The Use of Precision Teaching Techniques to Increase Mathematics Skills in Adults with Schizophrenia
Jennifer E. MacDonald, David A. Wilder, & Carl Binder

Precision Teaching in Developmental Mathematics: Accelerating Basic Skills
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Leaf’s Chart
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STATEMENT OF PURPOSE: As the official journal of the Standard Celeration Society the Journal of Precision Teaching and Celeration has dedicated itself to a science of human behavior founded on a technology of direct, continuous and standard measurement. This measurement technology includes: a standard unit of behavior measurement – frequency; a standard measure of change in behavior frequencies – celeration; a standard measure of the variability of behavior frequencies – bounce; and a Standard Celeration Chart to display frequency, celeration and bounce data. The Standard Celeration Chart enables chart based statistical procedures to determine changes in frequency-frequency jumps, changes in celeration – celeration turns and changes in bounce – bounce verge.

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The Standard Celeration Society (SCS) publishes the Journal of Precision Teaching and Celeration (ISSN# 1088-484X) annually. To join the SCS visit www.celeration.org or send SCS membership to SCS Administration, PO Box 3351, Kansas City, KS 66103. Membership dues: Student – 25.00 yearly membership includes reduced International Precision Teaching Conference rates; Regular – 50.00 yearly membership includes reduced International Precision Teaching Conference rates; Sustaining – 100.00 yearly membership includes reduced International Precision Teaching Conference rates; Institutional – 90.00 yearly membership includes one issue of the Journal of Precision Teaching and Celeration.
Ogden Lindsley defined Precision Teaching as a system for basing decisions on performance frequencies displayed on Standard Celeration Charts (SCCs). So as its foundation, all Precision Teaching occurs by evaluating data on SCCs. Out of the long history of Precision Teachers measuring and monitoring behavior on SCCs a number of interesting developments occurred. For example, behavioral fluency came about through the careful analysis of a number of academic performances and learning projects displayed on SCCs. In this present journal, Volume 22, two articles show how Precision Teachers have applied fluency intervention on SCCs. The first article discusses practice techniques which helped adults with schizophrenia improve their mathematics skills. The second article demonstrated how five students in an elementary algebra course accelerated their skills in basic mathematics operations. And a chart share shows how Precision Teaching helped a young man improve his vocabulary.

This journal also marks another transition. I will resume full time editing duties as Jesus Rosales-Ruiz turns over his responsibilities to me. I would like to extend a heartfelt thank you to Jesus who helmed JPT&C for 2 years and brought about a number of positive changes. Thank you Jesus!
The effectiveness of precision teaching techniques to teach basic math skills to 2 adults with schizophrenia was evaluated. Results suggest that the intervention increased the rate of correct answers to multiplication problems. In addition, during a follow-up phase, both participants maintained increased levels of correct responding and made few errors on problems learned to a fluency criterion.

DESCRIPTORS: Mathematics Skills, Precision Teaching, Schizophrenia

Schizophrenia is a chronic disorder that has a devastating impact on an affected individual’s life. The features of schizophrenia include a combination of positive symptoms, such as delusions, hallucinations, and disorganized speech, and negative symptoms, such as restricted emotional expression. “Dysfunction in one or more major areas of functioning such as work, interpersonal relations, or self-care,” (DSM IV, 1994, p. 285) accompany the symptoms of schizophrenia. Additionally, individuals with schizophrenia may exhibit difficulty acquiring and maintaining skills, are distractible, and have trouble concentrating or focusing attention, perhaps due to preoccupation with private stimuli such as voices (DSM IV, 1994). Functional deficits and severe impairment combined with attention problems result in a dilemma: individuals who desperately need skills training have problems attending, staying on task, and retaining information.

According to Roder, Jenull, & Brenner (1998), behavior therapy represents the “psychosocial treatment of choice for schizophrenia,” (p. 35), and evidence supports the efficacy of skills training with behavioral techniques for teaching various social and life skills to persons with diagnoses including schizophrenia (Dilk & Bond, 1996). However, much of the research has focused on what to teach, not on how to teach or how to measure intervention effectiveness. In addition, there is no mention of the use of frequency as a measure of skill acquisition. Therefore, precision teaching, with a focus on frequency-based instruction, is proposed as a possible addition to the procedures currently used for rehabilitating and instructing individuals with schizophrenia. Because acquisition and retention of novel skills is often a problem for individuals with this diagnosis, frequency-based instruction may be particularly helpful.

Precision teaching, founded by Ogden R. Lindsley, is a set of procedures used to measure performance and to evaluate the efficacy of any educational program, teaching technique, curriculum, or behavioral intervention (Beck & Clement, 1991). In other words, precision teaching is not itself a curriculum or a way of teaching, but a set of principles and procedures used to evaluate or measure the effectiveness of a curriculum and to guide instructional changes (White, 1986).

