

The delay reduction hypothesis suggests that completing discrete tasks may serve as discriminative stimuli that indicate that the amount of time before being reinforced has been reduced (Fantino, 1969; Fantino, 1981; Staddon et al., 2002). In previous studies (see Skinner, 2002), students were given assignments printed on paper and the assignments contained a terminal problem. Thus, each completed discrete task may have served as a stimulus that signaled they were closer to completing the assignment. However, in the current studies, a completed problem did not signal to the students that they were any closer to finishing. The discrete task completion hypothesis may interact with the delay reduction hypothesis. Specifically, discrete problems may be more reinforcing when they signal that the end is near.

Future researchers conducting additional studies to investigate whether a discrete task is a reinforcing stimulus should consider designing their studies to determine if the delay reduction hypothesis (Fantino, 1969) explains these contradictory findings across the current and previous interspersal studies. One strategy may be to conduct an experiment using procedures similar to those used in the current studies, but instead of using computers, providing and pencil and paper assignments that have a clear terminal problem. Alternatively, conducting computer-based experiments that include an indication of student progress toward assignment completion may provide insight on the causal mechanisms responsible for interspersal effects.

Applied Implications

The present studies have several implications for practice, particularly related to use of additive interspersal procedures in the classroom. Experiment 2 indicated that educators should refrain from interspersing long problems, for such procedures resulted in a reduction of the number of target problems completed, thereby reducing the number of opportunities students have to respond. With fewer opportunities to respond to (or practice) target problems, students have fewer opportunities for skill development. Although past researchers have suggested that additive interspersal procedures with brief tasks can increase students' on-task levels, cause students to choose assignments with more work, and are preferred by students (e.g., Cates & Skinner, 2000; McCurdy et al., 2001; Meadows & Skinner, 2005; Skinner et al., 2002; Wildmon et al., 1999; Wildmon et al., 2004), Experiment 1 demonstrated that the interspersal of brief problems may reduce persistence. Consequently, educators should use caution when interspersing additional brief problems, especially in a context where persistence is a desired outcome.

Several limitations warrant caution in interpreting the findings of these experiments and emphasize the need for replication and extension studies. First, the circumstances of Experiment 2 did not mirror a classroom environment. The participants were not working in a typical classroom setting, on tasks they had just learned, and under conditions where responses would have consequences (grades based on performance). Instead, volunteer psychology students worked in a research setting on tasks that were irrelevant. During Experiment 1, the students were working at the request of their teacher. In Experiment 2, the students were working at the request of an experimenter and received extra credit for participation. However, the college students were informed that the extra credit would not be delivered contingent upon the effort they exerted. Across experiment comparisons suggest that the secondary students who participated in Experiment 1 worked longer periods of time than the college students in Experiment 2. Because the participants, settings, and tasks varied across Experiments 1 and 2, researchers should determine if demand characteristics accounted for these disparate findings by conducting similar studies while manipulating demand characteristics. Also, conducting similar studies with school-aged students, in a traditional math class, working on material that they had just learned would enhance the external and contextual validity of future findings.

Sample size particularly limited our ability to interpret results. In Experiment 1, differences in persistence measures across groups were not significant ($p = .60$); however, effect size indicated moderate effects. Similarly, in Experiment 2 differences in problem completion rates across the brief experimental assignment and the control assignment approached significant levels. Research with larger amounts of students could provide clearer information regarding the use of additive interspersal procedures with computer-delivered math problems.

Conclusion

The results of the current experiments failed to support the discrete task completion hypothesis (Skinner, 2002). Further research addressing the additive interspersal procedure's effects on persistence should focus on determining the context in which this procedure can help or when it could hurt students' learning. Specifically, these results suggest that researchers should determine if the delay reduction hypothesis (Fantino, 1969) and/or an interaction of the delay reduction hypothesis and the discrete task completion hypothesis can explain seemingly contradictory findings on the additive interspersal procedure. Continuing efforts to clearly delineate the causal mechanism associated with additive interspersal procedure's effects on student behavior may allow researchers to provide clear recommendations to educators indicating conditions when this procedure can be used to enhance student motivation, learning, and, of course, persistence.

