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The Effects of Direct Instruction Flashcard and Math Racetrack Procedures on Mastery of Basic Multiplication Facts by Three Elementary School Students

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Abstract

The purpose of this study was to determine if a typical third-grade boy and fifth-grade girl and a boy with learning disabilities could benefit from the combined use of Direct Instruction (DI) flashcard and math racetrack procedures in an after-school program. The dependent variable was accuracy and fluency of saying basic multiplication facts. A single subject multiple baseline design across three sets of facts showed a clear functional relationship between the DI flashcard combined with the math racetrack procedures and increased mastery of multiplication facts. By the end of the study, each participant mastered all target math facts. Additionally, all three participants correctly generalized from oral to written without instruction on written math facts. Also, the students' confidence in math seemed to grow as their mastery increased. The procedure was cost effective and required little training to implement.

Keywords: DI Flashcards, Math Facts, Action Research, Applied Behavior Analysis, Multiple Baseline Design, Student Research, Elementary School Students, Learning Disabilities.

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Mastery of multiplication facts represents a critical skill needed to progress to more advanced stages of the mathematics curriculum (Polya, 2002). Stein, Kinder, Silbert, and Carnine (2006) define mastery of a basic fact as saying the entire statement and answer within 2 sec. Mastery of math facts allows the student to focus on other critical components when solving more advanced math problems, such as story problems, and is imperative for success in K-12 math (Johnson & Layng, 1994; Stein, et al., 2006; Stood & Jitendra, 2007), as well as needed for functional living skills. Children should master all 100 multiplication facts (0-9 times 0-9) by the end of third grade or early fourth grade (Polya, 2002). If children fail to obtain mastery of these facts, they will likely have difficulty with more complex math skills, which could result in cumulative failure. Students' failure to meet math benchmarks for their respective grade levels is a continuing cause of great concern of parents, teachers, and school policy makers (Stein et al., 2006).

The use of flashcards to assist children with mastering basic facts has been a common practice in education, but its use is often unsystematic and its efficacy not evaluated. Silbert, Carnine, and Stein (1981) suggested the Direct Instruction (DI) flashcard procedure as a systematic way to teach basic math facts to students. Silbert et al. (1981) recommended using 15 flashcards with a mixture of 12 mastered and three unmastered facts. When employing this procedure, flashcards are presented to students in a rapid fashion. If the student says the statement and answer correctly within 2 sec (e.g., "four times five equals 20"), then the card is placed at the back of the pile and the next flashcard is presented. If the student makes an error or takes longer than 2 sec, the teacher verbally models the statement and answer. The student is then required to say the statement and answer. The teacher again presents this flashcard. If the student is correct, the card is placed two to three cards back so it will soon reappear. The student must answer the fact correctly three times in a row before the teacher places the card at the back of the stack. After the stack of flashcards is presented for several minutes, the student moves to another activity in the classroom (Hayter, Scott, McLaughlin, & Weber, 2007). Variations of the Direct Instruction flashcard procedure have produced promising results (Brasch, Williams, McLaughlin, 2008; Hayter et al., 2007; Sante, McLaughlin, & Weber, 2001; Silbert et al., 1981). The DI flashcard procedure has not only been effective in teaching math facts (Brasch et al., 2008), but also sight words (Ruwe, McLaughlin, Derby, & Johnson, 2011). The Direct Instruction flashcard procedure has been used to improve the basic math fact mastery of high school students with severe behavior disorders (Brasch et al., 2008) or intellectual disabilities (Hayter et al., 2007) and elementary students with learning disabilities and attention deficit disorders (Kaufman, McLaughlin, Derby, & Waco, 2011; Sante et al., 2001).

The DI flashcard procedure has been employed in conjunction with a "racetrack" procedure to teach basic skills (Beveridge, Weber, Derby, & McLaughlin, 2005; Falk, Band, & McLaughlin, 2003; Hyde, McLaughlin, & Everson, 2009; Kaufman et al., 2011; McLaughlin et al., 2009; Printz, McLaughlin, & Band, 2006). The racetrack consists of an illustration consisting of 28 segments arranged in an oval (Rinaldi & McLaughlin, 1996; Rinaldi, Sells, & McLaughlin, 1997). The teacher writes a math fact, sight word, etc., in each segment. The teacher mixes the order of the facts or words to avoid the child's memorization by order. The student's goal is to "race" around the track, correctly responding to each square in the shortest possible amount of time. The major advantage of combining the racetrack procedure with the DI flashcard procedure is that it is in a game format and will likely add "intrinsic" motivation for spending more time on the mastery of basic facts. The studies that combined the DI flashcard procedure with the math or reading racetrack purposely had the racetrack procedure follow the DI flaschcard procedure to help maintain the students' motivation.

