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Evaluating Computerized Math Performance Using Progressive Ratio Schedules in Children With Attention Deficit Hyperactivity Disorder

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Evaluating Computerized Math Performance Using Progressive

Ratio Schedules in Children With Attention Deficit Hyperactivity Disorder

by

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Evaluating Computerized Math Performance Using Progressive
Ratio Schedules in Children With Attention Deficit Hyperactivity Disorder
a thesis by Lauren Stroker

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Abstract

Title: Evaluating Computerized Math Performance Using Progressive Ratio Schedules in Children With Attention Deficit Hyperactivity Disorder

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One method of assessing reinforcer strength is to use a progressive ratio (PR) schedule of reinforcement, whereby response requirements to access reinforcers gradually increase. PR schedules have been used to assess reinforcer potency in numerous applications with nonhumans in basic research, children and adults with disabilities, and individuals with histories of substance abuse problems. However, the utility of PR schedules to determine robust reinforcers has not been assessed with children with attention deficit – hyperactivity disorder (ADHD) regarding academic tasks, such as mathematics. The inability to remain on task presents a challenge for teachers in schools, and poses detrimental effects on children who may fail to achieve academic success. In the present study, we evaluated the effectiveness of PR schedules for increasing mathematics compliance in two children with ADHD and one child who was identified as highly distractible and frequently off-task by teachers and parents.

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Dedication

I dedicate this thesis to my family, my friends and my boyfriend who offered unconditional love and support throughout this journey.

Chapter I:

Introduction

Difficulty sustaining attention creates problems for many children in school settings. Elementary school teachers expect students to sit in their chairs for increasingly long periods of time, quietly, attending to multiple stimuli (e.g., teacher instructions, writing on the board, taking notes, or independent seatwork). For a typical child without disabilities, attending to multiple stimuli in school can sometimes be difficult, but for a child with ADHD, such tasks present daunting challenges (LD Online, 1998). Recent data indicate that children as young as four years old are increasingly receiving a diagnosis of ADHD, with symptoms ranging from mild to severe, including characteristics of inattention, hyperactivity and impulsivity, or a combination of symptoms that interfere with social and academic behavior development (DSM-V, 2013).

A primary emphasis in behavior analysis research includes improving socially significant behavior, including academic skills, while decreasing inappropriate behavior. For many children with ADHD, off-task behavior, including inattention or hyperactivity occurs at higher rates than on-task behavior, and results in impaired academic performance (DSM-V, 2013). Applied behavior analysis approaches to treatment involve addressing specific, operational definitions of behaviors that indicate skill deficits or behavioral problems, and steps to improve academic performance via modification of environmental variables (i.e., antecedents and consequences) to achieve desired results.

To improve desired performance, teachers use antecedent prompting procedures, such as verbally directing a child (e.g., "open your book to page 235") or prompting a student to copy spelling words written on the board. Consequence-based procedures may be used to reinforce compliance with instructions, such as praise responses, e.g., "good job, class!" or behavior-specific praise, "nice work writing your spelling words, Charles!" Other desired items may be offered, such as edibles or preferred tangible items to reinforce desired behavior. Teachers conduct preference assessments to determine items that function as putative reinforcers for desired performance (Pence, Peter, & Tetreault, 2012),

Preference Assessments and Reinforcement

One of the most common empirically-based, recommended methods of preference assessment is the Paired Stimulus (PS) preference assessment (Fisher et al., 1992). In the PS arrangement, the experimenter selects multiple items and presents them in pairs. The experimenter prompts a child to select one item from each pairing, records the child's selection, and allows him or her to consume or manipulate the item. Each item is presented in random order with rotation of side placement to ensure all potential pairings. Preference is calculated by dividing the number of selections by the number of presentations. Using a preference assessment such as the PS arrangement, investigators obtain data about a hierarchy of stimulus preference, whether an item was ranked as highly preferred (i.e., selected on 80% or more of presentations), moderately preferred (i.e., selected between 40 to 79% of presentations), or low preferred (i.e., selected on 39% or less presentations). The logic applies that highly ranked items or edibles are more likely to function as reinforcers, thus increasing the likelihood of occurrence of a target behavior they systematically follow. Initially, each selection results in immediate access to the item. Due to fatigue, satiation, and potential interruption of on-going academic time, it is neither desirable nor feasible to provide access to preferences following every desired instance of behavior. Over time, other methods of reinforcer assessment involve multiple responses to access preferences, and the schedule of reinforcement becomes "leaner," meaning that potential reinforcers are accessible after a designated period of time (interval-based) or a designated number of responses (ratio-based) schedules (Catania, 1970). Two of the most important questions to answer when evaluating potential preferences relate to whether stimuli function as reinforcers for designated responses, and the relative potency of those reinforcers. These two questions hold special relevance for applied questions in areas such as improving academic performance for children who possess academic skills, but who lack the focus or ability to remain on tasks at levels comparable to same-aged peers.

Identification of effective, robust reinforcers comprises an essential component of effective programming (Hagopian, Long & Rush, 2004). Following preference assessment, items may be deemed reinforcing if a student engages in a target response to access them at rates higher than before the items were provided contingent upon a designated behavior (or set of behaviors). Experimenters conduct further testing of the effectiveness of items as reinforcers by systematically arranging delivery via concurrent-operants arrangements to determine which items are chosen when two or more items are simultaneously available contingent upon a simple response, or by applying progressive ratio schedules of reinforcement, whereby the response requirements to access a preferred item systematically, and gradually increase. The latter of these, progressive ratio (PR) schedules, stems from an extensive history of application in both the basic and applied literature to determine reinforcer "strength"—which may prove beneficial for research questions in areas such as academics, whereby students are expected to sustain attention on tasks to meet criterion levels that approximate those of same-aged peers (See Poling, 2010).

Progressive Ratio Schedules

Hodos first described the application of PR schedules of reinforcement (1961) in basic research. PR schedules involve systematic increases in fixed-ratio (FR) response requirements to access reinforcement, (e.g., 3 consecutive completions of a FR 1 schedule, or 1 response to access reinforcement), followed by a FR 3 schedule, (i.e., 3 responses required to access reinforcement), followed by a FR 5 schedule (i.e., 5 responses required to access reinforcement), and so on. Hodos discovered that four food-deprived, experimentally naïve rats engaged in higher numbers of responses to access food at gradually increasing schedule requirements, and proposed that PR schedules functioned as indices of reinforcer "strength."