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APPENDIXES

Appendix A

Appendix A: Procedural Integrity Document

Experiment 1

1. Before class begins, randomly place computer with flash drive and a puzzle pack at 20 desks.
2. Prepare each computer so that demographic form is displayed.
3. As students enter tell them not to touch computers yet.
4. Call roll using informed consent (parent permission) forms.
5. Remove computers from the desks of students who do not have consent forms.
6. Pass out assent forms, read it to them, and collect them.
7. Collect assent forms. If someone does not sign assent form, remove the computer from their desk.
8. Instruct students to write their class period and their computer code number on their puzzle packs.
9. Teacher reads directions.
10. After answering questions, start a stopwatch and tell the student to begin working.
11. After 1 hour tell the students still working to click the stop button and close their laptops.
12. Collect puzzle packs from students.
13. Thank students for participating.

Appendix B

Appendix B: MANOVA of Target Problems Completed and Total Number of Seconds Worked before Quitting

Experiment 1

General Linear Model

Between-Subjects Factors

		N
ContExp	1	19
	2	21

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.911	188.851[a]	2.000	37.000	.000
	Wilks' Lambda	.089	188.851[a]	2.000	37.000	.000
	Hotelling's Trace	10.208	188.851[a]	2.000	37.000	.000
	Roy's Largest Root	10.208	188.851[a]	2.000	37.000	.000
ContExp	Pillai's Trace	.104	2.151[a]	2.000	37.000	.131
	Wilks' Lambda	.896	2.151[a]	2.000	37.000	.131
	Hotelling's Trace	.116	2.151[a]	2.000	37.000	.131
	Roy's Largest Root	.116	2.151[a]	2.000	37.000	.131

a. Exact statistic

b. Design: Intercept + ContExp

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square
Corrected Model	TNumber	735.431[a]	1	735.431
	TotalSeconds	1.956E6	1	1956441.223
Intercept	TNumber	38009.831	1	38009.831
	TotalSeconds	2.027E8	1	2.027E8
ContExp	TNumber	735.431	1	735.431
	TotalSeconds	1956441.223	1	1956441.223
Error	TNumber	7355.669	38	193.570
	TotalSeconds	1.985E7	38	522491.143
Total	TNumber	45668.000	40	
	TotalSeconds	2.230E8	40	
Corrected Total	TNumber	8091.100	39	
	TotalSeconds	2.181E7	39	

a. R Squared = .091 (Adjusted R Squared = .067)

b. R Squared = .090 (Adjusted R Squared = .066)

Tests of Between-Subjects Effects

Source	Dependent Variable	F	Sig.
Corrected Model	TNumber	3.799	.059
	TotalSeconds	3.744	.060
Intercept	TNumber	196.362	.000
	TotalSeconds	387.898	.000
ContExp	TNumber	3.799	.059
	TotalSeconds	3.744	.060

Estimated Marginal Means

ContExp

Estimates

Dependent Variable	ContExp	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
TNumber	1	35.158	3.192	28.696	41.619
	2	26.571	3.036	20.425	32.718
TotalSeconds	1	2475.217	165.830	2139.512	2810.922
	2	2032.347	157.736	1713.028	2351.666

Pairwise Comparisons

Dependent Variable	(I) ContExp	(J) ContExp	Mean Difference (I-J)	Std. Error	Sig.[a]
TNumber	1	2	8.586	4.405	.059
	2	1	-8.586	4.405	.059
TotalSeconds	1	2	442.871	228.867	.060
	2	1	-442.871	228.867	.060

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Pairwise Comparisons

Dependent Variable	(I) ContExp	(J) ContExp	95% Confidence Interval for Difference[a]	
			Lower Bound	Upper Bound
TNumber	1	2	-.331	17.504
	2	1	-17.504	.331
TotalSeconds	1	2	-20.446	906.188
	2	1	-906.188	20.446

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.104	2.151[a]	2.000	37.000	.131
Wilks' lambda	.896	2.151[a]	2.000	37.000	.131
Hotelling's trace	.116	2.151[a]	2.000	37.000	.131
Roy's largest root	.116	2.151[a]	2.000	37.000	.131

