

**THE TAPED PROBLEMS INTERVENTION:
INCREASING THE MATH FACT FLUENCY OF A STUDENT WITH AN INTELLECTUAL
DISABILITY**

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The Taped Problems intervention is an evidence-based practice that involves a self-monitored, audio-recording procedure in which students follow along with automated recordings of math facts and their solutions. A multiple-probes-across-tasks design was used to evaluate the effectiveness of the Taped Problems intervention on the division-fact fluency of an eighth-grade student with an intellectual disability. Results indicated immediate and sustained increases in the student's division-fact fluency across sets of problems. Discussion focuses on the practical implications of the results, limitations of the current investigation, and directions for future studies.

Although general and special education teachers devote much instructional time to teaching mathematics, the 2009 Nation's Report Card indicates that only 39 percent of fourth-grade students and 34 percent of eighth-grade students are performing at or above the level of proficiency in mathematics (NCES, 2009). Relevant to the current study, only 19 percent of fourth-grade students with disabilities and nine percent of eighth-grade students with disabilities are performing at or above this level (NCES, 2009). These data indicate that as the grades progress, an increasing number of students eligible for special education fail to meet grade-level curricular expectations in math. As such, efficient interventions are needed to prevent and/or remedy basic math skill deficits, particularly among students with disabilities.

Basic math facts (one-digit by one-digit addition, subtraction, multiplication, and division computations) are the most fundamental computational skill for all higher math tasks. Research has historically focused on math fact acquisition, or teaching strategies and procedures for correctly solving these basic math computations (Poncy, Skinner, & Jaspers, 2007). Acquisition strategies such as number lines, manipulatives, and finger counting procedures have value because they can be applied across contexts and may lead to higher conceptual understanding of mathematics (Poncy, Skinner, & O'Mara, 2006). Although these procedures have merit, there are also limitations associated with the use of such acquisition strategies (Pellegrino & Goldman, 1987). Many of these strategies are time-consuming (e.g., those that involve manipulatives and finger counting) and students may become dependent upon these laborious techniques for solving problems. Additionally, when a strategy requires several steps, a single mistake may prevent a student from arriving at a correct answer that otherwise could be automatically retrieved.

The limitations associated with complex procedures to teach the acquisition of basic math facts, have led to increasing interest in strategies that build math fact fluency. Recently, researchers have begun to argue that students should not only be able to respond accurately to math problems, but also be able to respond quickly and with little effort (Poncy, Skinner, & Jaspers, 2007). Haring and Eaton (1978) referred to fast and accurate responding as *fluency*. Math fact fluency is important for a variety of reasons. Cognitive processing theory suggests that individuals have a limited amount of cognitive resources (working memory, attention) to devote to any given task (Lagerge & Samuels, 1974; Pellegrino & Goldman, 1987). When faced with a complex math task, a student who is fluent with respect to math facts has more cognitive resources to devote towards finding a solution to the problem. A *dysfluent* student must divert cognitive resources away from the complex components of the problem and towards lower level skills like solving the math facts (Delazer et al., 2003; LaBerge & Samuels, 1974).

Math fact fluency is also important from the standpoint of behavioral learning theory. Much behavioral research has demonstrated the importance of opportunities for active responding for enhanced academic performance (Skinner, Belfiore, Mace, Williams, & Johns, 1997; Skinner, Pappas, & Davis, 2005). First, students who fluently complete math facts are presumably able to complete more math problems within a given time frame. These increased opportunities to respond also result in additional occasions for reinforcement for correct responses. Additionally, research has demonstrated that students who are fluent with math facts are less likely to suffer from math related anxiety (Cates & Rhymer, 2003). Finally, data is present to suggest that fluent students are more likely to choose to engage in assigned math tasks than dysfluent students (Billington, Skinner, & Cruchon, 2004). In brief, the positive choices often made by fluent students lead to more opportunities for practice, more reinforcement, and less math anxiety, all factors contributing to higher performance relative to dysfluent students.