The purpose of the present study was to evaluate the effects of the DI flashcard procedure combined with a math racetrack procedure on the oral mastery of basic multiplication facts. A second purpose was to assess generality of the procedures by implementing these procedures with students with and without disabilities in an after-school tutoring program or in a special education resource room. This study sought to improve the multiplication fact mastery of three elementary-age students who had not attained mastery in multiplication facts - two typically developing students (a third grade boy and fifth grade girl) and a fifth grade student with a learning disability. A third purpose was to determine if targeting five to seven new facts at a time, rather than only three originally recommended by Silbert et al. (1981) would be effective. A fourth purpose was to assess generalization (Stokes & Baer, 1977, 2003) from oral mastery of math facts to written mastery. A final purpose was to determine if first-year college students, taking their first course in applied behavior analysis, could implement the DI flashcard and math racetrack procedures and successfully improve pupil mastery of basic facts.

Method

Participants and Settings

There were three participants. Participant 1 was an 8-year-old, third-grade boy. Participant 2 was a 10-year-old, fifth-grade girl. Both attended a private parochial school in Spokane, WA. The first two participants were brother and sister who came from a middle-income family and had not mastered the 100 basic multiplication facts. The private school they attended emphasized mastery of these basic facts by the end of third grade, yet the two participants had not mastered them. The mother of these two children asked one of the senior authors to help her children master basic facts. Participants 1 and 2 were cooperative and personable. Participant 3 was an 11-year-old fifth-grade boy enrolled in general and special education at an urban public school in Spokane, WA. Participant 3 was diagnosed with a learning disability and had received special education services since the second grade in math, reading, writing, and social behavior. One of the researchers was completing practicum work in the participant's resource room. The teacher asked the researcher to help the participant master multiplication facts. At the time of the study, he was receiving 45 minutes per day of special education services. Like the other two participants, he was cooperative and excited about learning his basic math facts.

For the first two participants, the study took place in a small office space in the Rosauer Education Center at Gonzaga University in Spokane, WA. The study took place for about 30 min on Mondays and Thursdays between 3:10 p.m. and 3:50 p.m. The first four authors who were responsible for the instruction were first-year college students completing their first course in applied behavior analysis as part of the endorsement to teach special education and as part of the academic major in Special Education at Gonzaga University. For Participant 3, data were taken in a resource room with about four other students in the classroom at the same time. The students were receiving individualized education for reading, writing, and math. All of the students in the resource room attended general education for most of the school day. The study was conducted for about 20-30 min at a table in a quiet hallway outside of the classroom to reduce distractions on Tuesdays and Thursdays between 12:45 p.m. and 2:45 p.m.

Response Definition and Observation Procedures

The target behavior was the accuracy of saying target multiplication fact statements and answers within 2 sec. The target facts were selected from facts that were answered incorrectly on a pre-assessment of all 100 multiplication facts presented on flashcards. Twenty-one unmastered facts based on the pretest were broken into three sets of seven target facts for Participants 1 and 3. Participant 2 only missed 17 of the 100 basic multiplication facts on the pre-assessment. These 17 unmastered facts were broken down into three sets of target facts (six facts for Sets 1 and 2, and five for Set 3) for Participant 2. In order to measure progress, the researchers assessed the children's accuracy by presenting flashcards in a mixed order of all three sets of target facts at the beginning of each session. Improvements at the beginning of the sessions would reflect mastery and retention of facts from the previous sessions. The participants were encouraged to do their best, but no feedback was given during this assessment. The researchers recorded on observation forms with a plus or minus sign to indicate whether or not the student correctly answered a given math fact within 2 sec following the presentation of each flashcard card.

The researchers gave each of the three participants 5 minutes to complete a written pretest and 5 minutes to complete a written posttest of the 100 basic multiplication facts presented in a mixed order. The posttest was a measure of generalization because the intervention was only for orally stating the math fact statements and answers in response to the presentation of flashcards.