Tustin (1994) addressed the question of efficacy of commonly used preference assessments, under reinforcement on a fixed-ratio 1 (FR1) schedule. To assess the efficacy of a reinforcer chosen using a preference assessment, Tustin used progressive concurrent schedules with gradually increasing response requirements to identify a proposed reinforcer. His study revealed that responding to access reinforcers under an FR1 schedule, failed to maintain when response requirements increased to FR10, indicating probable effects of ratio strain—a common observation when an organism ceases responding with abrupt increases in response requirements. Tustin's research (1994) focused on procedures for researchers and practitioners to choose effective reinforcers under low schedule requirements (i.e., less responses to access a reinforcer), and promote maintenance by gradually increasing schedule requirements to match naturalistic schedule values.

Direct and systematic replications of PR schedules extend from basic to applied human research, showing the potential utility of this approach for gradually increasing response requirements that mitigate against ratio strain. DeLeon, et al. (1997) tested results observed by Tustin (1994), assessing whether similar results could be obtained with more than one participant. DeLeon and colleagues implemented a FR1 schedule of reinforcement, and found that participants chose two edibles at "roughly equal" levels. However, as schedule requirements increased for one food item, responding decreased for the item with the higher schedule value, and increased for the item with the lower schedule value. This distinction emerged during a FR 5 schedule and further differentiation occurred when the schedule value increased to FR 10. DeLeon et al. and Tustin (1994 and 1997, respectively) underscored the importance of evaluating the efficacy of potential reinforcers under different schedules of reinforcement. Results of the studies by DeLeon and Tustin hold interesting implications for future applications to academic performance.

Roscoe, et al. (1999) further elucidated the distinction between reinforcer *preference* and reinforcer *potency*. When conducting a preference assessment, the choice of one stimulus over another indicates preference, and preference for a stimulus implies that the chosen item is something the individual "wants" or is "motivated" to access. *Potency* refers to the capacity of a stimulus to maintain or increase performance when delivered contingently under leaner schedules of reinforcement. Therefore, even though preference assessments produce a discrete hierarchy of preferred stimuli, assessment of relative potency remains important for investigators to evaluate to promote responding that approximates schedules of reinforcement under naturalistic contingencies (Roscoe et al., 1999). Questions of reinforcer potency add value to practitioners and researchers in educational settings to promote generalization and maintenance of academic responding when immediate reinforcement is neither feasible nor desirable.

Under PR schedules, the number of responses required to receive reinforcement systematically increase by a predetermined value from one reinforcer delivery to the next. Response requirements increase incrementally, and refer to the "step" size (Stafford & Branch, 1998). For example, a PR 2 or step size of two means delivery of the first reinforcer occurs after two responses. After reinforcement, successive requirements to access reinforcers increase by addends of two. The defining characteristics of the PR schedule, therefore, are: (a) the number of responses required for reinforcement, and (b) a systematic increase following delivery of every reinforcement (Stafford & Branch, 1998).

In PR schedules of reinforcement, response requirements and schedule values increase systematically as individuals meet designated schedule values. Increases continue according to step sizes until the individual reaches a "breaking point"–or the point at which responding ceases in the presence of a reinforcer (Roane, Lerman, & Vorndran, 2001). Higher breaking points indicate more powerful or potent reinforcer effects, as evidenced when an organism's responding persists at higher schedule values. Researchers associate reinforcer potency with an individual's motivation for the particular reinforcer under relative conditions of deprivation or satiation (Roane, 2008).

Poling (2010) notably questioned the utility and ethics of PR schedules for persons with intellectual and developmental disabilities. Poling asserted that the benefit of PR assessment of reinforcers potentially lies only in its application to maintain socially significant responding, rather than merely verifying conceptual questions regarding reinforcer strength. That is, an assessment of how much responding a person emits to access a reinforcer for an arbitrary response (e.g., lever pressing, or key pressing) offers less clinical relevance than how long a person engages in functional tasks that directly improve their lives. For children who experience academic problems due to inattention and distractibility, PR schedules offer promise for promoting compliance at increasing response requirements (Sinn et al., 2011). Academic performance under PR schedules has been understudied. A few preliminary investigations suggest that programs that include computer assisted instruction may benefit children with ADHD by improving academic engagement, and increasing tolerance to delays to access reinforcers (Neef, et al., 2005; Neef, Bicard, & Endo, 2001).

Computer Assisted Instruction in ADHD

Research shows that computer assisted instruction (CAI) benefits some learners with ADHD who struggle in mathematics, resulting in improved test scores pre-and post-implementation (DuPaul, Weyandt, & Janusis, 2011; Mautone, DuPaul, & Jitendra, 2005; Ota & DuPaul, 2002). Loe and Feldman (2009) posit that recent advancements in technology potentially bolster the efficacy of CAI for children with ADHD, allowing teachers to individualize academic goals, arrange educational materials in an interactive format, and provide immediate feedback on performance. Computer-assisted instruction (CAI) may be particularly amenable for further study using PR schedules of reinforcement.

The questions garnered during prior educational research on CAI perhaps relate more to the effects of reinforcer potency and increasing tolerance for delays to reinforcement. Neef, Bicard, and Endo (2001) found that the use of a fixed-duration/progressive duration delay procedure resulted in increased self-control in children with ADHD using a computerized math application. The authors systematically manipulated aspects of the reinforcer effort, quality, and immediacy. Their findings indicated that three students with diagnoses of ADHD successfully shifted allocation from immediate low-effort responses to delayed, more effortful responses to access reinforcers. The students tolerated delays as long as 24 hr. In a second study of 58 children with ADHD, Neef and colleagues (2005) found that children with ADHD who completed a computer-based arithmetic assessment responded differentially to reinforcer immediacy followed by reinforcer quality. The authors noted the potential for students with ADHD to demonstrate longer delays to access to high quality reinforcers (Neef et al., 2005). Similar to research on fixed duration/progressive duration research, the implementation of CAI instruction using PR schedules may yield beneficial results for children with ADHD, by teaching tolerance to delayed reinforcement.

In the present investigation, a co-investigator developed a computerized application to tailor equations to individual learners' needs. The application included the following parameters for the independent variable, allowing for systematic arrangement by the experimenter: (a) the operation to be performed, i.e., addition, subtraction, multiplication, or division, (b) the numbers of digits computed per equation, and (c) special operations, such as carrying, borrowing, or remainders, etc. Furthermore, the application collected data *in vivo* on dimensional quantities of dependent variable: (a) latency to beginning work, (b) inter-response times, (c) total duration of work, and (d) correct versus incorrect responses.

