

Using 1-Minute Time Trials and 4-Minute Practice Sessions to Improve a Student's Performance of Fraction Problems

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This study examined the use of time trials with a high school student with behavior disorders for improving his math fluency in fraction problems. The target behavior was the number of correctly executed steps on mixed subtraction of fraction worksheet problems, while the intervention was the amount of time allotted during each time trial or practice session. A time series analysis (Cambell & Stanley, 1966) was used to evaluate the effects of different timing periods on the student's performance from 1-minute time trials to 4-minute practice sessions. During baseline, 10-minute practice sessions were used to establish the number of fraction problem steps completed per minute by the student. Data from this baseline were then compared to a two phased intervention using time trials and timed practice sessions. The first phase compared the number of correct fraction problem steps completed per minute by the student during the 1-minute, 2-minute, 3-minute, and 4-minute time trials. The variability in the data during this phase made it difficult to discern any meaningful differences from the four timing conditions. The second intervention phase compared the results of 1-minute time trials and 4-minute practice sessions to each other, as well as the phase one intervention results. The results showed an increase in the participant's math fluency, especially under the 1-minute timing condition. The data suggest a possible relationship between the student's performance and the length of the timings or fatigue factors. Implications regarding the length of timings and fatigue as related to performance were discussed.

When students progress through math curricula, they may not learn the necessary prerequisite skills fluently before moving onto more difficult math problems and concepts (Miller, Hall, & Heward, 1992). Accuracy measures alone do not reflect learning mastery of skills. All students who perform at the same level of accuracy are not equally skilled (Miller & Heward, 1992). The combination of the two dimensions of responding--accuracy and number of responses over time--gives a more complete picture of learning (West, Young, & Spooner, 1990). Haughton (1972) found that students who could calculate math problems at 30 or more digits per minute progressed easily to more complex mathematical skills. This combination of accuracy and speed of performance has been defined in terms of fluency or fluent responding. For example, two students working on the same math assignment both complete the assignment with 100 percent accuracy; however, one student completes the assignment in half the time of the second student. It is obvious that the first student is more fluent, demonstrating both accuracy and speed. This example illustrates the importance of emphasizing fluency in our classrooms rather than just focusing on accuracy.

Effective teaching of math skills must start with the concept that it is important for students to experience success (Mercer & Mercer, 1993). Various traditional and common approaches are employed in classrooms that attempt to promote successful acquisition of math concepts. Using traditional worksheets, working at the blackboard paired, and using manipulatives are but a few examples (Jacobsen, Eggen, & Kauchak, 1989; Callahan & Clark, 1988). Although many of these instructional strategies are commonly employed in the classroom, Lindsley (1992) pointed out that many of these procedures have not been empirically verified; thus, their effectiveness in terms of instruction appears questionable.

In terms of optimizing student performance in the classroom, Binder and Watkins (1990) advocated for the adoption and implementation of data-based instructional strategies which have long histories of success with students in a variety of settings. Examples of such data-based procedures include Direct Instruction (Carnine, Granzin, & Becker, 1988; Binder & Watkins, 1990), peer tutoring (McKenzie & Budd, 1981), criterion-referenced curriculums (Joseph & Cooper, 1991), Precision Teaching strategies (Sweeney, Omness, Janusz, & Cooper, 1992), and time trials (Miller &

Heward, 1992). In one investigation, Joseph and Cooper (1991) increased the math performance in multiplication, subtraction, and division of fourth-grade students through the use of data-based instructional procedures that included a criterion-referenced curriculum. In another study, Wilson and Sindelar (1991) increased the performance of students with learning disabilities in math word problems through the use of a Direct Instruction strategy. The search for effective, efficient, and innovative data-based procedures to develop students' fluency in math facts needs to be an ongoing quest in our schools.