Each F tests the multivariate effect of ContExp. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

Univariate Tests

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
TNumber	Contrast	735.431	1	735.431	3.799	.059
	Error	7355.669	38	193.570		
TotalSeconds	Contrast	1956441.223	1	1956441.223	3.744	.060
	Error	1.985E7	38	522491.143		

The F tests the effect of ContExp. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Appendix C

Appendix C: ANOVA of Seconds per Problem

Experiment 1

Univariate Analysis of Variance

Between-Subjects Factors

		N
ContExp	1	19
	2	21

Tests of Between-Subjects Effects

Dependent Variable:RateSecPerProb

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3532.215[a]	1	3532.215	4.424	.042
Intercept	193394.432	1	193394.432	242.234	.000
ContExp	3532.215	1	3532.215	4.424	.042
Error	30338.358	38	798.378		
Total	225138.366	40			
Corrected Total	33870.573	39			

a. R Squared = .104 (Adjusted R Squared = .081)

Estimated Marginal Means

ContExp

Estimates

Dependent Variable:RateSecPerProb

ContExp			95% Confidence Interval	
	Mean	Std. Error	Lower Bound	Upper Bound
1	79.029	6.482	65.906	92.152
2	60.211	6.166	47.729	72.694

Pairwise Comparisons

Dependent Variable:RateSecPerProb

		a			95% Confidence Interval for Difference[a]	
(I) ContExp	(J) ContExp	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	18.818*	8.946	.042	.707	36.929
2	1	-18.818*	8.946	.042	-36.929	-.707

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable:RateSecPerProb

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	3532.215	1	3532.215	4.424	.042
Error	30338.358	38	798.378		

The F tests the effect of ContExp. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Appendix D

Appendix D: Summary Table of Results from Experiment 1

Table 6

Summary of Results for Experiment 1.

		Control Group			Experimental Group		
					Brief		
		N	*M*	*SD*	*N*	*M*	*SD*
Total	Total Number of Problems Completed	19	35.16	13.74	21	39.62	21.10
	Total Seconds (s) Worked before Quitting	19	2475.22	831.77	21	2032.35	608.34
	Number of s to Complete each Problem (Rate: s/problem)	19	79.03	34.03	21	60.21	21.79
Target	Number of Target Problems Completed	19	35.16	13.74	21	26.57	14.07
	Time (seconds) to complete all Target Problems (Sum of time working on Target)	19	2453.52	818.90	21	1877.85	589.25
	Number of s to Complete each Target Problem (Rate: s/problem)	19	78.29	33.41	21	82.08	28.49
	% Correct on Completed Target Problems	19	52.85	36.68	21	56.99	25.46
Brief	Number of Brief Problems Completed	19	0	0	21	13.05	7.03
	Time (seconds) to complete all Brief Problems (Sum of time working on Brief)	19	0	0	21	135.71	39.74
	Number of s to Complete each Brief Problem (Rate: s/problem)	19	0	0	21	13.28	7.99

Appendix E

Appendix E: Procedural Integrity Document

Experiment 2

Experiment 2 Procedure/Script

Date:			
Please initial as steps are completed correctly for each session.			
#1	#2	#3	
			1. Before class begins, make sure there is a computer with the math program as well as a Puzzle Pack and scrap paper with each computer.
			2. Make sure each computer is ready to go with the demographics & program before the students sit down. There will be a sign covering the keyboard that also tells students not to touch the computer.
			3. Have students sign in with name and e-mail address.
			4. When students have entered, state the following:
			"Can I have your attention please? My name is Emily Kirk and I am running this study. Please do not touch the computer or packets before you have been told to do so. Before we begin I need to get your consent to participate in this study. We will be passing informed consent forms down the rows. Take one and pass the rest on. I'm going to read this aloud and make sure no one has any questions. [Reads informed consent form.] … Are there any questions? If you do consent to participate, please sign the form. If not, you may go now without penalty and will still receive your points. Please pass the consent forms to this side of the room. They will be copied, and you will get a copy of it at the end of this session. Also, please be sure you have signed in with your name and e-mail address to ensure that you will receive your credit."
			5. "Make sure your cell phone is off. Again, I ask that you not touch the computer or Puzzle Pack until you are told to do so. Are there any questions?"
			6. "Does everyone have a packet and a pen or pencil?... Great. Let's get started. We are going to walk through some instructions together so follow