Experimental Design and Conditions

A single subject multiple baseline design (Kazdin, 2011) across three sets of multiplication facts was used to evaluate the effects of the DI flashcard and a math racetrack procedures on mastery of basic multiplication facts by three elementary students

Baseline. During baseline, the researchers presented the three sets of target facts (facts unmastered on the pretest) on flashcards in a mixed order. After this brief assessment, the researchers presented mastered (based on the pretest) facts using the DI flashcard and math racetrack procedures to familiarize the participants with the procedures (four sessions for Participants 1 and 2 and three sessions for Participant 3). No instruction was given during baseline on the unmastered target facts. The number of sessions in baseline ranged from 3 to 20 sessions.

Direct Instruction flashcard and math racetrack procedures. The DI flashcard and math racetrack procedures were used to help the children master targeted basic multiplication facts. One of the researchers presented 15 multiplication facts on flashcards. Six to seven of these facts were target facts and the other facts were previously mastered facts based on the pretests. Additionally, if a target fact, such as 5x6=30 was used, then the target fact of 6x5=30 was also included. The authors believed that including the problems showing this commutative property would facilitate the participants' mastery of all facts. The six to seven unmastered facts used in the current study was at least double the three target facts that Silbert et al. (1981) had originally recommended be used with the 15 flashcards. The participants had to say the entire statement and answer correctly within 2 sec. If not, the researcher modeled the statement and answer and the child had to then repeat the entire statement and answer. The researcher then put the flashcard back in the pile two to three cards back so the card came up again quickly so the child's likelihood of remembering the fact would be increased. The researcher continued to put the missed fact only two to three cards back until the child answered that particular fact correctly three times in a row. At that point the particular fact was put at the back of the pile so that the child had to remember the fact for a longer period of time to promote retention. The researchers encouraged the participants to do their best and contingent praise was used for stating the math fact and answer within 2 sec.

The math racetrack was a board game (see Figure 1) with 28 segments forming a "racetrack." On each of the segments was written a math fact-14 mastered facts based on the pretest and five to seven target facts placed at least twice each on the math racetrack. The researchers mixed up the targeted facts and mastered facts each time they worked with the participants. The child had to say the entire statement and answer correctly before moving on to the next fact. The child was timed when completing the entire racetrack. The researchers gave contingent praise for quick correct responses. If an error occurred a researcher modeled saying the statement and correct answer and then the child repeated the entire statement and answer before going to the next fact. When the racetrack was completed the researcher praised the participant and challenged each participant to beat his or her previous time. The child completed at least two laps around the racetrack, but sometimes three if time permitted.

Once Set 1 facts were mastered, Set 1 facts then became mastered facts to be reviewed with the unmastered Set 2 facts. Set 2 target facts were added to both the DI flashcard and math racetrack procedures on the same session. Once Set 2 facts were mastered, these facts were retained for review on the DI flashcard procedures while Set 3 became the new target facts. For the math racetrack Set 3 facts were placed twice each on the racetrack and Set 1 and Set 2 facts became review facts, which were placed once each on the math racetrack.

The senior author gave the first four authors (first-year college students) the authority to determine when to move to the next set of facts for the participants. The senior author told them that they needed