AUTHOR NOTES: This report is based on a thesis submitted by the first author in partial fulfillment of the requirements for the M.A. degree in psychology at the University of the Pacific. Jennifer E. MacDonald is now at Quality Behavioral Outcomes in San Francisco, CA. David A. Wilder is now at the Florida Institute of Technology in Melbourne, FL. The authors would like to thank Todd Fabien and Cris Clay, of the Community Re-Entry Program, for their assistance with the recruitment of participants and for providing the facility for conducting training sessions, and Ralph Pampino for his assistance with data collection. Request for reprints should be addressed to Jennifer E. MacDonald, Quality Behavioral Outcomes, 1 Embarcadero Center, Suite 500, San Francisco, CA, 94111 or David A. Wilder, School of Psychology, Florida Institute of Technology, 150 W. University Blvd., Melbourne, FL, 32901.
Principles in precision teaching include: the philosophy that the learner knows best; the environment impacts behavior; a focus on observable behavior; and the use of a standard chart to assess learning (Lindsley, 1990; West, Young, & Spooner, 1990; White, 1986). However, the use of frequency as a measure of response strength is perhaps the most important principle, and was considered by Skinner to be one of his most important contributions (Skinner, 1976). Although most use percentage correct as the usual measurement of performance strength in a variety of educational settings, this measure neglects speed of responding. According to Lindsley (1990), this focus on percentage correct as a measure of learning “produces highly accurate, painfully slow learners who have very low tolerance for error-filled, courageous learning” (p. 10). Additionally, rate of response was found to be at least twice, and often 50 times more sensitive, to environmental changes than was percentage correct (Lindsley, 1992). Vargas wrote that:

Teaching is not only producing new behavior, it is also changing the likelihood that a student will respond in a certain way. Since we cannot see likelihood, we look instead at how frequently a student does something. We see how fast he can add. The student who does problems correctly at a higher rate is said to know addition facts better than one who does them at a lower rate (Vargas, 1977, p. 62).

Binder (1996) defines fluency as “that level of accuracy plus speed that characterizes competent performance” (p. 164). According to Binder, the practice of precision teaching “set the stage for discoveries about relations between behavior frequency and specific outcomes, notably retention and maintenance of performance, endurance or resistance to distraction, and application or transfer of training” (p. 163). To become fluent, a learner must interact repeatedly with material until able to respond not only accurately, but automatically, effortlessly, and quickly (West et al., 1990). In essence, material is “overlearned” so that it may be performed without hesitation.

One of the selling points of precision teaching has been the claim that material learned to a accuracy only, will be retained for longer time periods. Some of the research on precision teaching and rate building techniques has focused on retention of the skills taught. For example, Olander, Collins, McArthur, Watts, and McDade (1986) compared traditional teaching methods with rate building methods to teach physiology to college students. The students taught with rate building techniques showed greater accuracy and speed of responding than did the group taught with traditional methods at an eight-month follow-up.

Shirley and Pennypacker (1994) taught participants two spelling lists, one to a criterion of rate and accuracy, and one to a criterion of accuracy only. Participants were exposed to both of these lists an equal number of times, and at a one-month follow-up, slightly greater retention was found for the list that was taught to the rate and accuracy criterion. Although the differences between the two lists were small, the authors suggest that higher rate criteria might have resulted in larger effects.

More recently, Bucklin, Dickinson, & Brethower (2000) taught college students relations between Hebrew symbols and nonsense syllables and Arabic symbols and nonsense syllables using either an accuracy-only criterion or an accuracy plus rate criterion. Participants in the rate building condition showed increased response rates after training. In addition, compared to the participants who were taught to an accuracy-only criterion, participants in the rate building condition showed better retention at 4 and 16-week follow-up sessions.

Although retention of skills learned via rate building techniques has been investigated with a variety of populations, no research has examined rate building techniques with adults who have a diagnosis of schizophrenia. In the present study, precision teaching techniques (i.e., use of rate as a measure, 15-sec timings, the use of the standard celeration chart to graph and provide feedback) were used to teach 2 individuals with schizophrenia multiplication facts. The main purpose of the study was to illustrate the use of these techniques to teach two adult members of this population. An additional purpose was to determine the extent to which skills are maintained when training continues beyond a criterion of 100% correct and focuses on speed of responding.
METHOD

Participants and Setting

Sue was 52 years of age and had a diagnosis of schizophrenia, paranoid type. Sue had good language skills and lived, with assistance, in an apartment. She attended a daily recreation/educational program which emphasized life skills such as job interviewing and appropriate social behavior. Mary was 49 years of age and had a diagnosis of schizophrenia comorbid with bipolar disorder. Mary had completed the eighth grade and lived in a group home with some of her peers. She also attended a daily recreation/educational program. Both of the participants were being taught math facts to assist in their ability to function in the community (e.g., their ability to pay for items, make change, etc.). Two to three sessions per week were conducted in a private classroom at a university-affiliated drop in socialization center for individuals with mental illness. A graduate student in psychology who had training in precision teaching and rate building techniques conducted the sessions. During instruction, the instructor and student were the only people present, except for one assistant who collected interobserver agreement and independent variable integrity data during some sessions.