			along carefully. Find your Puzzle Pack… Okay. Please look at your computer. There should be a number on the computer. Write that number on the top of your Puzzle Pack. Also write today's date and the time of this study [tell date & time]."
			7. "Today, we will be working some multiplication problems on these computers. Please listen carefully to my directions before touching your computer. It's very important that there is no talking while you are in here. If you have a question at any time, quietly raise your hand and someone will come around to help you. The only thing we cannot help you with is telling you the answers to the math problems."
			"When I say begin, you will first answer questions about yourself. You must answer these before beginning the math problems. When you have answered these questions, hit "Submit." Then, to begin the multiplication problems, click the button that says, "Click here to start" in the center of your computer screen. You will see problems come up on the screen one at a time. Please try to answer each problem as best you can. You may use the scrap paper to work the problems. If you need more scrap paper, please raise your hand. After you have typed in your answer, press the "Enter" button on your keyboard and a new problem will come up."
			"**You may keep working on the math problems for as long as you would like. You must start working on the math problems, but you are allowed to stop whenever you would like.** When you are ready to quit, hit the "Stop" button in the bottom right corner of your screen. Then, **do not touch your computer again**. If you choose to quit, please work on the crossword puzzles, sudokus, or word searches in your Puzzle Pack."
			"Remember, there is no talking and you should keep your eyes on your own screen. Also, please do not pull out your cell phone for talking or texting. Your neighbor will probably not have the same problems as you, so this is your work only. Again, you may work as long as your would like after you get started. Are there any questions?"
			8. Begin timing after questions are answered. Allow students to work for 1 hour. Stop timing at 1 hour.
			Time started: _______________
			9. After 1 hour, say, "Stop. Please hit the 'Stop' button in the bottom right corner of your screen or put away your Puzzle Pack immediately."
			10. Once everyone is done say: "Please leave your Puzzle Pack and scrap paper on top of your keyboard. Someone will come by to collect them after you have left the room."
			11. Say: "Thanks again for your participation in this study. Does anyone have any guesses as to what this study was about? ______ As you may know, one

			obligation of all researchers is to debrief the participants after the study is over. This study was looking at persistence. We were investigating how long you continued working on the math problems on the computer screen, The computer program collected data about the problems and amount of time you worked; we will use that for our study. Does anyone have any questions? … I'd like to ask you not to share the purpose of this study with others who may be participating in this study in future sessions. Then the last thing we have to do is give you the copy of your informed consent form. Collect Puzzle Packs. Make sure computer number and date/time is written on the top of each pack.

Appendix F

Appendix F: MANOVA of Target Problems Completed and Total Number of Seconds Worked before Quitting

Experiment 2

General Linear Model (Seconds)

Between-Subjects Factors

		N
ProblemType	1	44
	2	44
	3	51

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.743	195.525[a]	2.000	135.000	.000
	Wilks' Lambda	.257	195.525[a]	2.000	135.000	.000
	Hotelling's Trace	2.897	195.525[a]	2.000	135.000	.000
	Roy's Largest Root	2.897	195.525[a]	2.000	135.000	.000
ProblemType	Pillai's Trace	.250	9.697	4.000	272.000	.000
	Wilks' Lambda	.752	10.341[a]	4.000	270.000	.000
	Hotelling's Trace	.328	10.982	4.000	268.000	.000
	Roy's Largest Root	.321	21.856[b]	2.000	136.000	.000

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

c. Design: Intercept + ProblemType

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square
Corrected Model	TotalSeconds	1.565E6	2	782311.208
	TNoProb	8637.372[b]	2	4318.686
Intercept	TotalSeconds	4.660E8	1	4.660E8
	TNoProb	259060.186	1	259060.186
ProblemType	TotalSeconds	1564622.415	2	782311.208
	TNoProb	8637.372	2	4318.686
Error	TotalSeconds	1.621E8	136	1192060.420
	TNoProb	136560.240	136	1004.119
Total	TotalSeconds	6.332E8	139	
	TNoProb	398951.000	139	
Corrected Total	TotalSeconds	1.637E8	138	
	TNoProb	145197.612	138	

a. R Squared = .010 (Adjusted R Squared = -.005)

b. R Squared = .059 (Adjusted R Squared = .046)