The present investigation included three phases for all participants, and an additional tutoring phase for participants who needed further math instruction. During the first phase, the experimenter conducted systematic preference assessment using the PS method, followed by a concurrent-operants arrangement to determine highly preferred reinforcers as defined by Fisher and colleagues (1992). In the second phase of the experiment, the investigator implemented a PR procedure, including baseline and PR/ breaking point assessment. In phase three, investigators evaluated maintenance of performance using a yoked FR based on the mean breaking point. In phase four, the investigator provided supplemental tutoring as needed. The purpose of the present investigation was to evaluate the effect of a CAI application on correct versus incorrect equation completion and on-task behavior under PR schedules of reinforcement.

Chapter 2:

General Method

Participants and Setting

The inclusion criteria to participate in this study included: (a) a diagnosis of ADHD and/or symptoms of inattention, and (b) reported difficulty in mathematics for children in elementary and middle school. Observations took place in either quiet areas of the school or in the childrens' homes based on convenience to participants. Room sizes varied widely across participants and during the course of the study. James was a 14-year-old boy with a diagnosis of ADHD. He attended a public middle school. Eddy was a 6-year-old boy with a diagnosis of ADHD and Autism Spectrum Disorder (ASD). He attended Kindergarten in a private school. Vicky was an 11-year-old girl who was referred to the study due to highly distractible, off-task behavior that potentially impaired her math performance. Participants were referred to the study by teachers due to inattention or off-task behavior, and problems with mathematics, warranting referrals for additional tutoring.

Materials

Research materials included a table, two chairs, and a Windows operating system based laptop. In phase three, the tutoring component, the investigator used a handheld video camera mounted on a tripod to capture the participant, researcher, and computer screen for later scoring of sessions. A custom computer-based mathematics program was used to assess performance on solving addition and multiplication equations, which were individualized based on each student's skill level. Students viewed math problems individually on a computer screen in a vertical orientation, including a box underneath to enter the correct answer.

Procedure

Prior to each session, the experimenter launched the program, and directed the participant to come to the table. Students received instruction on how to enter their answers using the keyboard, and the investigator modeled the correct responses on the keyboard, i.e., pressing numbers, enter, and delete buttons, until he or she independently demonstrated appropriate responding. The application locked irrelevant keys on the keyboard to discourage random presses. Sessions took place two to three times per week, including no more than four per day. The duration of each session lasted between 15 to 30 min.

Phase 1

Stimulus Preference Assessment

Researchers implemented a PS preference assessment (Fisher et al., 1992). The experimenter presented six to 10 edible items, each paired in a counterbalanced order regarding the item and side orientation. Stimuli were ranked by the number of selections, divided by the number of presentations. Consistent with the PS preference assessment literature, a stimulus selected between 80% and 100% of presentations is deemed a HP item, or a "putative" reinforcer. The highest preferred

(HP) items obtained were used during the PR assessment as an index of reinforcer potency.

Inter-Observer Agreement

The investigator scored interobserver agreement (IOA) for 100% of PS preference assessment trials regarding stimuli selected by participants. A selection was defined as the participant moving toward, touching, or consuming the stimulus within 10 s of the presentation. IOA was calculated using the interval-by-interval method by dividing intervals with agreements by intervals with agreements plus disagreements, multiplied by 100. IOA for the PS preference assessment equaled 100% for all three participants.

Accuracy Measures

The computer program collected data on the frequency of *correct and incorrect responses*, including the parameters of latency to beginning the task, inter-response times, and total duration of work. The application terminated if a participant ceased responding for a designated time period, or breaking point. The experimenter checked calibration of the application following each session by reviewing the data logs in the spreadsheet to ensure accuracy of scoring.

Treatment Integrity

The experimenter collected data using a treatment integrity checklist including four items: (a) the therapist prepared materials in advance (e.g., executing the program on the laptop and making reinforcers available), (b) the therapist stated the correct phrase depending on the phase of the experiment, (i.e., in baseline, "Do as many as you want," or in the PR phase, "Complete *X* (number of problems) to get *Y* (reinforcer)," (c) the therapist placed the laptop and scratch paper in front of the participant with a pencil, and (d) the experimenter delivered the correct consequence (i.e., the reinforcer if criteria was met, or removal of the laptop for 30 s if not met). Treatment integrity was calculated by dividing the number of trials the protocol was correctly implemented by the total number of possible trials and multiplying by 100. Treatment integrity data were collected for James during 34 % of sessions, and averaged 94% (range: 85 to 100%) . For Vicki treatment integrity data were collected for 35% of sessions and averaged 97% (range: 85 to 100%). Treatment integrity data were collected during 54% of Eddy's sessions, with 100% accuracy.

Social Validity

At the conclusion of the study, the principal investigator issued a brief questionnaire to each participant and one family member regarding the efficacy, feasibility, and satisfaction with the intervention. Parent and participant questionnaires contained five questions, each of which was tailored to their roles in the study. The participant and family member rated each question on a 7-point Likert-type scale, ranging from (1: strongly disagree to 7: strongly agree). Social validity ratings, returned by two parents, included high ratings for all questions. Results are summarized in Appendix A.

Results

Results of the PS preference assessment are depicted in Figure 1 across all participants. For James, the HP item selected was Juicy Drop Gummies, selected on 90% of presentations. For Vicky, two HP items tied at 88% of selections, dark chocolate and potato chips. Eddy selected pizza during 100% of presentations. All participants progressed to phase two of the experiment, the PR phase, to assess reinforcer potency during the computerized math program.

Phase 2

Participants

The investigator evaluated the mean breaking points using a PR assessment for three participants. Experimental conditions included: (a) a baseline phase, with no programmed consequences and (b) the PR assessment utilizing a fixed-ratio/progressive ratio schedule to determine mean breaking points. Computerized math performance was calculated across all components of phase two.

Dependent Variables and Data Collection

The second phase of the study included two dependent variables regarding math performance. The computer scored the first dependent variable, *correct versus incorrect computation*, by calculating student answers to equations, and converting them to an Excel file. The second dependent variable, the *breaking point*, referred to the last completed step before the participant ceased responding. Experimenters determined breaking point criteria individually for participants, including either cessation of responding or stating that he or she did not wish to continue. The experimenter set the breaking points 30 s for James and Vicky, and 1 min, for Eddy. The longer breaking point for Eddy accounted for direct observations that he was on-task, but counted on his fingers to solve equations. For all participants, if more than the designated number of seconds elapsed between keystrokes, specified for each participant, the application "timed out," and the screen turned to black.

Baseline

At the beginning of each session, the experimenter placed the laptop in front of the participant and asked him or her to complete as many problems as he or she could. During baseline there were no programmed consequences for problems completed (e.g., no subsequent delivery of items or verbal praise). The trial ended when the participant ceased responding for 30 s (James and Vicki), or 1 min (Eddy). Baseline sessions continued until low, stable rates of responding were observed across at least three consecutive sessions.