Although math fact accuracy and fluency are typically part of the elementary school curriculum, the overwhelming majority of middle- and high-school students with disabilities have not mastered these skills (NCES, 2009). This is problematic as individuals with math fact deficiencies may be excluded from certain vocational and career paths (Sante, McLaughlin, & Weber, 2001). Because of this risk, interventions are needed to increase the math performance of students with disabilities.

One evidence-based intervention that has been used to efficiently increase the math fact fluency of elementary and secondary students with and without disabilities is the Taped Problems intervention (TP). This intervention involves listening to audio recordings of math facts followed by brief pauses and then the answers to the math facts. Students are provided follow-along worksheets and instructed to try to beat the recording by writing the solution to each math fact before hearing the correct answer spoken on the recording. If a student fails to answer a problem within the provided time delay, or answers a problem incorrectly, she writes the correct answer upon hearing it on the recording. Incorporated within TP are (a) numerous opportunities for accurate responding, (b) reinforcement for correct responding, and (c) immediate feedback on responses (whether correct or incorrect). The combination of these three factors is thought to contribute to the effectiveness of the TP intervention.

The TP intervention was first used to increase the division fact fluency of an elementary student with a math disability (McCallum, Skinner, & Hutchins, 2004). Subsequently, TP has proven to be effective across populations of students (special education and general education) and contexts (individual and class-wide) (Carroll, Skinner, Turner, McCallum, & Woodland, 2006; McCallum, Schmitt, Schneider, Rezzetano, & Skinner, 2010; McCallum, Skinner, Turner, & Saeckar, 2006; Poncy, Skinner, & Jaspers, 2007). To date, all empirical TP studies have evaluated the intervention using single subject research designs. Although sometimes confused with qualitative case study research approaches, single subject designs differ as they are quantitative experimental research methods in which each participant serves as his or her own control (Sidman, 1960). Additionally, in single subject research, each participant is exposed to a *control* condition (known as the baseline phase), as well as an intervention condition in which the dependent variable is repeatedly measured while controlling for common threats to internal validity. Across disciplines, single subject research has been used to evaluate the effectiveness of enumerable educational interventions (e.g., Barlow & Hersen, 1984; Skinner, 2004; Horner et al, 2005).

The purpose of the current study was to add to the TP evidence base by evaluating the effectiveness of a self-monitored TP procedure for increasing the division fact fluency of an eighth-grade student with an intellectual disability. Improving the math skills of students with intellectual disabilities is not only essential for future mathematics instruction, but also to promote the development of adaptive behavior skills like number concepts, time, and money (American Association of Intellectual and Developmental Disabilities; AAIDD, 2010).

Method

Participant and Setting

Emily was a 13 year old, 8th grade student educated within a public middle school in the Northeastern United States. She received special education services as a student with an intellectual disability. This disability was reported to have resulted from a cerebrovascular accident (stroke) at birth. In addition to services provided within a self-contained, *life skills* classroom, she also received speech, occupational, and physical therapies. Most recent psycho-educational evaluation data revealed that Emily earned an FSIQ of 59 and an adaptive behavior composite of 70. After learning of the TP intervention through an educational consultation with this study's investigators, her teacher reported that Emily may benefit from

this math fluency intervention as she learned rote academic tasks (e.g., spelling) more easily than academic tasks that required reasoning (e.g., reading comprehension, math reasoning, and written expression). The study's procedures were implemented within Emily's self-contained classroom. Other students were present and working on other assignments as she participated in the intervention. Emily sat to the back of the room and wore headphones in order to not distract her classmates, and to help focus her attention.