Tests of Between-Subjects Effects

Source	Dependent Variable	F	Sig.
Corrected Model	TotalSeconds	.656	.520
	TNoProb	4.301	.015
Intercept	TotalSeconds	390.934	.000
	TNoProb	257.997	.000
ProblemType	TotalSeconds	.656	.520
	TNoProb	4.301	.015

Estimated Marginal Means

ProblemType

Estimates

Dependent Variable	Problem Type	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
TotalSeconds	1	1685.168	164.597	1359.666	2010.669
	2	1936.167	164.597	1610.666	2261.668
	3	1885.043	152.885	1582.704	2187.382
TNoProb	1	48.614	4.777	39.167	58.061
	2	48.841	4.777	39.394	58.288
	3	32.373	4.437	23.598	41.147

Pairwise Comparisons

Dependent Variable	(I) ProblemType	(J) ProblemType	Mean Difference (I-J)	Std. Error	Sig.[a]
TotalSeconds	1	2	-250.999	232.776	.848
		3	-199.875	224.646	1.000
	2	1	250.999	232.776	.848
		3	51.124	224.646	1.000
	3	1	199.875	224.646	1.000
		2	-51.124	224.646	1.000
TNoProb	1	2	-.227	6.756	1.000
		3	16.241*	6.520	.042
	2	1	.227	6.756	1.000
		3	16.468*	6.520	.038
	3	1	-16.241*	6.520	.042
		2	-16.468*	6.520	.038

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

*. The mean difference is significant at the .05 level.

Pairwise Comparisons

Dependent Variable	(I) ProblemType	(J) ProblemType	95% Confidence Interval for Difference[a]	
			Lower Bound	Upper Bound
TotalSeconds	1	2	-815.237	313.238
		3	-744.408	344.657
	2	1	-313.238	815.237
		3	-493.409	595.656
	3	1	-344.657	744.408
		2	-595.656	493.409
TNoProb	1	2	-16.603	16.149
		3	.437	32.045
	2	1	-16.149	16.603
		3	.664	32.272
	3	1	-32.045	-.437
		2	-32.272	-.664

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.250	9.697	4.000	272.000	.000
Wilks' lambda	.752	10.341[a]	4.000	270.000	.000
Hotelling's trace	.328	10.982	4.000	268.000	.000
Roy's largest root	.321	21.856[b]	2.000	136.000	.000

Each F tests the multivariate effect of ProblemType. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

Univariate Tests

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
TotalSeconds	Contrast	1564622.415	2	782311.208	.656	.520
	Error	1.621E8	136	1192060.420		
TNoProb	Contrast	8637.372	2	4318.686	4.301	.015
	Error	136560.240	136	1004.119		

The F tests the effect of ProblemType. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Appendix G

Appendix G: ANOVA

Dependent Variable: Total time working target problems

Independent Variable: Group (Control, Experimental Long, Experimental Brief)

Experiment 2

Univariate Analysis of Variance of Seconds to complete Target Problems (SUM # of seconds per target problem)

Between-Subjects Factors

		N
ProblemType	1	44
	2	44
	3	51

Tests of Between-Subjects Effects

Dependent Variable:TTotalTime

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8.225E6	2	4112713.937	4.794	.010
Intercept	3.209E8	1	3.209E8	374.069	.000
ProblemType	8225427.874	2	4112713.937	4.794	.010
Error	1.167E8	136	857940.163		
Total	4.403E8	139			
Corrected Total	1.249E8	138			

Tests of Between-Subjects Effects

Dependent Variable:TTotalTime

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8.225E6	2	4112713.937	4.794	.010
Intercept	3.209E8	1	3.209E8	374.069	.000
ProblemType	8225427.874	2	4112713.937	4.794	.010
Error	1.167E8	136	857940.163		
Total	4.403E8	139			
Corrected Total	1.249E8	138			

a. R Squared = .066 (Adjusted R Squared = .052)