Dependent Variable and Experimental Design

The dependent variable was the number of correct and incorrect responses/min spoken aloud to multiplication problems on a worksheet. Spoken answers were used instead of written answers because saying numbers was thought to be a more frequently used skill than writing numbers for these particular participants. Fifteen s timings provided the measure of the dependent variable; responses per 15-sec were converted into responses per min by multiplying by 4. Fifteen s timings were selected instead of 1 min timings to reduce exposure to the problems and to minimize any practice effects during baseline and during the “probes only” treatment (described below).

An ABCD design was used to evaluate intervention effectiveness. A multielement design component was used to compare two procedures during the third phase (i.e., the “C” phase) and the fourth phase (i.e., the “D” phase) of the study. The two procedures (i.e., probes + practice and probes only) were randomly alternated. The probes + practice condition consisted of 15-sec timings used to measure the dependent variable, in addition to frequency training. The probes-only condition consisted of 15-sec timings used to measure the dependent variable, but included no further training or practice (see further description of the design in Procedures).

Procedures

During baseline (i.e., the “A” phase), 15-sec timings were administered on one of 10 possible 80-problem worksheets generated randomly by computer. The rate of correct answers and of errors was graphed on a Daily per min Standard Celeration Chart (the results were not shared with the participants) and timings continued until the level of the dependent variable was stable and the celeration was less than 1.1 (i.e., there was less than a 10% increase/week).

The purpose of the Instruction phase (i.e., the “B” phase) of the intervention was to achieve accurate responding; speed of responding was not a focus. During this phase of the intervention, participants worked on achieving accuracy on one set of problems at a time (e.g., set 1 was 1 X 1, 1 X 2, set 2 was 2 X 1, 2 X 2, etc.) until all sets of problems (sets 1-10) were mastered. Procedures consisted of modeling how to use a practice worksheet, prompting participants to answer or to move on to the next problem, and correcting errors by stopping a participant after an error or after hesitations longer than 5-sec, modeling the correct answer, and allowing them to repeat the correct answer. Participants used multiplication tables to practice skip-counting upward by 2s, 3s, etc. and worksheets to practice multiplication problems. A cumulative “knowledge quiz” was presented at the end of a session. When either participant had difficulty with particular problems, the next day’s session was started with “extra practice” worksheets comprised exclusively of the difficult problems. The instructional sessions and quizzes continued until participants reached a criterion of 100% accuracy (i.e., they were able to answer all problems accurately within 5-sec of presentation and without prompting from the experimenter during a knowledge quiz that included all sets of problems). A 15-sec timing at the end of each session was also administered in order to provide a
measure of the dependent throughout all phases of the study.

During the practice phase (i.e., the “C” phase) of the intervention, the total number of multiplication problems was randomly divided into Set A and Set B. The probes-only condition was applied to one set of problems and the probes + practice condition was applied to the other set of problems. In addition to random assignment, one participant learned Set A problems during the probes + practice condition and the second participant learned Set B problems during the probes + practice condition to control for differences between the two sets of problems. During this phase, participants attended two sessions each day, one session for each of the two conditions. The probes-only condition consisted only of 15-sec timings used to measure the dependent variable and included no further training or practice. The probes + practice condition consisted of 15-sec timings in addition to frequency training.

During frequency training, participants engaged in frequent practice (i.e., 2-3 times per week), with an emphasis on fluency, or accuracy plus speed of responding. Procedures included 1 min practice timings, goal setting, prompting, and verbal feedback. For incorrectly answered problems, the experimenter modeled reading the problem and the correct answer, and then retested the participant until she answered the problem correctly. At the end of each session, a 15-sec timing on that set of problems provided the measure of the dependent variable. The experimenter graphed the results of the Treatment 2 set on a Daily per min Standard Celeration Chart and shared the results with the participant. The experimenter provided feedback relative to the previous day’s performance and relative to the aim range of 60-90 whole answers (e.g., “sixty-four”) per min. This aim range was obtained by administering the math worksheets to a small group of competent adult performers and recording the number of correct problems spoken per min.

During the probes-only condition, the participants only completed a 15-sec timing. The experimenter also graphed the results of the session on a Daily per min Standard Celeration Chart, but did not share the results with the participants.