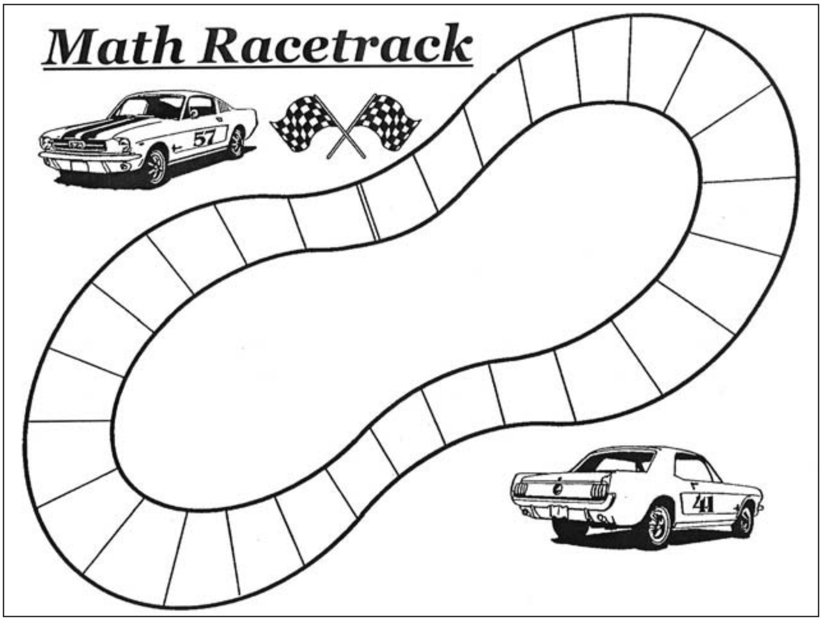

Figure 1. A sample of the math racetrack, on which the basic multiplication facts were presented, is shown.

at least three days of a clear-cut effect and demonstrated mastery for a given set of facts before implementing the DI flashcard and math racetrack procedures with a new set of facts.

Reliability of Measurement

Interobserver reliability or agreement assessment was conducted six times during baseline and the DI flashcard and math racetrack procedures for each of the three participants. Each of the observers independently recorded each child's responses. One of the authors worked with the child and recorded the child's responses while another author or classroom teacher recorded the child's responses. Both observers recorded the children's responses on the recording form with a plus for a correct response or minus sign for an incorrect response or a response that took longer than 2 sec. The percent of interobserver agreement was calculated by dividing the number of agreements by the number of agreements plus disagreements and then multiplying by 100. The overall percent of interobserver agreement across observations for the three participants was 99% (range 97-100%). The only disagreements were whether the facts were stated within the 2 sec time limit or not.

Results

The number correct during baseline and during the DI flashcard and math racetrack procedures across the three sets of target multiplication facts for Participant 1 is shown in Figure 2. With the implementation of the DI flashcard and math racetrack procedures, there was an immediate increase in the number of facts correct for each set of the three sets of facts. The mean number correct for Set 1 during baseline was 2.5 out of seven (range: 0 to 4), which increased to a mean of 6.8 (range: 6 to 7) during the DI flashcard and math racetrack procedures. For Set 2 the mean number correct during baseline was 1.8 out of seven (range: 0 to 3), which increased to a mean of 6.3 (range: 4 to 7) during the DI flashcard and math racetrack procedures. For Set 3 the mean number correct during baseline was 0.9 out of seven (range: 0 to 5), which increased to a mean of 6.3 (range: 5 to 7) during the DI flashcard and math racetrack procedures. Participant 1 showed mastery of all three target sets (21 target facts) for the last three sessions of the study.

The number correct during baseline and during the DI flashcard and math racetrack procedures across the three sets of target multiplication facts for Participant 2 is shown in Figure 3. With the implementation of the DI flashcard and math racetrack procedures, there was an immediate increase in the number of facts correct for Set 1 and Set 3 facts and a gradual increase for Set 2. The mean number correct for Set 1 during baseline was 2.0 out of six (range: 0 to 3), which increased to a mean of 5.8 (range: 4 to 6) during the DI flashcard and math racetrack. For Set 2 the mean number correct during baseline was 0.6 out of six (range: 0 to 2), which increased to a mean of 3.8 (range: 0 to 6) during the DI flashcard system and math racetrack. For Set 3, the mean number correct during baseline was 1.4 out of five (range: 0 to 3), which increased to a mean of 5.0 for the DI flashcard and math racetrack procedures. Participant 2 showed mastery of all three target sets (17 target facts) for the last three sessions of the study.

The number correct during baseline and during the DI flashcard and math racetrack procedures across the three sets of target multiplication facts for Participant 3 is shown in Figure 4. With the implementation of the DI flashcard and math racetrack, there was an immediate increase in the number of facts correct for each set of facts. The mean number correct for Set 1 during baseline was .7 out of seven (range: 0 to 2), which increased to a mean of 6.5 (range: 4 to 7) during the DI flashcard and the math racetrack procedures. The mean number correct for Set 2 during baseline was 1.4 out of seven (range: 0 to 3), which increased to a mean of 6.6 (range: 4 to 7) during the Direct Instruction flashcard and the math racetrack procedures. The mean