Progressive Ratio Schedule

The experimenter placed the laptop in front of the participant and issued the verbal prompt, (e.g., "Complete *X* (number of problems) and you will get *Y* (putative reinforcer.") When completed, the experimenter gave the child a predetermined HP stimulus from the first phase of the experiment. Completion of 2 consecutive PR schedule values resulted in a subsequent increase in the trial requirements by a step size of 2 in an arithmetic progression. After completion of the designated requirement, the experimenter delivered a preferred item, and removed the laptop for 30 s. Trials continued until the termination criterion was reached, responding no longer occurred at the set value, or if the participant indicated he or she wanted to stop.

Results

Results of phase two are depicted in Figure 2. Baseline data for James show responding at or near zero levels. During sessions 4 and 5 another therapist entered the room to observe, and his responding dramatically increased. Following this observation, the therapist agreed to leave the room to prevent potential reactivity. In the PR assessment, James, showed a steady increasing trend for problems completed correctly except at PR schedule values of 26 and 30. The study criteria involved a minimum of two consecutive sessions with cessation of responding, and he resumed responding on the second attempt for each of the unmet schedule values. He reached the breaking point at the PR 36 schedule, when he stopped responding or failed to meet schedule criteria across two consecutive sessions.

During baseline, Vicky showed low, stable responding on the computerized math application. During the PR assessment, she failed to meet PR schedule values of 4, 10, and 30. She resumed responding on the second attempt at each schedule value, and reached a breaking point at a PR 32 schedule value.

Eddy exhibited low responding during the baseline phase. During the PR schedule assessment, he failed to meet criteria at schedule values of 10, 12, and 14, but resumed responding to meet criteria during a second attempt. He reached a breaking point at the PR 16 schedule value, failing to respond to criterion across two consecutive sessions.

Phase 3

Participants

All participants continued to phase three of the experiment, the yoked-FR schedule assessment. The purpose of the phase was to evaluate whether participants would maintain responding under the mean breaking point values established during the PR assessment. All materials remained consistent in this phase of the investigation.

Fixed-Ratio

Following phase two, breaking point data for each participant were analyzed, by computing the mean PR schedule value based on the mean of all break point values observed in the prior phase, including each schedule value a participant failed at least once, during the PR assessment. The mean breaking point value was used to develop a yoked-FR schedule value. For James, the FR value was yoked to 30, for Vicky it was set to 19 and for Eddy, the FR value was yoked to 12.

Procedure

The procedure for phase three looked similar to prior research phases with one exception. Following a return to baseline, the experimenter told participants to complete the equivalent number of equations under the yoked-FR value to access a reinforcer. Once responding maintained across five consecutive sessions, phase three concluded.

Results

Results of phase three are depicted in Figure 3. Initial baseline data for James showed moderate responding. Following the first session responding decreased to zero levels. In the yoked FR schedule James maintained responding at the yoked- FR value of 30, for five consecutive sessions.

Vicki initially showed zero level responding. During the third baseline session, responding increased; however, the following sessions returned to zero levels. In the yoked-FR schedule Vicky's responding maintained for five consecutive sessions at the predetermined criteria of 19.

Eddy showed zero responding across three consecutive sessions in baseline. During the yoked-FR schedule, Eddy's responding initially showed moderate variability. He met criterion during the first two sessions; however, during the following three sessions he only met criterion once. During the last five sessions he maintained responding at required levels.

Following phase three, researchers analyzed each participant's performance regarding correct and incorrect equation completion. All participants increased their attempts to complete equations to access reinforcers; however two of three participants also showed high rates of incorrect responding. Participants who did not show a mastery of the math skill continued to a tutoring phase, for additional tutoring.

Phase 4

Math to Mastery

The Math to Mastery (MTM) program includes previewing, repeated practice in the form of probes, immediate corrective feedback, summative feedback and self-monitoring (Mong & Mong, 2010). Investigations of MTM showed beneficial results for improving fluency and performance in targeted math skills. The MTM procedure includes clear operational definitions of the procedures and aligns well with applied behavior analytic principles, making it a good choice for replication in the present math tutoring phase. Mong and Mong (2010) reported that the MTM procedure resulted in improved computation skills, and increased math fluency in three 3rd-grade children who performed below grade level. In another study in 2010, Mong and Mong compared two math interventions; Cover, Copy, and Compare (CCC) and MTM using an alternating treatment design. Results showed that although both CCC and MTM resulted in increases in fluency and corresponding decreases in errors, MTM yielded more effective results than CCC for two of three participants (Mong & Mong, 2010).

In a systematic replication of Mong and Mong (2010), Everett and Swift (2014) evaluated the most effective components of the MTM sequence using a component analysis. This study emphasized the most effective components for improving academic performance included previewing, repeated practice and immediate feedback (Mong, 2008). As a result of the overall findings regarding MTM effects on math acquisition, the investigator chose this strategy to provide additional tutoring to children who showed possible skill deficits during the course of the investigation.

Participants

Two participants (James and Eddy) progressed to the MTM phase due to observed increases in incorrect responding to mathematics equations, with higher than 20% of equations missed. Phase four continued for a minimum of three tutoring sessions, with a goal of mastery of the math skill consisting of three consecutive trials at 80% or higher digits correct per min (DCPM). A secondary criterion level included stability in DCPM data for at least three consecutive points, based on visual inspection of the data.

Materials

The experimenter developed paper-and-pencil worksheets with problems the children commonly answered incorrectly during the computerized math application. The same worksheet used in the preview portion was also used in 1-min probes. The investigator used a hand-held timer to time participants' responding during 1-min probes and recorded sessions using a video camera for later scoring of agreement.

Math to Mastery

A modified MTM tutoring phase consisted of four components: (a) preview, (b) repeated practice, (c) corrective feedback, and (d) performance feedback. The investigator streamlined the steps based on findings by Everett and Swift that indicated the necessary and sufficient components to improve math performance (2014). During *preview*, the therapist verbally and manually completed the worksheet while the student completed a copy of the same worksheet on his own. During *repeated practice,* the participant completed the worksheet three times, in a series of timed 1-min trials. While the student completed the worksheets, the therapist provided immediate, *corrective feedback* on errors made by the student. No consequences were given for correct responses. Following each trial the experimenter calculated the DCPM.

Dependent Variables

Following each 1-min trial, the experimenter computed DCPM for each participant. The primary dependent variable included the *DCPM*. A secondary measure included the *percentage of digits completed correctly* in the 1-min time limit. The experimenter calculated performance based on the number of digits completed correctly, divided by the total number of digits computed, multiplied by 100.