Materials

Emily's TP intervention procedures concerned division math facts. As such, basic division facts with quotients (answers) of two through nine were separated into three distinct sets of problems (see Appendix A). Problems with a quotient of 1 (e.g., $6 \div 6$), problems that involved a 0 (e.g., $0 \div 4$), and inversion facts (i.e., $14 \div 2$ or $14 \div 7$, but not both), were excluded from the problem sets. Baseline and intervention outcome data were collected using these three sets of experimenter constructed division fact probes. The order of division problems within each probe was randomly assigned. For purposes of the intervention, three CD tracks, one for each problem set, were created using voice recording computer software. A track consisted of an experimenter reading a problem set that corresponded to an intervention worksheet. Specifically, the item number of each problem was read, and then the division fact was read at a rate of one utterance per second (e.g., *6... divided by ... 2... equals*). After the problem was read, a two second delay was present before the answer was provided. Each answer was in turn followed by a brief delay before the next item number was read. A track and corresponding worksheet was comprised of four repetitions of the problem set in randomized order. The intervention worksheets contained every problem on the corresponding CD track and a space to write each answer. In sum, a CD player, problem set CD tracks and corresponding intervention worksheets, headphones, assessment probes, a stopwatch, and a pencil were required to implement this study.

Experimental Design and Procedures

A multiple-probes-across-tasks (multiple baselines) design was used to evaluate intervention outcomes (Cuvo, 1979; Horner & Baer, 1978). This study used digits correct per two minutes (DC2M) by way of two minute assessment probes as the dependent variable. Each item on an assessment probe was worth only one digit correct as the answer for each problem ranged from two to nine (Deno & Mirkin, 1977). Therefore, the sum of all correctly answered problems within the two minute period of each assessment probe resulted in the DC2M score for that probe.

Assessment procedures. Assessment procedures were completed for each problem set for each of the initial four sessions (baseline phase). This was to obtain baseline data regarding all three problem sets. A stopwatch was used to time each of Emily's randomly ordered problem set assessment probes. She was directed to complete as many division problems as she could in two minutes, and when time was up, Emily was instructed to put her pencil down and wait for the next assessment probe (see Appendix C for assessment and intervention instructional scripts). At no point in the study's assessment procedures was Emily provided performance feedback. After the completion of the four baseline assessment sessions, the intervention procedures were initiated with Problem Set A. Before beginning an individual intervention session that targeted a specific set of problems, an assessment probe for that set of problems was administered. This data from the assessment probe prior to the daily intervention session constituted the dependent variable in this study. Problem sets not targeted by the intervention were sporadically probed. Maintenance data were collected using the procedures of the first three baseline sessions. The final two sessions (sessions 18 and 19) were collected one and two weeks following the final intervention session (session 17) respectively. This procedure was intended to determine whether effects were maintained over time.

Taped problems intervention procedures. After the initial baseline sessions, the first intervention session was implemented using Problem Set A. The following intervention procedures were used across problem sets and sessions. For each intervention session, the experimenter placed a problem set intervention packet face down on Emily's desk. The packet was comprised of division math fact problems that were numbered in the order of the problems provided on the corresponding CD track (see Appendix B for an example intervention worksheet). Emily was told that she would complete math problems while listening to a CD. She was instructed to follow along with the CD as it would read problems that matched her worksheets and also provide correct answers. Emily was directed to write her answer in the space provided on the worksheet after the problem was read, before the answer was provided. Hence, she was encouraged to try to *beat the recording* by writing each answer before hearing it on the CD. If she

incorrectly answered a problem, she was told to cross out the incorrect answer and write the correct answer provided by the CD (see Appendix C for instructional scripts). After the experimenter confirmed that Emily understood the intervention procedures each session, Emily placed headphones over her ears and pressed play on the CD player. When the CD was finished, she removed her headphones and the problem set intervention packet was collected.

Treatment integrity and interscorer agreement. Treatment integrity data were collected by a second experimenter during three of the ten intervention sessions (30%) using a treatment integrity checklist. The checklist included procedural steps such as: researcher placed problem set intervention packet upside down in front of the student, researcher read intervention directions verbatim, researcher instructed the student to turn over the packet, student pressed play on the CD player, etc. One hundred percent integrity was achieved. Interscorer agreement data were also obtained by having a second experimenter score 7 of the 35 assessment probes (20%) across baseline, intervention, and maintenance phases. Interscorer agreement regarding digits correct per two minutes (DC2M) across these assessment probes was 100%.