Using time trials is another way to increase fluency of math skills within the community and in schools (Miller & Heward, 1992). As Howell and Lorson-Howell (1990) pointed out, rate per minute is a more sensitive measure of changes in performance than accuracy measures alone. Daily time trials provide students with the opportunities to improve their fluency, while at the same time, provide teachers with direct, frequent measures of each student's progress (Miller & Heward, 1992). Time trials help students improve their fluency by providing many opportunities to respond at a fast rate (Greenwood, Delquadri, & Hall, 1984). For example, Miller et al. (1992) showed dramatic academic and fluency improvements in math using time trials in a fourth-grade regular education classroom. Many educators may think that when someone is being timed or set under time constraints, performance would decrease. However, accuracy typically does not suffer, but usually improves, and existing data suggest that students enjoy being timed (Allyon, Garber, & Pisor, 1976). In fact, in a study conducted by Miller et al. (1992), 26 of 34 students indicated they liked time trials better than the untimed work period.

One of the biggest obstacles to mastery and fluency of math concepts is related to the maintenance and generalizability of the results across other curricula, other settings, and other response classes. As Cooper, Heron, and Heward (1987) and Stokes and Baer (1977) pointed out, one of the most frequent criticisms of behavior analytic research is the lack of attention to the need for programming for generalized behavior change. Several studies have shown the importance of programming maintenance and gener-

ality into intervention procedures (Koegel & Rincover, 1977; Sweeney, Salva, Cooper, & Talbert-Johnson, 1993; Van den Pol, Iwata, Ivanic, Page, Neef, & Whitley, 1981).

Binder, Haughton, and Van Eyk (1990) discussed the importance of developing instructional procedures for improving the performance duration or endurance of students in the classroom. It is probable that students with low attention spans may have difficulty generalizing academic behaviors because of the length of instruction (e. g., math seat-work) or fatigue factors related to the lack of programming for endurance within the classroom. This is true of generic classroom procedures, such as: seat-work, lectures, and small group activities, as well as many Precision Teaching strategies that emphasize short 1-minute timings to assess fluency. Students need to work intensely for short as well as long periods of time in the classroom. Strategies need to be developed that will build upon measurably effective instructional procedures, such as 1-minute time trials, to improve the duration and performance of students on a given task. Therefore, it is important that endurance considerations be taken into account for improving the duration of performance and to decrease the effects of academic fatigue and boredom when teachers are programming for generalized behavior change. This is the first study on the use of math time trials, that the authors could find, that investigates the possible effects of endurance programming on math performance of a high school student with severe behavior disorders.

The purpose of this study was to evaluate and improve the math performance, through the use of time trials, of a high school student with behavior disorders who expressed a dislike for math calculations, especially fractions. Fluency levels of 1-minute, 2-minute, 3-minute, and 4-minute time trials were combined with visual feedback from the Standard Celeration Chart, in an effort to improve the student's math performance. A secondary purpose of the study was to evaluate the student's repeated performance on 4-minute practice sessions that were immediately followed by a 1-minute time trial over the same material. This was conducted to assess the possible endurance effects as related to the increased performance

in the 4-minute practice condition, when compared to the fluency levels in the 1-minute timing.

Method

Participant and Setting

Bob was a 15 year old sophomore in high school who received special education services for students labeled as behavior disordered with severe social and emotional problems. Placed in a self-contained classroom at a hospital psychiatric unit, he received special education services due to academic and conduct-related problems in the regular classroom. Easily distracted by other students, Bob disliked doing math problems and had poor adaptive and social skills. Bob used profanity frequently; he also had difficulties when approaching his peers to request them for something.

The study took place in an enclosed office room between 1:00 and 2:00 p.m. Monday through Thursday when the student was present at school. Within the office room were a desk and chair, a portable tape-recorder and headphones, a copy machine, a file cabinet, and a telephone. The enclosed office was also used to eliminate any external stimuli in order for the subject to have maximum concentration. He liked to have all of the lights off except for one desk lamp when working on math problems. Bob also listened to his portable tape-recorder and headphones during the time trials to eliminate any additional audio stimuli.