Treatment Integrity

To assess treatment integrity, a second experimenter collected data on whether the therapist correctly implemented the protocol across the following dimensions: (a) presented the participant with a worksheet, (b) verbally and manually completed the worksheet while the child followed along on their worksheet, (c) the therapist corrected incorrect responses, and (d) reinforced on-task performance. Treatment integrity calculations involved dividing the number of trials the protocol was correctly implemented by the total number of possible trials and multiplying by 100. Treatment integrity data were collected for James during 90% of sessions, and averaged 96% (range: 80 to 100%). Treatment integrity data were collected during 100% of Eddy's sessions, with 100% accuracy.

Results

Figure 4 shows the DCPM and percent of digits correct for James. James showed high variability with an increasing trend for correct math performance. He reached stability criterion for three consecutive data points in session 11. The average percent correct for James across all probes equaled 98% (range: 96-100%).

Figure 5 depicts Eddy's scores during MTM tutoring sessions. Eddy showed an increasing trend in correct math equation completion, and achieved mastery by session 6. Eddy's average responding maintained at 95%, with only one session below criterion level at 75% (range: 75 to 100%).

Chapter 3:

Discussion

In phase one, the investigator evaluated participants' choices between edible stimuli as putative reinforcers. The PS preference assessment revealed HP items for all three participants. The items selected on more than 80% of presentations progressed to the PR assessment phase.

The purpose of phase two was to evaluate the effects of PR schedules on attention and compliance with equation completion for two children with ADHD and one child who was highly distractible, based on teacher reports. Preliminary results suggest the implementation of PR schedules resulted in increases in independent equation completion on a computerized app; however, error rates also increased for two participants. All participants showed low levels of equation completion in baseline. Equation attempts increased relative to advancing PR requirements to access HP reinforcers, until all participants reached breaking points.

In phase 3, a return to baseline showed low or zero levels of responding for all participants. Following the implementation of an FR schedule phase yoked to the mean break point, all three participants maintained responding across five consecutive sessions. A computer algorithm tracked key presses as a measure of task engagement. Continued key pressing on specified keys (e.g., numeric, enter, and delete keys) resulted in reinforcement based on PR schedule requirements, whereas cessation of responding resulted in the program "timing out," darkening of the screen, and no reinforcement. Overall results showed the use of a PR schedule resulted in increasing key presses as students responded to math equations on the screen as a measure of continued attention to the task.

The findings of this study underscore the potential importance of measures of performance under PR schedules related to math equation completion for children with ADHD or highly distractible behavior. Based on prior research by Mautone, DuPaul and Jitendra (2005), Loe and Feldman (2009), and Ota and DuPaul (2002), computerized applications resulted in improvements in math performance for children with ADHD. Other investigations by Neef and colleagues (2005) also found improved math performance in children with ADHD, using a variation of the PR schedule, a fixed-duration/progressive duration schedule as a measure of self-control.

CAI procedures, such as the computerized math application used in the present investigation offer a unique format for tailoring educational material to students' needs, as well as immediate monitoring and feedback on performance. CAI programs such as the one evaluated in this study potentially allow students to experience gradual exposure to leaner schedules of reinforcement, mimicking naturalistic schedule values while maintaining on-task behavior. Teachers and families may be able to extend time between deliveries of extrinsic items (e.g., edibles or other items) to motivate children to work continuously, for longer time periods, without the distractions caused by giving them items. Furthermore, students who improve time on task better match levels to their peers, making them less likely to be identified as needing additional services. As stated previously, a primary emphasis in behavior analysis research involves the improvement of socially significant behavior, including academic responding, and concomitant reductions of inappropriate behavior, such as distractible or off-task responses. For children with ADHD, the improvement of on-task behavior and reduction of distractibility reflects both social and academic significance warranting continued research and evaluation.

Future Research

The current investigation included increasing schedule requirements by a step size of 2 following two consecutive sessions. Data show that on a few occasions, each one of the participants ceased responding at least once, i.e., failed to meet criteria, for the predetermined level; however each participant recovered to meet criteria in the following two sessions. This occurred three times for James and Vicky and twice for Eddy. These findings potentially indicate interference in naturalistic environments, as the study was conducted in schools, homes, or aftercare settings. For instance, when Vicky failed to meet the schedule requirements at the PR schedule value, her younger sister screamed from another room, resulting in a temporary distraction. James showed improved performance during two baseline sessions when a therapist entered the room. Every attempt was made by the interventionist to control for disruptions during the study; however, conducting research in community settings sometimes results in variability. Other outliers in the data may relate to covert events related to the diagnosis of ADHD or other undefined factors.

The investigator calculated a "mean breaking point" following phase two to test the hypothesis that the items selected as highly preferred functioned as reinforcers for math equation completion, and to mitigate against potential stress associated with ratio strain. As noted by Poling (2010) and Tustin (1994), obtaining a final breaking point typically involves the highest response effort for participants; therefore, PR schedules possibly represent aversive conditions as participants work for longer periods of time to access reinforcers. Therefore, the researcher calculated mean "breaking points" to develop the yoked-FR schedule. Notably, recent research involved a "best response point" as opposed to the mean break point (Sinn et al., 2011). In this study, the author sought to prevent cessation of responding due to ratio strain by evaluating the last few data points before responding stopped. Future investigations may include the use of a best response point rather than a breaking point for academic behavior.

Further analysis following phase two revealed that participants attempted increasing numbers of equations; however, error rates also increased for two participants. Reasons for this finding indicate the potential need for future research on the interaction of PR responding and response effort. For instance, during an equation analysis, the investigator observed that James completed only easy problems correctly, i.e., equations with fewer addends, or requiring no carrying, and he entered clearly wrong answers or bypassed hard problems. Future research should evaluate the effects of embedded differential reinforcement schedules or rule-setting for correct responding within PR schedules. For instance, at the beginning of a session, a teacher may inform the participant he or she must *correctly* complete a specified number of consecutive problems or percentage of problems to earn reinforcers. In the present study, since equations were generated from mastered math problem set for the children, researchers designed the PR schedules to focus on task completion and sustained attention, since these were the primary reasons for the participants' referrals.