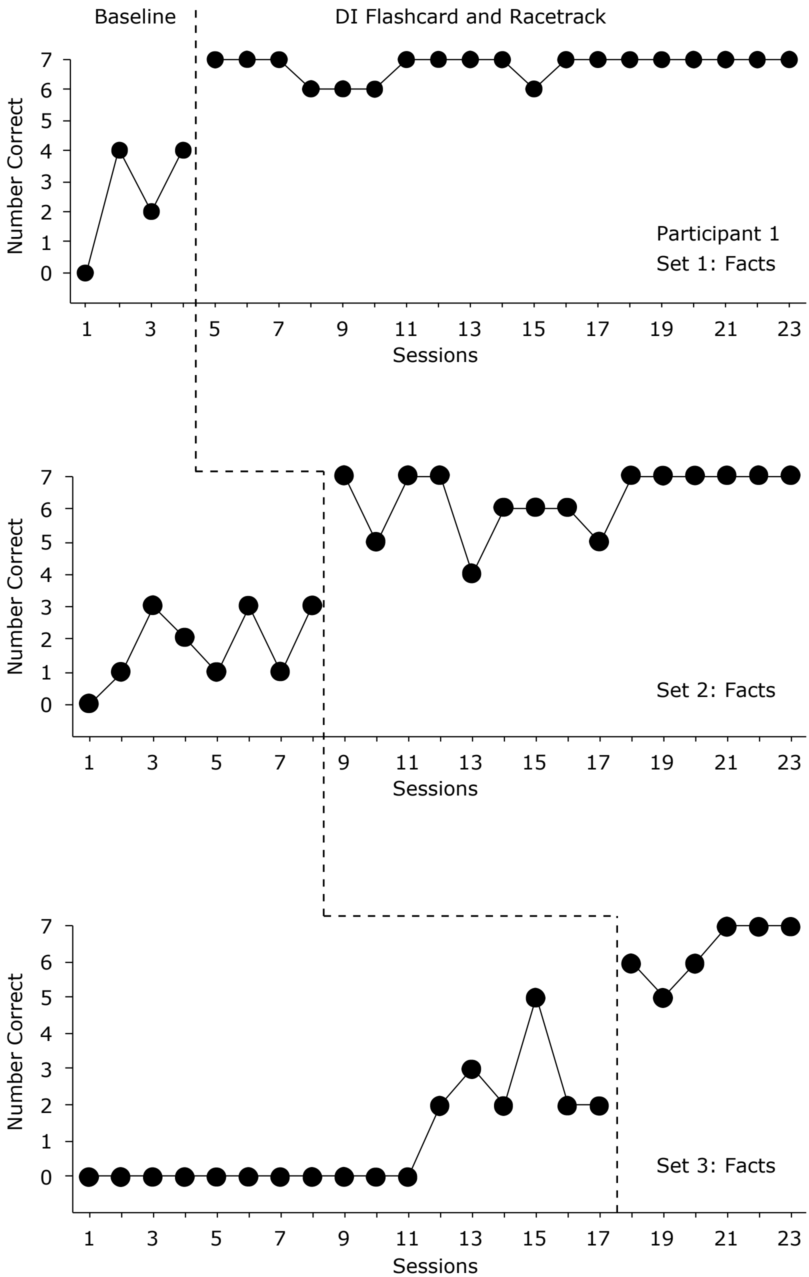

Figure 2. The number correct for the three target sets of multiplication facts during baseline and Direct Instruction and math racetrack is shown for Participant 1.