Results

Emily's DC2M performance across phases and sets of problems is displayed in Figure 1. Regarding baseline Set A, visual analysis reveals an increasing trend in performance across sessions one through four with the largest increase occurring between sessions one and two. However, a slight decreasing trend is present between baseline sessions four and five. Visual analysis of baseline data for Set B reveals a large increase in performance between sessions one and two, and a small increase in baseline performance thereafter. Baseline performance in Set C increased across sessions one through three, but no further improvement in Set C baseline scores manifested through session six.

Data included in the intervention phase reflects DC2M assessment scores obtained at the start of the next intervention session (delayed assessment), but before the next session's treatment was applied. A rise in DC2M delayed assessment data the session following the application of the TP intervention is present across problem sets. Figure 1 reveals seeming treatment inertia across sets when one considers change in performance across sets between the last baseline data point and the first delayed intervention assessment score (initial baseline-intervention latency period). For example, the difference in this performance measure is 3, 9, and 20 DC2M for Sets A, B, and C, respectively. Furthermore, increasing trends in performance are present during the intervention phase across sets of problems.

Maintenance of Treatment Effects

Intervention maintenance data are also presented in Figure 1. Visual analysis of problem Sets A, B, and C reveal sustained DC2M performance compared to the intervention phase and improved performance judged against baseline across problem sets. Maintenance phase data for Sets A and B also reveal increasing trends in division fact fluency. Furthermore, between baseline and intervention/maintenance phases for any given problem set, there is zero percent of non-overlapping data. All baseline data points for a problem set are below all intervention and maintenance data points for that set. The existence of non-overlapping data is a further indication of significant improvements of DC2M across problem sets (Daly, Chafouleas, & Skinner, 2005).

Treatment Acceptability Outcomes

Student and teacher acceptability data were obtained following the last intervention session. A student acceptability form (elementary readability) was read to Emily and she checked either *Yes*, *Maybe*, or *No* for each item. Emily indicated the TP intervention was fun, her division math fact speed and accuracy improved, and that others would like to learn math using the intervention. Her teacher also assigned favorable rating for the intervention. Overall, her teacher found the intervention to be an acceptable intervention for future use and would recommend it to others. The intervention was viewed as a time-efficient means to improve the math fact fluency of students with intellectual and developmental disabilities with no discernable negative side-effects.