Limitations

One interesting aspect of this study involved consideration of whether participants possessed the requisite skills to complete math equations, or if distractibility precluded performance on equations presented in the math application. The investigator treated incorrect responses as possible skill deficits, and addressed them via implementation of the MTM intervention. For Eddy, MTM resulted in effective results in completing equations at or above 80% correct criterion level within a few sessions. Although James initially appeared to demonstrate a potential skill deficit based on his high rate of errors on the computer, he quickly answered all problems on a paper worksheet during MTM, indicating a different potential issue regarding his math performance. Anecdotally, he said it was harder to "see" the steps on the computer as clearly as on the worksheet. Future research might involve modification of the application to signal each step of solving an equation correctly with salient discriminative stimuli, such as arrows, or circling digits in each equation as the child progresses through the problems. Further development of the application might provide valuable information on the precise location of the errors, and guide students to complete equations in an orderly manner.

Potential history and maturation effects may have been observed during the course of the investigation. All three participants began a new school year in the second month of this investigation, and therefore encountered mathematics instruction during this study. The study lasted approximately three months. On-going math instruction in schools potentially accounted for some improvements in math computation scores. It would neither be feasible nor ethically responsible to discontinue mathematics education in schools; however, future research during summer months might prevent possible threats to internal validity.

Contributions

This study presents a few interesting contributions to the existing literature on the applied uses of PR schedules in academic tasks. Common applications of PR schedules in human and nonhuman participants primarily involve measures of reinforcer potency for arbitrary, simple responses. In the current investigation, we applied PR schedules to evaluate math equation completion, a functional, relevant skill for the participants. Preliminary data suggest the math application created for this investigation provided an effective method for increasing time on task for three participants with highly distractible behavior. Future research may address some limitations observed in this study by adapting the procedure to incorporate embedded rules and differential reinforcement to improve correct performance under PR schedules. Other modifications to the application may include salient discriminative stimuli to prompt participants on the correct order of operations.

The computerized application used in this investigation offers versatility, including programming of multiple dependent and independent variables. The application allows teachers, parents, and tutors to customize equation types and difficulty, and calculate multiple measures of performance including latency to respond, total time on task, inter-response times, and correct versus incorrect performance. Features of the program offer adaptability for teachers and families to use it in naturalistic settings with children, including schools or homes as a supplemental aid. It is also noteworthy that all participants and families indicated they found the application to be feasible, effective, and sustainable. Furthermore, both participants who responded to the social validity questionnaire indicated they preferred the computerized application to completing pencil-and-paper worksheets. The application program was developed specifically for the present study, and offered at no cost to families in the study. The investigator intends to offer the application to other schools and families at no cost.

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Appendix

Table 1

Social Validity Questionnaire: Participant Intervention Ratings on a 7 Point Likert Rating Scale.

Question	Eddy	Vicky
Math on the Computer helped me work for longer.	5	5
I do more problems on the computer then on a worksheet.	5	7
I could do this program at home with my mom or dad.	5	7
I liked doing math on the computer.	7	7
Math on the computer helped me stay focused.	7	5

Note. Average rating = 6.4 on a scale from 1 (strongly disagree) to 7 (strongly agree)

Table 2

Social Validity Questionnaire: Parent Intervention Ratings on a 7-Point Likert Rating Scale.

Question	Parent 1	Parent 2
This was an acceptable intervention for distractible children to aid in attending to a math task.	7	7
This was an efficient procedure.	7	7
This is a feasible procedure that I would be willing to use with my child.	7	7
I like the procedures used in this intervention.	7	7
Overall I am satisfied with the intervention.	7	7

Note. Ratings across both respondents: 7 on a scale from 1 (strongly disagree) to 7 (strongly agree).

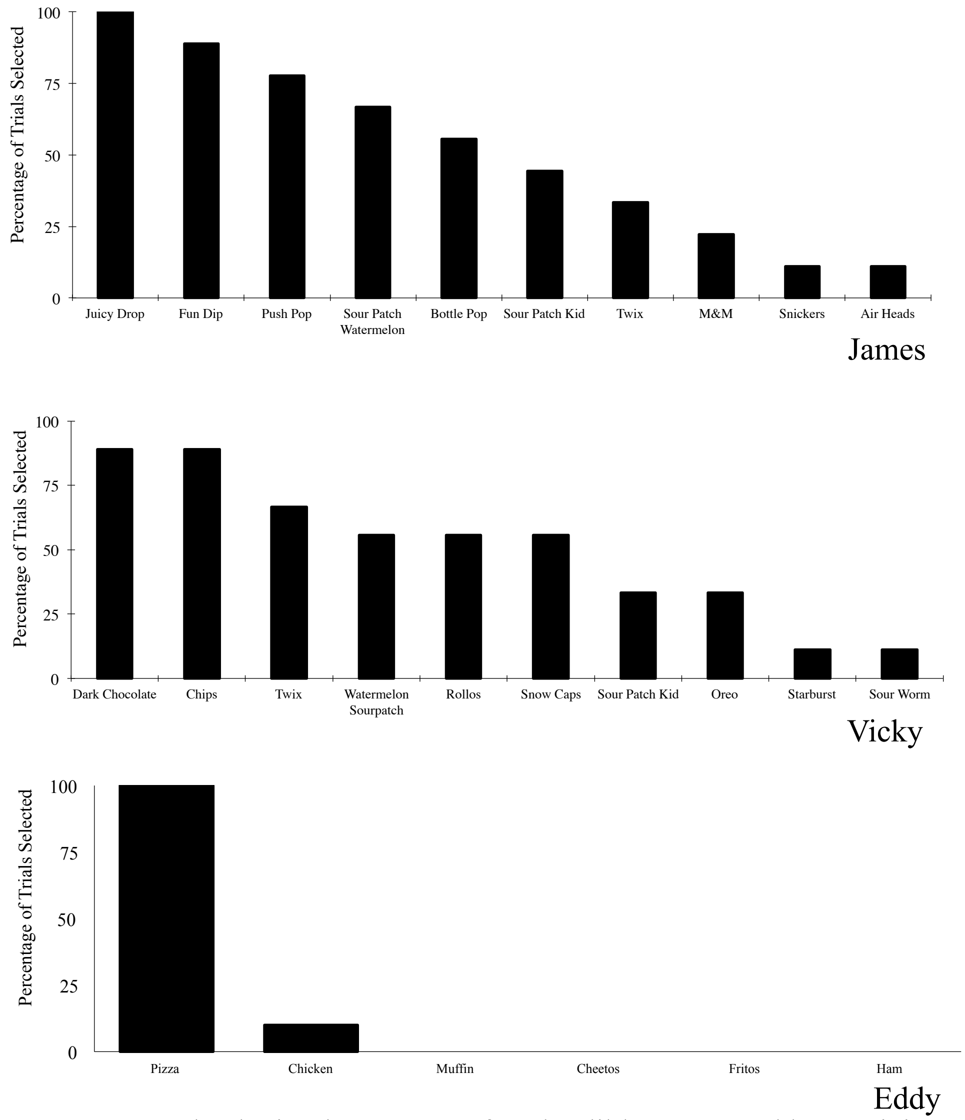

Figure 1. Graphs depict the percent of each edible consumed by participants during the Paired-Stimulus preference assessment.