Sue maintained an adequate celeration (i.e., an increase in the rate of responding over time) and reached the goal within a few sessions, so no procedural adaptations were made. However, Mary’s frequency was “flat” (i.e., no increase in the rate of responding over time) after the first three sessions, so the procedures were adapted. These adaptations were determined based on Mary’s report of the source of her difficulties. For the first adaptation (sessions 37 and 38), Mary reported that she was having trouble resuming the task after she paused, so she was stopped during 15-sec timings whenever she paused for more than 1-sec. Then, the timing was re-started. This adaptation was not effective and resulted in a relatively large increase in errors and no change in correctly answered problems. During the next adaptation, two additional types of worksheets were used (sessions 39, 40, 41). On the first set of worksheets (“easy”), commonly missed problems were extracted. On the second set of worksheets (“hard”), only previously extracted problems were included. At Mary’s request, one additional adaptation was made (Sessions 42, 43, and 44); she “warmed up” by completing the entire worksheet once with no time limit before starting the 15-sec pull-out timings.

This treatment phase continued until the participants reached a fluency criterion for the probes + practice problems (i.e., they performed at a rate that fell within the aim range of 60-90 corrects/min, and committed errors at or below the rate exhibited during the instruction phase). Each participant continued practice sessions until her rate of correctly answered problems fell within the aim range for at least three consecutive timings.

During the Follow-up phase (i.e., the “D” phase), participants no longer received frequency training, but completed a 15-sec timing on each set of problems. Timings were administered on the same day, and the order was determined randomly. Timings were administered approximately once a week for 4 weeks.

**Interobserver Agreement**

A trained observer collected Interobserver Agreement (IOA) data during 54% of Mary’s timings across all phases and agreement averaged 99%. IOA data were collected during 48% of Sue’s timings across all phases and agreement averaged 99%. Agreement was obtained answer by answer during a session, and total agreement was
by the number of agreements plus disagreements and multiplying by 100.

Independent Variable Integrity

A trained observer conducted treatment integrity checks. For the Instruction phase, percentage agreement was obtained across the six intervention elements (count-bys modeled, multiplication tables with answers modeled, use of prompting during practice, use of error correction during practice, and use of promoting during knowledge quiz). For the Practice phase, percentage agreement was obtained across the three intervention elements (use of prompting during timings, use of goal related feedback, use of error correction) during the session and the presence or absence of three elements (15-sec timing conducted, errors and correct charted, performance feedback provided) at the end of the session. For Sue, checks were not conducted across instruction sessions due to resource constraints. Checks were conducted across 42.8% of practice sessions for Sue and agreement averaged 97.2%. In addition, all three elements from the end of session checklist were completed 100% of the time. For Mary, checks were conducted across 38.5% of instruction sessions and agreement averaged 100%. Checks were conducted across 72.7% of practice sessions and agreement averaged 99.8%. In addition, all three elements from the end of session checklist were completed 100% of the time.

RESULTS

Figure 1 depicts Sue’s performance across phases. During the baseline phase, Sue made as many errors as she did correct responses. During the instruction phase, errors decreased and correct responses increased, and a fair amount of variability in correct responses is apparent. Sue achieved 100% accuracy during this phase. During the practice phase, Sue completed more probe + practice problems per min and committed fewer errors per min than probe-only problems; the mean percentage correct for probe-only problems was 85% while the mean for percentage correct probe-practice problems was 99%. In addition, an increasing trend is evident in the rate of correct probe + practice responses in this phase. During the follow-up phase, Sue continued to complete more probe + practice problems per min (range 72-84) than probe-only problems (range 32-64), and committed fewer probe + practice errors per min (range 0-4) than probe-only errors (range 4-12). The mean percentage correct for probe-only problems was 80% while the mean percentage correct for probe-practice problems was 99%.

Figure 2 depicts Mary’s performance across phases. During the baseline phase, Mary made as many errors as she did correct responses. A decreasing trend in the rate of correct responses is evident. During the instruction phase, errors decreased and correct responses gradually increased. Sue achieved 100% accuracy during this phase. During the practice phase, when compared to probe-only problems, Mary completed more probe + practice problems per min and committed fewer errors per min. The mean percentage correct for probe-only problems was 73% while the mean percentage correct for probe + practice problems was 94%. In addition, an increasing trend in the rate of correct probe + practice responses is apparent. During the follow-up phase, Mary continued to complete more probe + practice problems per min (range 64-72) than probe-only problems (range 28-36), and committed fewer probe + practice errors per min (range 0-4) than probe-only errors (range 14-16). The mean percentage correct for probe-only problems was 67% while the mean percentage correct for probe + practice problems was 97%.