Movement Cycle

The movement cycle was defined as the number of correctly written individual steps within a given five-step, mixed-number subtraction problem, completed per fraction, during a given counting period. The fraction problems were developed by the first author to ensure a consistent difficulty level. The first step to be counted was finding and writing down the common denominator. The second step was finding the number that needed to be multiplied to obtain that common denominator and writing it in both the numerator and the denominator places. The third step was multiplying and writing down the correct number in the numerator place. The fourth step was subtracting correctly. The final step was

determined if the answer was completely reduced. The five steps necessary to correctly complete each mixed number subtraction of the fraction problem were then multiplied by the total number of problems per probe sample. This means that on a 12 problem probe sheet, with 5 steps each per problem, the student has the possibility of completing 60 individual steps correctly. The author decided on 12 problems (i. e., 60 individual steps) after an informal assessment of the student's work production prior to the beginning of the study. The number problems were chosen for two reasons: 12 practice problems were consistent with the math homework that was often assigned to this student and rarely completed on time; and to ensure that the student would not complete all the problems during a given timing and ceiling out prematurely. Although it could be argued that if the student made an error on one of the early steps of a given problem, he would probably continue to err on subsequent steps due to the linear nature of the fraction problems. The first author did not observe this phenomena occurring during his pre-baseline and subsequent observations and is thus confident in the measurement procedures. The number of correct steps completed were totaled at the end of each session and charted by the first author.

Experimental Design

A time series analysis (Cambell & Stanley, 1966) was employed to evaluate the frequency of correct completion of steps in calculating fractions across different timing periods. The independent variable was the amount of time in each trial, and the dependent variable was the number of steps correctly completed while calculating fractions. This design allowed for a comparison of the fluency levels across time interval variances. The first phase of the intervention condition assessed the differential fluency levels of 1-minute, 2-minute, 3-minute, and 4-minute time trials. The second phase compared trends in fluency levels between the 1-minute time trials with the 4-minute practice sessions.

Baseline. During baseline the student was given a mathematics sheet with 12 mixed subtraction fraction problems and was shown each individual step. Bob was then asked to repeat the steps to ensure that he understood and was

able to perform each step. The experimenter gave the instructions by saying, "Complete as many problems as possible, and then stop when told."

Intervention. Two phases were implemented during the intervention. The first included alternating time trials in sequence from 1-minute, 2-minute, 3-minute, and then 4-minute trials. This sequence from 1 to 4-minute time trials was repeated three times. This phase was implemented to determine which timing period resulted in the highest number of correct fraction problem steps completed per minute. During the time trials the kitchen timer was set at the designated time and was visible to Bob throughout the interval. Bob was told the amount of time available for completion prior to beginning each set of problems. The experimenter would set the timer and say, "go," and the student would begin working on the fraction problems until the timer sounded. These timing procedures were consistent throughout the alternating treatment phase of the intervention. A break was provided for Bob while the experimenter corrected the mixed number fraction worksheet. Praise was given for his correct responses, and his current scores were compared to his previous performance as shown by the data on the Standard Celeration Chart. Corrective feedback was provided for incorrect responses, through modeling correct responses, before moving on to the next learning trial.

During phase two of the time trials, a 4-minute practice session was followed by a 1-minute time trial. These two intervals would always be paired together. If a 4-minute practice session were conducted, then a 1-minute time trial immediately followed. As many 4-minute practice sessions and 1-minute time trials were completed as time allowed during the hour tutoring sessions in the afternoons. Each 4-minute practice session and 1-minute time trial combination represented a separate session. An average of two or three pairings was conducted daily with a minimum of zero and a maximum of four. Factors influencing how many pairings could be conducted daily depended on Bob's activity level, lack of attention, and absence from class. Noncompliance required behavioral consequences by the experimenter which disrupted the flow and productivity of the session. If Bob asked any questions not

pertaining to the fractions, he was ignored or told that he was "off-task."

Practice sessions. The 4-minute practice session consisted of six steps. (1) The kitchen timer was set and remained visible for four minutes. (2) The student attempted to calculate the fraction problems. (3) The participant was allowed to ask any questions or ask for any help pertaining to the fraction problems during the 4-minute practice session. (4) The experimenter provided immediate corrective feedback when errors were made. For example, noting that the student had made an error, the experimenter would say, "What is the common denominator?" or "What is the answer to 18 divided by 3?" If Bob did not answer correctly after one verbal prompt, the experimenter would assist him in figuring the answer out correctly or model the correct response for the student if the assistance was not effective. (5) If he was "off-task" (i. e., not doing the fraction problems or engaging in activities other than those assigned), the timer would be stopped by the experimenter until work on the fraction problems resumed. Time off-task was not subtracted from the total time engaged in the instructional activity. (6) When a 4-minute practice session followed a 1-minute time trial, previous errors were reviewed and corrected at the beginning of the practice session. These procedures for the 4-minute practice sessions were consistently applied throughout the study.