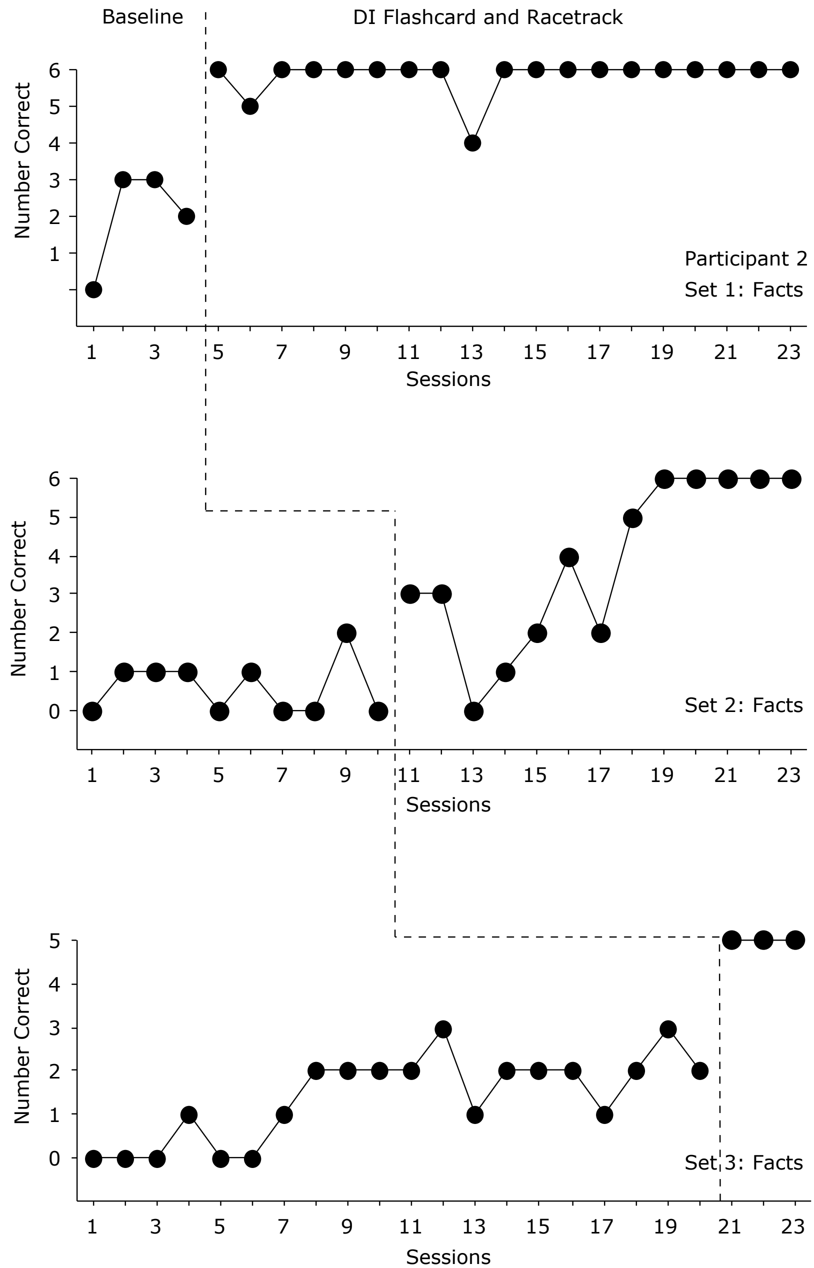

Figure 3. The number correct for the three target sets of multiplication facts during baseline and Direct Instruction and math racetrack is shown for Participant 2.