DISCUSSION

In the present study, precision teaching was used to measure the effectiveness of an instructional package designed to teach 2 individuals with schizophrenia multiplication facts. After reaching a criterion of 100% accuracy during an Instruction phase, both participants demonstrated further performance improvement (i.e., faster responding and fewer errors) during frequency training for the set of problems trained to a criterion of fluency. Probes on the problems trained only to accuracy did not show further improvement. Follow-up probes indicated that treatment gains for problems trained to a fluency criterion maintained over a four week time period. This suggests that even when a learner can perform a
Behaver: Sue

Successive Calendar Days (by weeks)

Target: See/say math facts (X)

Figure 1. Rate of correct and incorrect responses to multiplication problems for Sue.
Figure 2. Rate of correct and incorrect responses to multiplication problems for Mary.
skill with 100% accuracy, additional benefits may accrue when further instruction is provided and a focus on teaching to a criterion of fluency is utilized. This study provides additional evidence for the effectiveness of rate building techniques on retention of material with a novel population (i.e., adults with schizophrenia).

Anecdotal observations revealed that as the participants became more fluent, they both increased the tone and volume of their voices and improved their posture. Sue boasted about the speed at which she was able to perform, jokingly commenting that “I should call Guinness (Book of World Records).” Mary reported that she now helped her daughter balance her checkbook, and her employment supervisor at the Center approached the experimenter and said that Mary’s new work responsibilities included tabulating numbers because her skill level now surpassed his.

It is possible that effective teaching of academic and vocational skills to members of this population may help them to become more independent. Adults with schizophrenia are known for their lack of motivation (this is mentioned as a symptom or outcome of the disorder in the DSM IV). Any new or improved skill may assist them to obtain or maintain employment or develop improved social relationships. In behavioral terms, the acquisition of new skills may establish certain types of interactions as reinforcers, which may also increase the likelihood of engagement in behavior that produces access to these reinforcers.

One limitation of the study involves the lack of control for exposure to the learning material. That is, during the practice phase, participants had more exposure to the material in the “probes + practice” condition that they did in the “probes only” condition. This additional exposure to the material, as opposed to the way in which the material was taught, could have been responsible for the improved performance in the “probes + practice” condition at follow-up. Nevertheless, this limitation does not negate the finding that teaching beyond a criterion of 100% correct improved retention among participants, which was a focus of the study.

Another limitation of the study involves the experimental design. The change from baseline to instruction was done in an AB fashion.

That is, because a more rigorous experimental design was not employed, it is difficult to determine whether or not the intervention was responsible for the changes in performance exhibited by the two participants.

Additional limitations of the study include the small sample size and the restricted subject matter. Replications across materials and across individuals are warranted. For example, future research should explore the use of precision teaching with more functional skills, such as medication management or daily living skills. The maintenance of treatment gains over longer follow-up periods represents another important area for research.

Overall, the results of this study support rate building as a viable addition to skills training programs for individuals with schizophrenia. The addition of the time dimension to measurement of performance revealed that participants achieved a level of performance beyond the standard of 100% correct, and that training to a criterion of accuracy only does not ensure performance fluency. Implications for programming suggest that adding a time dimension to practice is critical, and that an individual’s objectives should reflect both accuracy and speed of responding.

REFERENCES


Five students placed in an elementary algebra course as a prerequisite to the university-level mathematics requirement participated in 12 sessions of a fluency-building program designed to accelerate skills in the basic mathematics operations of addition, subtraction, multiplication, and division over a period of six to nine weeks. The interventions consisted of 2 to 8 1-min timings solving single digit mathematics problems. Increases in response frequency were seen for all participants. Results indicated that improvements in the frequency of correct responses in basic mathematics operations were related to increases in the final course grade in the developmental mathematics course of participating students as compared to non-participants.

DESCRIPTORS: Mathematics, Precision Teaching, Fluency

For many years, colleges and universities have struggled with a trend indicating that a portion of students who meet admission standards fail to demonstrate mastery of mathematical skills sufficient for placement into the required mathematics courses (Akst and Hirsch, 1991). There is great variability in how different institutions determine readiness for university-level mathematics instruction. Trends indicate that at least one third of entering college students are placed in developmental mathematics courses through entrance examinations because they fail to demonstrate the necessary preparation for university level mathematics courses (Boylan & Saxon, 1998; McCabe & Day, 1998; Stratton, 1998). The failure of many students to master basic mathematics skills poses challenges not only to university admissions committees, but also to mathematics faculty charged with readying these students for university-level instruction. Students may be attracted to universities by admissions practices that maximize enrollment, but often find that the academic and social supports for their success disappear shortly after their arrival on campus (Jackson and Mallott, 1994).

Developmental mathematics programs have been designed in response to these challenges. The primary goal of developmental mathematics courses must, then, be to improve sufficiently students' mathematics skills to provide them the same opportunity as their peers to successfully complete university mathematics requirements. To bring about such rapid and deep changes in student repertoires, measurably effective instructional practices must be utilized.