Time trials. A 1-minute time trial consisted of four steps. (1) The student had to show readiness by having a pencil in his hand with the fraction worksheet on the desk in front of him. (2) The experimenter said, "When you begin, I will start the clock for a 1-minute time trial." (3) As soon as Bob began his work, the teacher started the count-down timer. Bob worked on his fraction problems and stopped his work when the count-down timer sounded. Unlike the 4-minute practice session, where feedback was provided while the student worked, no feedback was given during the actual 1-minute timing. Because feedback could detract or interfere with the student's ability to respond in a fluent manner during the 1-minute timing period, the teacher decided to wait until after this time trial to provide feedback and praise related to the student's work. (4) The student received a break while the author corrected the

worksheet and counted the number of correct steps completed. After counting the number of correct steps completed, the experimenter told Bob how many correct steps he completed, praised him for his effort, and compared the scores to his previous performance during the 1-minute timings. During the feedback sessions, the teacher and the student would negotiate a short- and long-term instructional aim related to the number of mixed subtraction fraction problems completed during the 1-minute time trials. Between trials and practice sessions, the student was often asked by the author, "How many steps do you think you can get this time?" or "What is your current record for the practice session?"

Reliability

Intergrader reliability was carried out by comparing the first author's recording to that of an outside observer. The fraction practice sheets were used as a permanent product recording. Reliability checks were carried out once during baseline and four times during intervention by an independent observer who regraded the worksheets. Reliability was calculated by summing the total number of correct step agreements and dividing them by combining the total number of correct step agreements and disagreements and then multiplying the quotient by 100. The reliability of the data of number of steps completed correctly was 100%.

Results

The overall outcomes indicated improvement in completing calculation steps with math fractions with the use of 1-minute time trials. Further, an endurance appears to have occurred during the 4-minute practice sessions over the duration of the study when compared to the fluency levels in the 1-minute time trials.

Baseline data showed that Bob completed only an average of 1.27 fraction calculations correctly per minute during a 10-minute session. This compares with average scores, during the alternating treatments phase, for the 1, 2, 3 and 4-minute time trials of 8.33, 6.33, 3.11, and 4.0 respectively, for fraction calculations steps correctly completed per minute. Results from Phase II of the Intervention condition generated

an average of 11.39 calculation steps correctly completed per minute during the 1-minute time trials, and 6.85 steps correctly completed per minute during the 4-minute practice session.