Estimated Marginal Means

ProblemType

Estimates

Dependent Variable:TTotalTime

ProblemType			95% Confidence Interval	
	Mean	Std. Error	Lower Bound	Upper Bound
1	1684.481	139.638	1408.340	1960.623
2	1698.260	139.638	1422.119	1974.402
3	1186.768	129.701	930.276	1443.259

Pairwise Comparisons

Dependent Variable:TTotalTime

(I) ProblemType	(J) ProblemType	Mean Difference (I-J)	Std. Error	Sig.[a]
1	2	-13.779	197.477	1.000
	3	497.714*	190.581	.030
2	1	13.779	197.477	1.000
	3	511.493*	190.581	.025
3	1	-497.714*	190.581	.030
	2	-511.493*	190.581	.025

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

*. The mean difference is significant at the .05 level.

Pairwise Comparisons

Dependent Variable:TTotalTime

(I) ProblemType	(J) ProblemType	95% Confidence Interval for Difference[a]	
		Lower Bound	Upper Bound
1	2	-492.455	464.897
	3	35.755	959.672
2	1	-464.897	492.455
	3	49.534	973.451
3	1	-959.672	-35.755
	2	-973.451	-49.534

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Pairwise Comparisons

Dependent Variable:TTotalTime

(I) ProblemType	(J) ProblemType	95% Confidence Interval for Difference[a]	
		Lower Bound	Upper Bound
1	2	-492.455	464.897
	3	35.755	959.672
2	1	-464.897	492.455
	3	49.534	973.451
3	1	-959.672	-35.755
	2	-973.451	-49.534

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Univariate Tests

Dependent Variable:TTotalTime

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	8225427.874	2	4112713.937	4.794	.010
Error	1.167E8	136	857940.163		

The F tests the effect of ProblemType. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Appendix H

Appendix H: ANOVA

Dependent Variable: Percent of Target Problem Correct

Independent Variable: Group (Control, Experimental Long, Experimental Brief)

Experiment 2

Univariate Analysis of Variance: TARGET prob % Correct

Between-Subjects Factors

		N
ProblemType	1	44
	2	44
	3	51

Tests of Between-Subjects Effects

Dependent Variable:TPercentC

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1188.467[a]	2	594.233	1.408	.248
Intercept	807743.825	1	807743.825	1913.272	.000
ProblemType	1188.467	2	594.233	1.408	.248
Error	57416.398	136	422.179		
Total	872149.782	139			
Corrected Total	58604.865	138			

a. R Squared = .020 (Adjusted R Squared = .006)

Estimated Marginal Means

ProblemType

Estimates

Dependent Variable:TPercentC

ProblemType	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	72.227	3.098	66.101	78.352
2	78.846	3.098	72.721	84.972
3	78.173	2.877	72.483	83.863

Pairwise Comparisons

Dependent Variable:TPercentC

(I) ProblemType	(J) ProblemType	Mean Difference (I-J)	Std. Error	Sig.[a]
1	2	-6.620	4.381	.399
	3	-5.946	4.228	.486
2	1	6.620	4.381	.399
	3	.673	4.228	1.000
3	1	5.946	4.228	.486
	2	-.673	4.228	1.000

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Pairwise Comparisons

Dependent Variable:TPercentC

(I) ProblemType	(J) ProblemType	95% Confidence Interval for Difference[a]	
		Lower Bound	Upper Bound
1	2	-17.238	3.999
	3	-16.194	4.301
2	1	-3.999	17.238
	3	-9.574	10.921
3	1	-4.301	16.194
	2	-10.921	9.574

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Univariate Tests

Dependent Variable:TPercentC

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	1188.467	2	594.233	1.408	.248
Error	57416.398	136	422.179		

The F tests the effect of ProblemType. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Appendix I

Appendix I: ANOVA

Dependent Variable: Rate (Number of Seconds Worked Per Target Problem)

Independent Variable: Group (Control, Experimental Long, Experimental Brief)

Experiment 2

Univariate Analysis of Variance of Target: Rate (# of seconds/target problem)