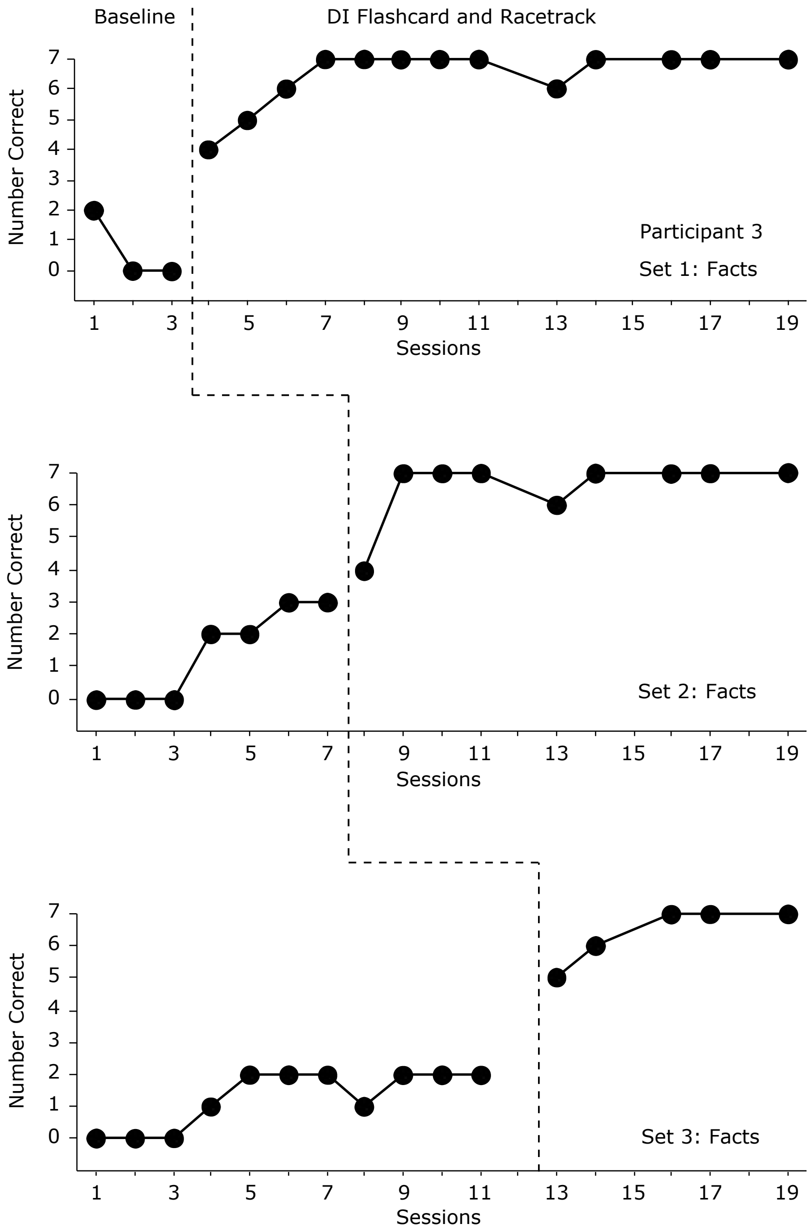

Figure 4. The number correct for the three target sets of multiplication facts during baseline and Direct Instruction and math racetrack is shown for Participant 3.

number correct for Set 3 was 1.3 out of seven (range: 0 to 2), which increased to a mean of 6.4 (range: 5 to 7) during the Direct Instruction flashcard and the math racetrack procedures. The child was absent on session 12; hence, the absence of data points on this session. Participant 3 showed mastery of all three target sets (21 target facts) for the last three sessions of the study.

The authors administered a pretest and posttest for the 100 written multiplication facts. Participant 1's pretest score was 29, which increased to 71 on the posttest (a 141% increase). Participant 2's, pretest score was 55, which increased to 100 on the posttest (an 82% increase). Participant 3's pretest score was 38, which increased to 62 (a 63% increase).

Discussion

Results indicated that there was a clear, functional relationship between the use of DI flashcard and a math racetrack procedures and the mastery of basic facts for each of the three participants. Figures 2-4 showed immediate and large increases in the number of math facts correct with the implementation of the DI flashcard and math racetrack procedures for eight of the nine sets of math facts. To further attest to the functional relationship demonstrated, there was no overlap in the ranges of correct responding between baseline and the intervention for eight of the nine sets of target facts. The combined effect of both the Direct Instruction flashcard and math racetrack proved highly beneficial for each child. Each participant mastered each fact across all three sets of targeted facts for at least the last three sessions of the study.

A team of college students worked with the first two participants and one college student worked with the third participant. These young researchers were instructed to implement the procedures with a given set of facts until there was at least 3 days of a clear effect and mastery of a given set of facts. Though Participant 1 initially mastered Set 2 facts, his accuracy showed less than full mastery when the procedures were implemented for Set 3 facts. One of the senior authors recommended moving on to Set 3 because all Set 2 facts would be retained as review facts, giving more trials to promote mastery. The data showed that these Set 2 facts were quickly mastered.

At the outset, Participants 1 and 2 appeared to lack confidence, were somewhat unsure of their knowledge of math facts, and frequently delayed responding or second-guessed their answers. By the end of the study, however, they both replied with conviction and speed. The authors hoped this apparent increase in confidence would carry over into their mastery of later, more advanced math skills. It is also important to mention the pride that the students began to take in their accuracy. This acquisition was evident in that the students frequently inquired as to how many errors they had made, and celebrated news of mastery with smiles. Doing well in and of itself seemed to become reinforcing, and their improved motivation was quite socially significant.

When the intervention was first implemented, Participant 3 was not excited about working on multiplication facts. However, once he had mastered Set 1, he appeared to have more self-confidence in his math skills. He mastered Set 2 and Set 3 in fewer sessions than Set 1. Participant 3 appeared to enjoy and look forward to the one-on-one instruction and the praise that he received when he answered problems correctly during the intervention.