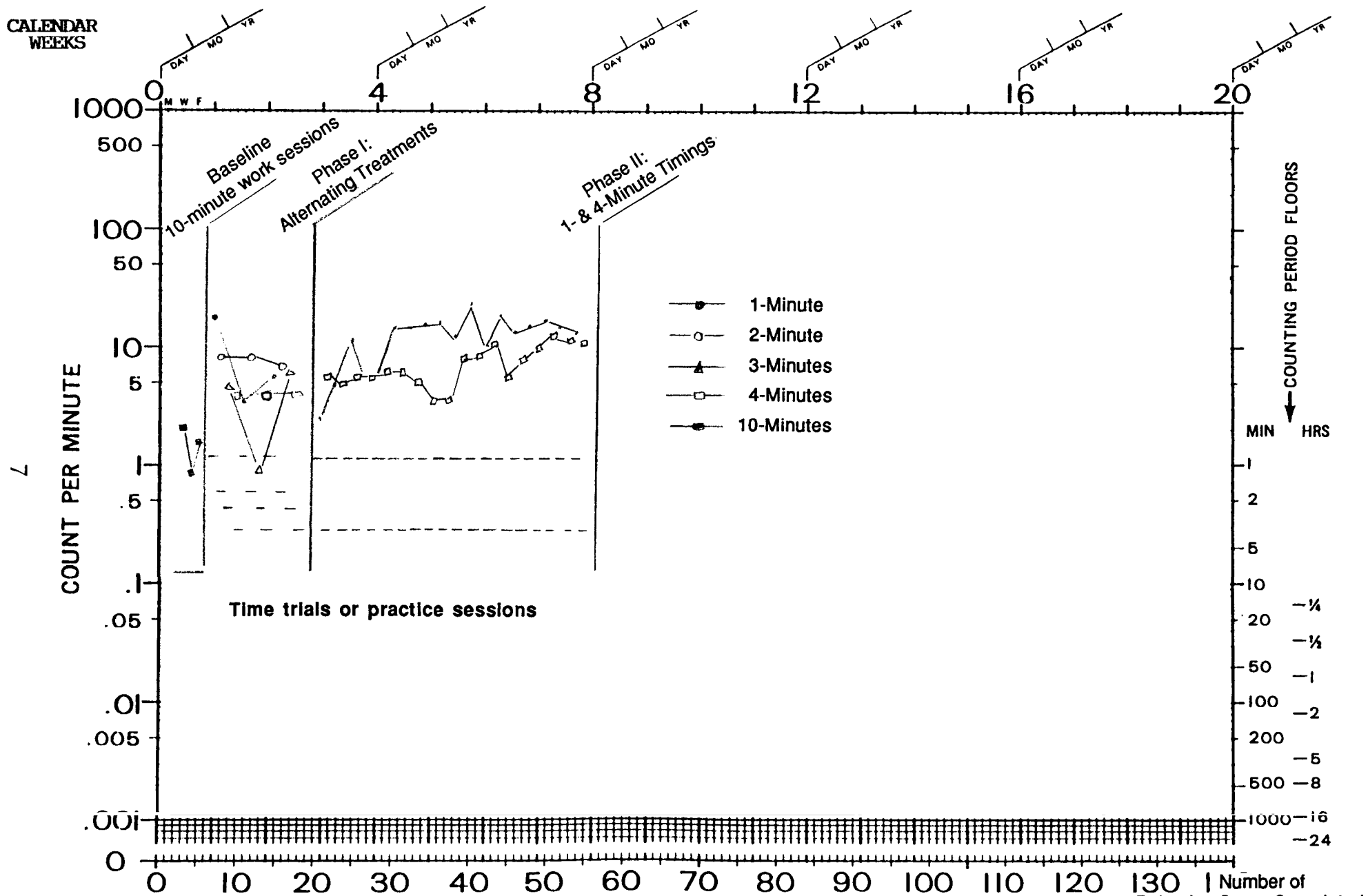
Although only three sessions of data were collected during baseline, the celerations of the number of correct steps completed appeared to be either decelerating significantly or showing no change (e. g., $x1.0$). Due to the large variability evident during the alternating treatment sessions of Phase I, it was difficult to determine appropriate celerations for the 1 and 3-minute timings. The celerations for the 2 and 4-minute time trials appeared to remain stable at a $x1.0$ celeration. Data from Phase II of the intervention condition appeared to initially jump-up during the first three sessions with celerations of $x2.0$ and $x3.0$ for the 1-minute time trials and the 4-minute practice sessions respectively. The overall data paths for both the 1-minute time trials and the 4-minute practice sessions showed accelerating trends with celerations of $x1.25$ and $x1.40$ respectively. The improvement in the celerations during the 4-minute practice session appears to indicate a possible endurance effect from the 1-minute time trials.

Discussion

Data from the present study suggests that the time trials in both Phase I and Phase II were effective for increasing overall, the performance of the student's fluency in subtraction fraction problems. Unfortunately, the data paths in the time series analysis in Phase I showed a great deal of overlap, and it was difficult to determine the differential effects of the levels of performance from the 1, 2, 3, and 4-minute timings. This process could be implemented in a regular education classroom with all students if teachers had the skills to implement the procedures correctly. Financially, this is an extremely practical procedure to implement and requires little effort by the teacher during instruction.