Between-Subjects Factors

		N
ProblemType	1	44
	2	44
	3	51

Tests of Between-Subjects Effects

Dependent Variable:TRateSpP

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3212.154[a]	2	1606.077	1.751	.177
Intercept	259219.919	1	259219.919	282.657	.000
ProblemType	3212.154	2	1606.077	1.751	.177
Error	124723.198	136	917.082		
Total	392442.748	139			
Corrected Total	127935.351	138			

a. R Squared = .025 (Adjusted R Squared = .011)

Estimated Marginal Means

ProblemType

Estimates

Dependent Variable:TRateSpP

ProblemType	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	40.511	4.565	31.482	49.539
2	39.444	4.565	30.416	48.472
3	49.913	4.241	41.527	58.298

Pairwise Comparisons

Dependent Variable:TRateSpP

(I) ProblemType	(J) ProblemType	Mean Difference (I-J)	Std. Error	Sig.[a]
1	2	1.067	6.456	1.000
	3	-9.402	6.231	.401
2	1	-1.067	6.456	1.000
	3	-10.469	6.231	.286
3	1	9.402	6.231	.401
	2	10.469	6.231	.286

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Pairwise Comparisons

Dependent Variable:TRateSpP

(I) ProblemType	(J) ProblemType	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-14.583	16.717
	3	-24.505	5.702
2	1	-16.717	14.583
	3	-25.572	4.635
3	1	-5.702	24.505
	2	-4.635	25.572

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Univariate Tests

Dependent Variable:TRateSpP

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	3212.154	2	1606.077	1.751	.177
Error	124723.198	136	917.082		

The F tests the effect of ProblemType. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Appendix J

Appendix J: Summary Table of Results from Experiment 2

Table 7

Summary of Results for Experiment 2.

		Control Group			Experimental Groups					
					Brief			Long		
		N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*
Total	Total Number of Problems Completed	44	48.61	39.54	44	64.80	41.00	51	44.29	31.46
	Total Seconds (s) Worked before Quitting	44	1685.17	1153.27	44	1936.17	1022.48	51	1885.04	1095.19
	Number of s to Complete each Problem (Rate: s/problem)	44	40.52	16.70	44	33.83	11.09	51	54.97	40.30
Target	Number of Target Problems Completed	44	48.61	39.54	44	48.84	30.76	51	32.37	23.95
	Time (seconds) to complete all Target Problems (Sum of time working on Target)	44	1684.48	1152.77	44	1698.26	892.88	51	1186.77	710.74
	Number of s to Complete each Target Problem (Rate: s/problem)	44	40.51	16.70	44	39.44	13.42	51	49.91	45.83
	% Correct on Completed Target Problems	44	38.45	35.55	44	39.64	27.18	51	27.08	21.38
Brief	Number of Brief Problems Completed	44	0	0	44	15.95	10.25	51	0	0
	Time (seconds) to complete all Brief Problems (Sum of time working on Brief)	44	0	0	44	237.00	135.55	51	0	0
	Number of s to Complete each Brief Problem (Rate: s/problem)	44	0	0	44	16.44	5.12	51	0	0
Long	Number of Long Problems Completed	44	0	0	44	0	0	51	10.59	7.89
	Time (seconds) to complete all Long Problems (Sum of time working on Long)	44	0	0	44	0	0	51	697.49	408.52
	Number of s to Complete each Long Problem (Rate: s/problem)	44	0	0	44	0	0	51	71.64	29.96

Vita

Emily Richardson Kirk was raised in Franklin, Tennessee. She graduated from Battle Ground Academy in Franklin, Tennessee in 2000. She then continued her education at Samford University in Birmingham, Alabama, where, in May 2004, she received a Bachelor of Arts in Family Studies. After college, she taught English at a high school and a middle school in Sokolov, Czech Republic for one year before pursuing her Doctor of Philosophy in School Psychology at the University of Tennessee. While at the University of Tennessee, she received a Master of Science degree in Applied Educational Psychology in December 2008. In August 2010, she will finish her doctoral studies after a year-long internship with Sweetwater City Schools in East Tennessee.