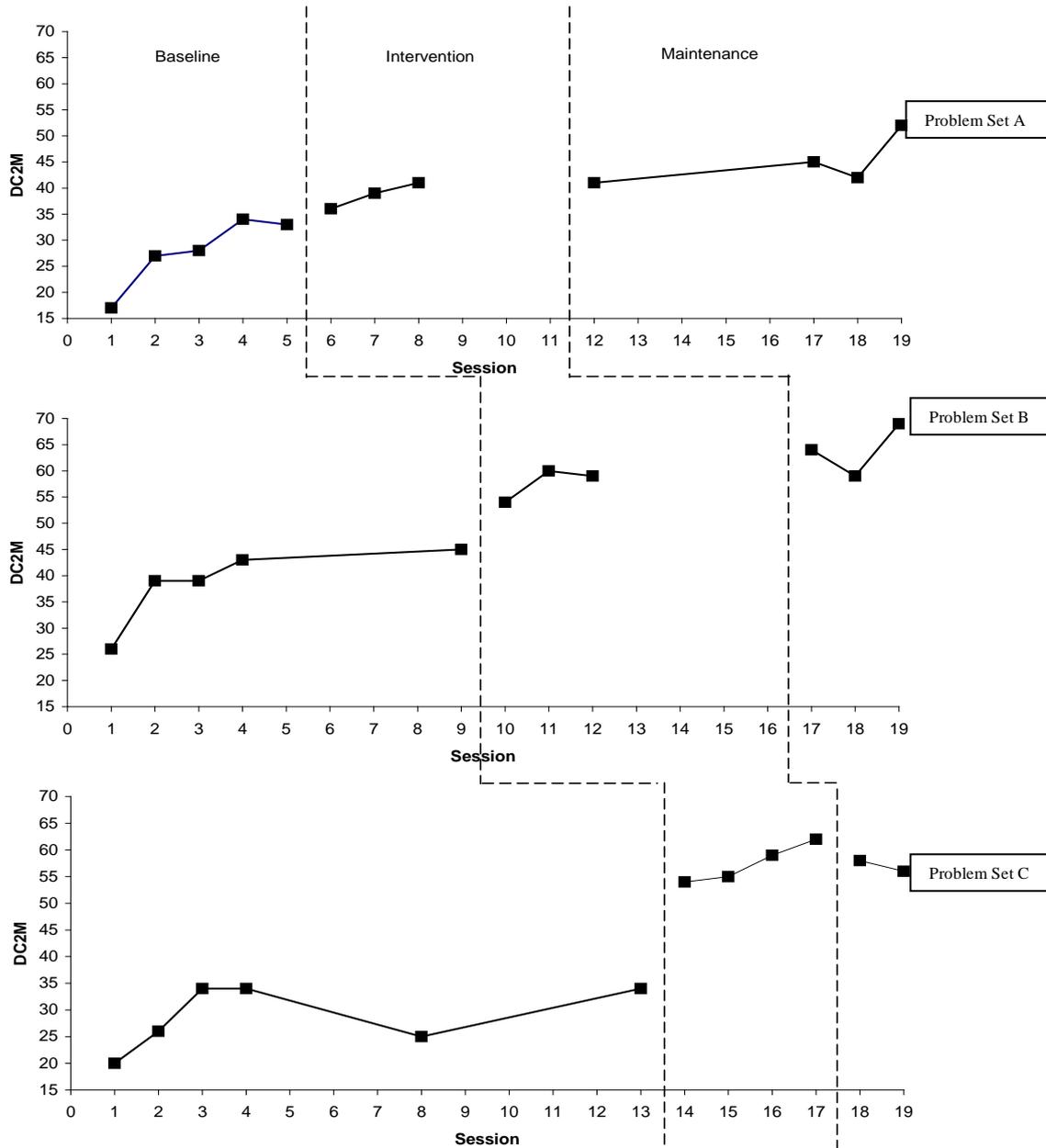


Figure 1. DC2M across problem sets and phases

Discussion

The TP intervention is an easily implemented, low-tech intervention for increasing math fact fluency. The current study adds to the TP literature supporting the procedure for use with students with intellectual disabilities. Results of this study demonstrated that across problem sets, the math fact fluency of a student with an intellectual disability increased immediately after the introduction of the intervention and was sustained following the removal of the intervention procedures. Furthermore, this study suggests that TP procedures can be self-monitored by students at learning centers.

Figure 1 depicts an increasing trend not only within problem sets but also across problem sets. As the study procedures progressed, Emily's response to the intervention was more pronounced. Following the first baseline phase (Set A), Emily's DC2M increased at a much less steep rate than following the introduction of the intervention to Sets B and C. A dramatic fluency increase is evidenced between the last baseline point in Set C (session 13) and the first intervention point in Set C (session 14). A possible

explanation for this across problem set's trend involves Emily's increasing familiarity with the TP procedures. Perhaps as the study went on, Emily became more accustomed to the procedures and was better able to focus on the elements crucial for success (answering the math facts quickly and accurately).

Given the immediate growth and sustained math fact fluency following the implementation of the intervention across problem sets, the practical implications of the current study are numerous. Math fact fluency is of importance for students with and without intellectual disabilities as their career and vocational experiences may require this skill (AAIDD, 2010). Therefore, this intervention may be used in an attempt to quickly remedy a student's basic math skill deficit when identified as a transition need. Additionally, the TP intervention is designed so that it can be tailored to the particular needs of a student or group of students. This study demonstrated that the TP procedures can be customized to the specific needs of a student with a significant disability. Furthermore, little teacher involvement is required beyond setting up and providing the materials. The current procedures were self-monitored by Emily as she wore headphones at a learning center in the back of the classroom. As most resource classrooms are comprised of students involved in various levels of academic skills, a self-monitored procedure may be particularly useful.