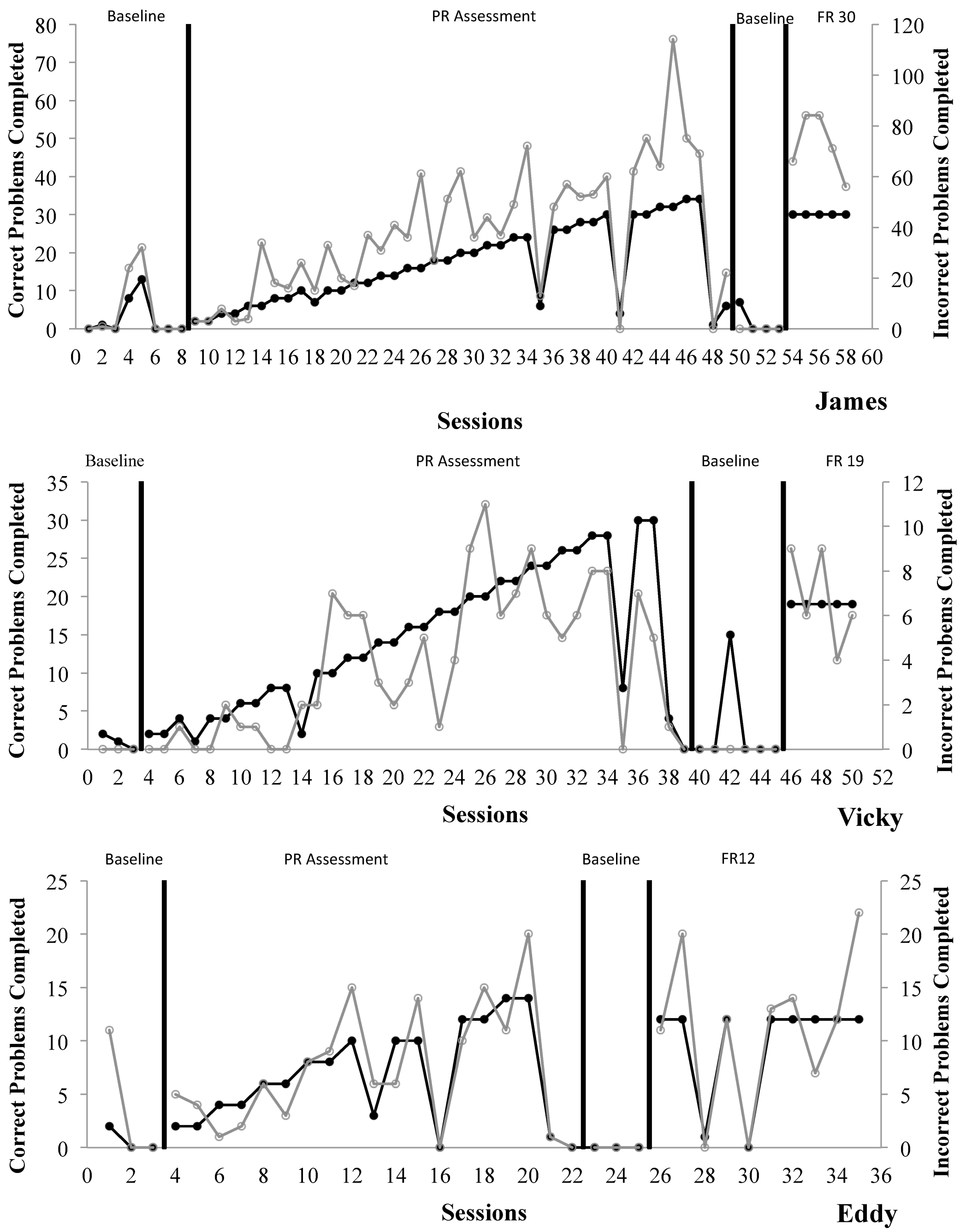

Figure 2. Shows data from phase 2 and 3 for James, Vicky and Eddy. The black closed circles depict correct problems completed and the grey open circles show incorrect problem completion