The time trials and practice sessions in Phase II of the intervention were chosen at 1 and 4-minute intervals since they differed most in terms of time. The student's performance dramatically improved initially with a jump up

CALENDAR WEEKS



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SUCCESSIVE CALENDAR DAYS

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Bob 15 Disordered Number of Behavior Steps Completed Correctly
 BEHAVER AGE LABEL COUNTED

at the 1-minute time trial during Phase II, and then Bob also began to set goals for himself during the 4-minute practice sessions. It was anecdotally observed that Bob was setting goals during the 1-minute time trials, as well as during the 4-minute practice sessions. This endurance effect from the 4-minute practice sessions to the 1-minute time trials showed increased performance and motivation when under time limitations. These time trials appeared to be effective at increasing the number of steps completed correctly since the student knew his aims during the time trial or practice session. Bob's performance appeared to support the claim that, "If you do not have a goal, there is nothing to shoot for!" By telling students about their best score and setting a new goal or instructional aim, the teacher is providing some incentive or setting the occasion for them to substantially improve their own performance. Further, when data are charted for the student to provide visual feedback, it may provide even more motivation to improve students' performance.

There were several limitations that must be considered when interpreting the results of this study. It was difficult to infer the existence of a functional relationship with this design because the researchers failed to return to baseline. Future studies using this type of experimental design could be strengthened by extending withdrawing the 1-minute time trials and extending the 4-minute practice sessions. This would help to determine whether the 1-minute time trials functioned as a means of improving the endurance of the 4-minute practice session or whether the sheer aspect of practice may have been more influential in the improvements with this student. Therefore, the results should be interpreted with caution.

The student's behavior and disability may also have limited the overall effectiveness of the intervention. The participant's erratic, oppositional, and off-task behavior may have contributed to a lack of overall experimental control as shown by the variability in Phase I of the intervention. It was evident that the student was often engaging in behaviors incompatible with those intended, expected, and implemented by the experimenter. For example, Bob would repeatedly strike the underside of the desk with his knee while sitting in his chair when he was

supposed to be doing the math problems. A further analysis should be conducted to isolate and provide alternate reinforcers that may exert a greater amount of control over the student's behavior.

Another potential limitation was the lack of a literature base that has explored the relationship between endurance effects and students' performance in math during time trials. It is evident from this study that further research needs to be conducted to verify the performance endurance demonstrated in this study and to determine the efficacy and social validity of this intervention with other populations. Further replication of these procedures should also examine, in more depth, the potential functional relations that may exist between students' math performance and the adoption of time trials in the classroom.

This study suggests some interesting effects on performance during seat-work activities when followed by a short 1-minute assessment of the skills being taught. The initial time series analysis, as shown in the baseline and Phase I of the intervention, seems to support the commonly held assumption by many Precision Teachers that the longer the duration of assigned work, the less produced by students. This would imply that endurance and fatigue may be important variables that need to be addressed during instructional programming for students. Further consideration may need to be given to developing interventions that can extend the duration of student performance without sacrificing speed, accuracy, and quality of the work production. Phase II of the intervention may provide one possible means of effectively programming to increase the duration or endurance of work performance while decreasing fatigue during instruction. For example, the data seemed to indicate that the student was becoming more fluent in correctly completing the number of mixed subtraction problems during the 1-minute time trials, as shown by the accelerating learning patterns in Phase II of the intervention. At the same time a concurrent acceleration was also evident during the 4-minute practice sessions. Although it would be premature to say that the improvements in the 4-minute practice sessions are a function of the concurrent 1-minute time trials, it does generate some interesting questions related to the

sequencing of instruction and the interval success of current instructional time intervals employed in many classrooms. Future research is needed to help determine the optimal time intervals necessary for sustained work performance and endurance in the classroom.

Time trials and timed practice sessions could be effective and efficient means for improving the overall math performance of students in the classroom. Further research should continue to explore the possible factors related to performance endurance from a given intervention across students, stimulus conditions, and response classes. Hopefully, a greater consideration of endurance and fatigue factors related to programming for generalized outcomes will improve the adoption and maintenance of measurably effective procedures for instruction, therefore resulting in the accelerated performance of students in our schools and communities.

This study should prompt other researchers to evaluate the effectiveness and efficacy of time trials and possible endurance effects during instruction. These procedures will hopefully be adopted and implemented in our schools to increase fluency of students and to maximize measurably superior instruction in the classroom.

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