During the intervention for Set 1 facts, the researcher noticed that Participant 3 was mastering some of the Set 2 and Set 3 facts. It was found that his mother was using flashcards at home with him, giving her son feedback on any of the problems that he was getting incorrect, which included the facts from Set 2 and Set 3. Similarly, there were some increases in correct responding by the first two participants on their respective Set 3 facts. However, the immediate jump in correct responding with the implementation of the intervention strongly supports the functional relationship between DI flashcard and math racetrack procedures and improved math fact mastery. All three participants were in school 5 days per week and their teachers were instructing on basic academics, including math.

Other researchers have found increases during baseline with tutoring in vocabulary for middle school students (Malone & McLaughlin, 1997). In that case, the participants started practicing with each other. In the present case, it appears that the parent of the third participant became interested in her child's performance in math and implemented some form of practicing math facts at home with flashcards. This may give these procedures some additional social validity (Kazdin, 1977; Wolf, 1978) for their use in the schools and home and suggests that parents might be motivated to learn to implement flashcard procedures in a systematic way at home.

The implementation of this intervention was quite practical. This intervention required little to no financial cost. The flashcards were computer generated and a laminated, reusable version of the racetrack helped avoid some cost. Data collection was simple and efficient. As far as continuing the use of the flashcards is concerned, the students could easily administer the Direct Instruction procedure to one another, as could a parent or aide. In fact, a classroom teacher could pair all students in the classroom with similar skill levels and implement the procedure concurrently with all students, while the classroom teacher monitored. All that was needed for the racetrack was a laminated version and a dry erase pen. The cost of the intervention was further minimized by the fact that no token or tangible reward system was required. The students responded well to researchers' praise.

First-year college students who were just beginning their studies in special education and applied behavior analysis carried out the intervention smoothly and without any major problems. One alteration in procedures was a change in setting implemented approximately three quarters of the way through the project's duration for Participants 1 and 2. After noticing a pattern of inattention resulting from interaction between the two siblings, the researchers decided to separate the siblings during data collection and much of the time for the intervention. A noticeable improvement was made following this change, as the fifth grade girl's concentration was especially improved when her brother was not present. An additional strength of this study was that these procedures could be implemented with both general and special education elementary students.

The present outcomes add further confidence for employing the DI flashcard and math racetrack procedures. In the present case the authors employed the procedures in an after-school program, as well as in a special education classroom. These results also provide an additional systematic replication (Sidman, 1960) of previous research efforts (Kaufman et al., 2011; McLaughlin et al., 2009; Ruwe et al., 2011; Sante et al, 2001). The current study showed that a reading racetrack could be modified for use in math and implemented in conjunction with a DI flashcard procedure. The authors purposefully used the math racetrack after the DI flashcard procedure because the game format seemed to help maintain the participants' motivation to master the facts. In the present study the ratio of mastered to unmastered math facts during the DI flashcard procedure was seven unmastered facts to eight mastered ones. Silbert et al. (1981) had recommended only three unmastered to 12 mastered facts, but they did not have empirical research to support their recommendation. The current ratio meant that the students were mastering double the number of new facts originally recommended, yet the data showed clear progress to full mastery of target facts. Additional research could examine generalization across other classroom settings, such as from the work in the resource or after-school program to their daily work in general education setting. The generalization from oral to written facts for all three participants was a particularly important finding. It is less time consuming to answer facts orally than answering in writing. Since generalization to written facts occurred, the current procedures using oral responding was likely much more efficient than written responding. Further examination of generalization from written to oral facts and generalization from multiplication facts to division facts would be warranted.

In order to try to ensure maintenance of math fact mastery by the participants, the researchers presented them with the flashcards used during DI flashcard procedure, as well as the laminated math racetrack. The participants were encouraged to continue to use the two procedures, as well as to share the steps of each procedure with their parents and teachers. It cannot be overstated that the DI flashcard procedure is a very systematic way at facilitating mastery and retention of basic facts on a completely individualized basis. Given effective tools and instruction methods, students' improved mastery, motivation, and confidence should provide a foundation upon which to build more competent mathematical skills. Furthermore, the clear efficacy of these two educational procedures combined suggests the wider applicability of their pairing. The senior authors have guided hundreds of first-year college students to use these procedures successfully to teach sight-word reading, letter/sounds correspondence, rote and rational counting, tacting colors and shapes, numeral recognition, etc.

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