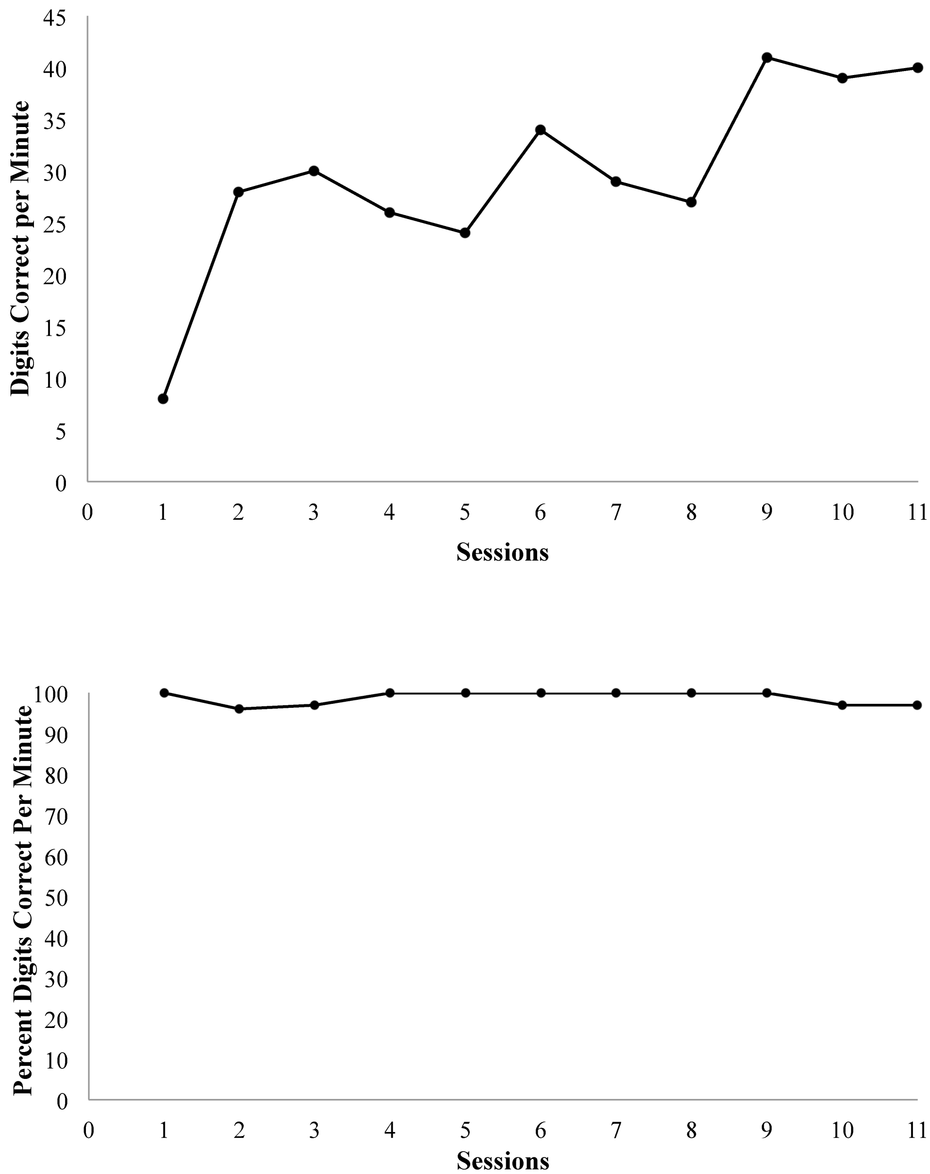

Figure 3. Shows James's DCPM (top) and percent of correct digits (bottom) for each probe session.

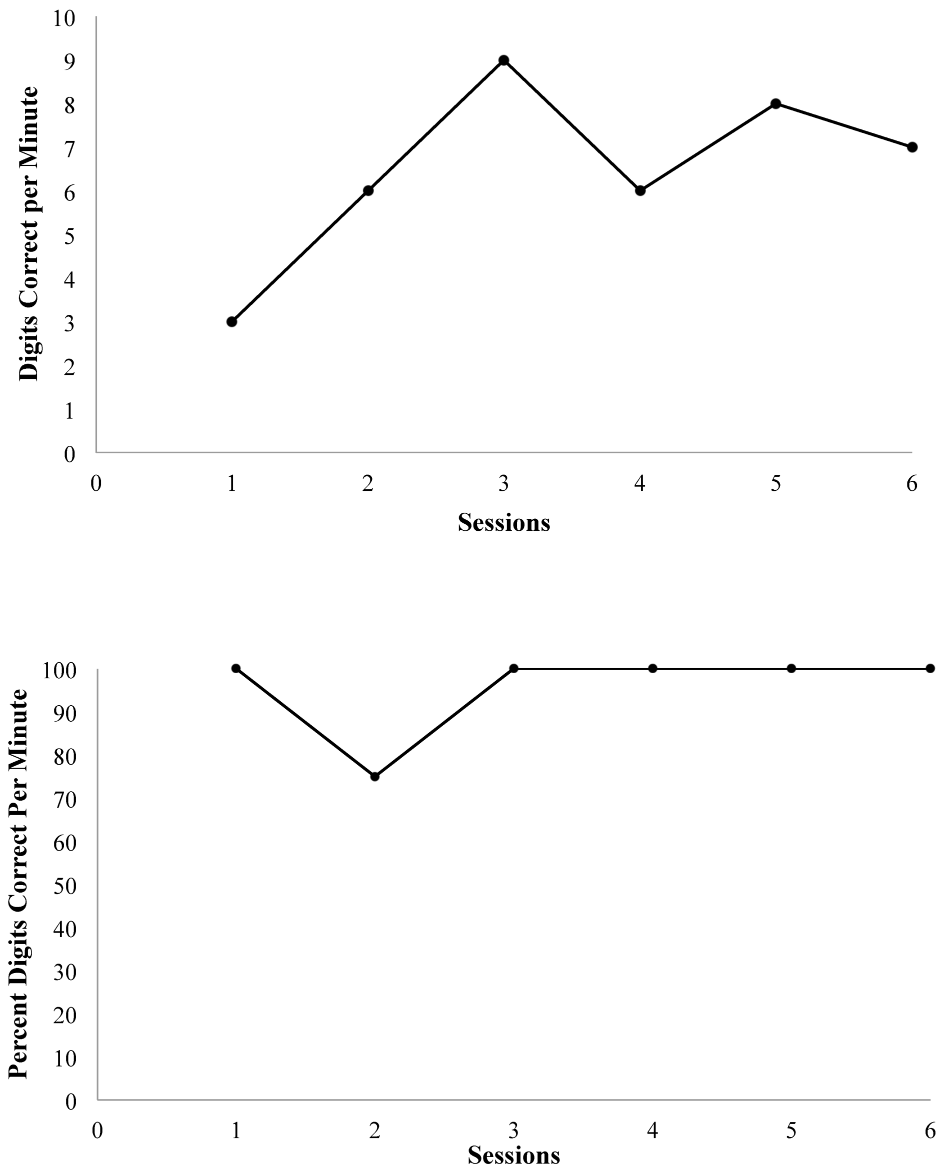

Figure 4. Shows Eddy's DCPM (top) and percent of correct digits (bottom) for each probe session.

Appendix A

Social Validity Parent Questionnaire

		Strongly Disagree						**Strongly Agree**
	Question	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	This was an acceptable intervention for distractible children to aid in attending to a math task.							
2	This was an efficient procedure.							
3	This is a feasible procedure that I would be willing to use with my child.							
4	I like the procedures used in this intervention.							
5	Overall I am satisfied with the intervention.							

Appendix B

Social Validity Participant Questionnaire

		Strongly Disagree						**Strongly Agree**
	Question	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	Math on the Computer helped me work for longer.							
2	I do more problems on the computer then on a worksheet.							
3	I could do this program at home with my mom or dad.							
4	I liked doing math on the computer.							
5	Math on the computer helped me stay focused.							

Appendix C

PR/FR Treatment Integrity

Session # _______
Participant _______

Have Materials Ready

Laptop _________

Reinforcer _________

Issue the Correct SD

Baseline: "Do as many as you want." _________

PR/FR: "Complete X problems and you get a Y ". _________

Place laptop and scratch paper in front of participant _________

Correct Consequence

Reinforce if criteria met _________

Remove Laptop for 30 seconds _________

Appendix D

MTM Treatment Integrity

Preview + Repeated Practice + Corrective Feedback (C)

Preview	
1. Student is given worksheet	Yes / No
2. Interventionist manually and verbally completes worksheet	Yes / No
3. Student follows along while interventionist completes worksheet	Yes / No
Repeated Practice	
4. Student completes 3 worksheets in a series of 1 minute trials	Yes / No
Corrective Feedback	
5. Interventionist follows along as the student completes math problems, verbally identifying errors and immediately correcting them	Yes / No