Precision Teaching is a method of assessing the outcomes of instruction at the level of the individual that is sensitive to changes in the frequency of behavior over time (White and Harring, 1980). The measurement system that makes these changes detectable is the Standard Celeration Chart. This system allows measurement of progress “toward clearly defined instructional objectives and stated criteria” (Neal, 1981, p. 290). Thus, Precision Teaching does not prescribe content or pedagogy, rather it can be combined with any curriculum or method to sensitively monitor and assess relevant changes in performance and to guide instructional decision-making (Lindsley, 1997).

Precision teachers provide students frequent opportunities to practice skills, called frequency-building exercises, until true mastery, or fluency, is evident in learners’ performances. “Fluency building refers to the process of promoting more fluent responding,” thus occurring after skills have already been acquired (Wolery and Sugai, 1988, p. 281). Increasing rapid and accurate responding is
important because we often assume that a learner’s failure to achieve a particular learning goal is a function of their motivation or dedication to the goal. However, it is more often the case that the learner lacks the foundation skills, adequate supports, or prerequisite knowledge to manage the level of task difficulty that they face. Given that the function of developmental mathematics course is to prepare learners for advanced studies, the development of fluency in basic mathematics is a vital component of meeting these course goals.

Through years of research and practice, practitioners of Precision Teaching have discovered a relationship between expert performances and later retention and application of knowledge. When behavior is fluid, automatic, or effortless, it is referred to as fluent. Fluency of a skill is important not only because it better describes true mastery of a skill than does accuracy alone (Binder, 1996), but it is also predictive of a number of significant outcomes of learning. For example, “retention and maintenance of skills and knowledge; endurance or resistance to distraction; and application or transfer of training” are consistent outcomes of learning that is fluent (Binder, 1993, p. 9). Cumulative disfluency can result from failure to develop true mastery of foundation skills (Johnson & Layng, 1992; McDowell & Kennan, 2001).

Universities are often faced with students who have this unbalanced collection of skills and must find ways to be effective in spite of absent student foundation skills. Fluency of basic skills is important if more complex skills are to also reach fluency, thus expectations for basic skill mastery must be stated in light of terminal goals. Research has indicated that correct response frequencies for simple skills such as writing the number 1 or naming pictures can be expected at levels of 200 per minute (Johnson and Layng, 1992); studies directly measuring solving mathematics equations indicate that up to 125 correct responses per minute can be expected in learners who are fluent (Wolery and Sugai, 1988).

The purpose of the present study was to determine if increases in component skill frequency would increase the mastery of composite skills. This question was addressed through the addition of brief, rapid practice sessions of basic mathematics operations outside the context of a not-for-credit university course in algebra. The effect of this intervention was evaluated through the measurement system of Precision Teaching. All students were expected to master mathematical computations with the appropriate experience.

METHOD

Participants

Seven undergraduate students enrolled in a developmental mathematics course taught by the second author volunteered to participate. Five students completed the study.

Students enrolled in the developmental mathematics course for one of two reasons: it was required by a university placement evaluation, or they were self-selected for additional skill building before enrolling in the required university-level mathematics course. Students required to take this course were identified by a score of 45 (out of a possible 120) or less on the Accuplacer mathematics entrance test, or through a need detected in the evaluation of their application for admission to the university. Participants’ average Accuplacer score was 42.37 (SD = 5.76).

All volunteers were female and taking courses at this university for one semester or less as either entering freshman or transfer students. Participants were from one of the following two age groups: 17 to 19 year olds, or 30-40 year olds.

Participation was voluntary and was compensated only by the opportunity to develop basic mathematics skills and the chance to receive tutoring and support in the completion of developmental mathematics coursework from the research assistants.

Matched Control Non-Participants

Seven students from the same course and section of the developmental mathematics who did not participate in the study were selected as matched controls. Because control non-participants were directly matched to study participants, when two participants left the study, their matched controls were also removed from all analyses, thus data from five matched control participants are presented.

Control non-participants were selected because they most closely resembled a study participant on the following three criteria, in order of importance: score on Exam 1 in the developmental
began work on the first problem.

**Baseline.** A baseline measure of the participant's number of correct responses per minute on basic mathematics problem solving was taken. The baseline included two to three one-min timings on the four basic mathematics operations. Breaks were provided between one-min timings to prevent fatigue. The purpose of this session was to familiarize participants with the format of later sessions. No feedback was given during the baseline session.

For participants Anne, Elizabeth, and Jane, the baseline was taken for each operation across two one-min timings during four of the odd numbered sessions where session one tested addition, session three tested subtraction, session seven tested multiplication, and session nine tested division.