One limitation of the current study is that DC2M for problem Set A were increasing during the baseline phase. This limits the ability of the data to demonstrate a functional relationship between the intervention and DC2M for this problem set. It is unknown whether the increasing trend for Set A would have continued even without the introduction of the intervention. However, the clear demonstration of the experimental effect of the TP intervention on DC2M in problem Sets B and C offset this limitation to some degree. Additionally, the lack of overlapping data points between the baseline phase and intervention/maintenance phases across all three problem sets further supports the effectiveness of the intervention.

Another limitation of this investigation involves the generalizability of the current results. Because the study included only one student, the external validity of the positive results is limited. Unknown is if similar findings would occur after implementing the TP intervention with other students with intellectual disabilities. Future research should address the impact of the TP intervention on additional students with intellectual disabilities. As indicated earlier, Emily's intellectual disability stemmed from a cerebrovascular accident at birth. Although Emily responded well to the TP intervention, the response of students with intellectual disabilities of varying etiology is presently unknown. Given the origin of Emily's disability, it is plausible that some neuropsychological functions may have been spared and resulted in her ability to remarkably respond to the current procedures. In fact, Emily's teacher did report that one of Emily's strengths was rote learning, a skill involved in TP procedures. Future researchers might also consider response to TP procedures against unique patterns of neuropsychological functioning.

The TP procedure involves a variety of components that may account for its effectiveness in improving math fact fluency. These components include numerous opportunities for accurate, academic responding, immediate feedback on accuracy of responses, and reinforcement for correct responses. Future research is needed to determine which components of the TP procedures led to the demonstrated fluency gains.

The current study is a replication of previous TP intervention procedures in which a student with an intellectual disability self-monitored the procedures, resulting in immediate and sustained division fact fluency gains. (Carroll et al., 2006) This study provides further support for the TP procedure as a time- and resource-efficient method of improving math fact fluency that can be used with students across settings and populations.

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Appendix A

The Three Problem Sets

Set A	Set B	Set C
9/3	4/2	8/2
10/2	14/7	12/2
16/8	12/4	18/9
15/3	18/6	6/3
24/3	27/9	21/7
16/4	20/5	24/6
36/4	32/8	28/4
30/5	35/5	25/5
42/7	45/9	40/5
54/9	36/6	48/6
49/7	63/7	56/7
72/8	64/8	81/9

Appendix B

TP Assessment Probe Script

When you get your sheet, write your name at the top and then look up at me to let me know you're ready. DO NOT START THE PROBLEMS UNTIL I TELL YOU TO.

When I say Go, write your answer to the first problem (point to the first problem) and keep working until I say Stop. Try to work each problem. If you come to one you really don't know, put an X through it and go to the next one. If you finish the first side, turn it over and continue working. Are there any questions? Go.

At the end of 2 minutes: Stop. Put your pencil down.

TP Intervention Worksheet Script

You will be listening to some math problems on this CD with your headphones. Follow along on your worksheet going across the page and try to beat the CD by writing the answer to each problem before you hear it on the CD. If you miss a problem or can't think of the answer, write the correct answer when you hear it on the CD. Do your best and STAY WITH THE CD. If you need help, raise your hand and I will come help you. Are there any questions?

Appendix C
Sample TP Intervention Worksheet (page 1)

1.	$3 \overline{)9}$	2.	$4 \overline{)16}$
3.	$8 \overline{)72}$	4.	$4 \overline{)36}$
5.	$3 \overline{)24}$	6.	$5 \overline{)30}$
7.	$2 \overline{)10}$	8.	$7 \overline{)42}$
9.	$8 \overline{)16}$	10.	$9 \overline{)54}$
11.	$3 \overline{)15}$	12.	$7 \overline{)49}$
13.	$7 \overline{)42}$	14.	$8 \overline{)72}$
15.	$3 \overline{)24}$	16.	$2 \overline{)10}$
17.	$3 \overline{)9}$	18.	$3 \overline{)15}$