Baseline for participants Alicia and Lucy was conducted for all four mathematics operations during session one and repeated in session 12 with three one-min timings per operation.

**Frequency-Building Intervention.** Participants Anne, Elizabeth, and Jane received 8 timings per session. They received two sessions containing three timings each with the following sequence of problems: addition, subtraction, mixed addition and subtraction, multiplication, division, and then mixed multiplication and division. Table 2 details the operations that these participants experienced in each session. Their goal was to reach 80-100 correct responses per minute (Johnson and Layng, 1992).

Participants Alicia and Lucy completed between three and 12 timings (with a modal score of eight) per session. They were scheduled to practice each basic mathematics operation during two timings per session. The number of timings and type of mathematics operation included on the worksheet for each participant per session can be seen in Table 2. Their goal was to make successive

<table>
<thead>
<tr>
<th>Pre-Intervention Measures</th>
<th>Participants</th>
<th>Matched Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>First Examination*</td>
<td>75.72</td>
<td>12.92</td>
</tr>
<tr>
<td>ACCUPLACER Placement Test Score **</td>
<td>42.37</td>
<td>5.76</td>
</tr>
</tbody>
</table>

Note: * = On a scale from 0 to 100, ** = Scores on an ACCUPLACER Test have a possible high score of 120.
increases in the number of correct responses per minute by achieving a total score per session that was ten percent greater than their best score on the previous session for each mathematics operation. If a participant did not meet their goal for one operation, they did not move on to practice the remaining operations in that session. After three sessions where a learner did not meet this goal, it was changed to 80-100 correct responses per minute.

Encouragement and praise was provided to all participants upon completion of each timing. At the end of each session, the research assistant identified participant’s strengths and areas for improvement. Table 2 illustrates the number of correct responses for each operation for each participant.

Table 2. Mathematics Operations and Number of Timings by Participant During Intervention

<table>
<thead>
<tr>
<th>Session</th>
<th>Anne</th>
<th>Elizabeth</th>
<th>Jane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Add</td>
<td>Sub</td>
<td>Mult</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>8</td>
<td>8</td>
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<tr>
<td>4</td>
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<tr>
<td>11</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

Note: In phases 5, 6, 11, and 12, participants Anne, Elizabeth, and Jane received practice on both of the previous operations in a single timing.

<table>
<thead>
<tr>
<th>Session</th>
<th>Alica</th>
<th>Lucy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Add</td>
<td>Sub</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>0</td>
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<tr>
<td>5</td>
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<tr>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2</td>
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<tr>
<td>8</td>
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<tr>
<td>9</td>
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<td>2</td>
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<tr>
<td>10</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
improvement on the development of basic mathematics skills. Participants were thanked for their time and offered additional worksheets to practice these skills at home. Participants were also offered the opportunity to discuss course work and to develop skills in their algebra class.

Measures

The effect of the frequency-building intervention on the development of the component skill of basic mathematics operations was evaluated on the Standard Celeration Chart by plotting the highest number of correct responses on a single timing for each operation in each session. Performance on the composite skill of mastery of elementary algebra was evaluated by examining scores on the in-class quizzes, examinations, and student grades in this and other courses.

RESULTS

Learners in this study were enrolled in a developmental mathematics course to address skill deficits in elementary algebra. Following the first examination in this course, an intervention to increase foundation skills necessary for success in the course was offered. Five students completed the intervention. In order to evaluate the effect of the frequency-building exercises for basic mathematics operations on participants’ performance in the developmental mathematics course, within-subject and between-group analyses were conducted.

Within-Subject Analyses. The number of correct and incorrect responses per one-min timing on each of the four basic mathematics operations is depicted on a Standard Celeration Chart for each participant. Learners Anne, Elizabeth, and Jane experienced one operation per session for two successive sessions and had a goal of performing 80-100 correct movements per minute. As can be seen in Figure 1, gains in the frequency of correct responding were seen for Anne in addition, subtraction, mixed addition and subtraction, and division problem solving. The frequency of correct responding decreased for multiplication and remained unchanged for mixed multiplication and division problem solving over the course of the intervention.

Elizabeth showed increases in the frequency of correct responding for each of the operations in isolation (e.g., addition, subtraction, multiplication, and division). Responding to mixed timings for addition and subtraction remained unchanged during the course of the intervention, while the mixed multiplication and division scores actually decreased. Figure 2 depicts these results.

In Figure 3, gains in the frequency of correct responding were seen in all operations for Jane, in isolation and in the mixed timings. Alicia and Lucy were expected to experience each operation each session. However, both participants failed to meet the performance goal of a 10% increase over their previous score on a given operation for the first three intervention sessions. This procedure was designed to reduce frustration when a goal was not met. Results indicated that failure to meet this goal also functioned to reduce the opportunity to practice other operations and was, therefore, abandoned after three sessions. Thus, Figures 4 and 5, representing the performance of Alicia on addition and subtraction, and multiplication and division, respectively, show no data for the sessions where operations were not practiced. The same results can be seen for Lucy in Figures 6 and 7. Thereafter, they practiced each operation twice each session from session five to session 12. Their goal was a frequency of 80-100 correct responses per minute. Overall increases in the frequency of correct responses were seen for addition, subtraction, multiplication, and division problem solving for both participants.

Only one participant in one operation obtained the performance goal of 80-100 correct responses per minute: Lucy for subtraction problem solving. Errors remained at low rates throughout the study for all participants.

The average number of problems correct on each of the four mathematics operations at the beginning of the study and the corresponding average at the end of the study for each participant is depicted in Figure 8. An average increase of 6.14 (SD = 4.98) correct responses per minute was seen for addition problem solving, 7.66 (SD = 6.53) for subtraction, 5.44 (SD = 7.71) for multiplication, and 8.04 (SD = 4.12) for division across the five participants.

Between-Group Analyses. Students in the developmental mathematics course who entered the study and the matched control students who did not participate
Figure 1
Standard Celeration Chart for Anne: Addition, Subtraction, Multiplication, and Division

Likeness of Daily Per Minute Standard Celeration Chart
6 Cycle - 140 Days (20 Weeks)
Behavior Research Co.
Box 3351 - Kansas City, KS 66103 Fax: 913-362-5800
www.behaviorresearchcompany.com
Figure 2: Standard Celeration Chart for Elizabeth: Addition, Subtraction, Multiplication, and Division
Figure 3

Standard Celeration Chart for Jane: Addition, Subtraction, Multiplication, and Division
Figure 5
Standard Celeration Chart for Alicia: Multiplication and Division
Figure 6
Standard Celeration Chart for Lucy: Addition and Subtraction

CALENDAR WEEKS

SUCCESSIVE CALENDAR DAYS

COUNT PER MINUTE

PERFORMER: Lucy

SUPERVISOR
ADVISER
MANAGER
DEPOSITOR
AGENCY
TIMER
COUNTER
CHARTER

PERFORMER
AGE
LABEL
COUNTED

Likeness of Daily Per Minute Standard Celeration Chart
6 Cycle - 140 Days (20 Weeks)
Behavior Research Co.
Box 3351 - Kansas City, KS 66103 FAX: 913-362-5600
WWW.BEHAVIORRESEARCHCOMPANY.COM
Figure 7

Standard Celeration Chart for Lucy: Multiplication and Division
Figure 8
Learning Gain in Basic Mathematics Operations Across Participants
had similar rates of class attendance, and similar scores on the placement test for mathematics upon entering the course. However, when comparing performance of the participants in the study to subjects selected as matched controls, important post-intervention differences became evident (Table 3 contains the between-group post-intervention comparisons).

Students in both groups completed two examinations, a cumulative final examination, and 13 quizzes in the elementary algebra course. Performance on the first examination averaged 75.72 percent for participants (SD = 12.92) and 74.28 (SD = 8.34) for matched controls. The intervention began after the first examination.

On the second examination, the average performance of the participants in the study exceeded the matched control group by 15 percentage points (X = 81.46%, SD = 12.01, and X = 66.50%, SD = 13.81, respectively). Scores on the cumulative final examination also differentiated the two groups, with the average score for participants in the study 11 percentage points higher than that of the matched control group (X = 87.02%, SD = 14.19 and X = 76.92%, SD = 9.75, respectively). A difference was also observed between participants in the study and the matched control group on the average quiz grade, favoring participants by 16 percentage points (X = 85.30%, SD = 8.03 and X = 69.88%, SD = 9.51, respectively).

Final course grades for participants were also higher than those in the matched control group. This difference in performance is represented by an average grade in the elementary algebra course of a 3.28 on a 4.0 scale (SD = 1.11), for the participants and a 2.26 (SD = 0.65) for the matched control group. These scores represent letter grades in the course of nearly B/B+ (3.30 is a B+) for participants and C/C+ for non-participants. Further increases were noted in the participant's cumulative grade point average at the university. Participants in the study earned an average cumulative grade point average of 3.41 (SD = 0.30), as compared to 2.97 (SD = 0.53) in the matched control group at the end of their first semester of college.

**DISCUSSION**

The goal of the current project was to increase the component skills of learners in a developmental mathematics course to increase their mastery of more complex composite skills in math through the application of short, frequent, and fast practice with frequency-building aimed at achieving expert levels. Results indicated that although the gains in the fluency of basic mathematics operations were meager (a few correct responses per minute, and still appearing at less than expert levels), meaningful increases in course mastery beyond the predicted preintervention levels were observed as compared to the matched control group. Precision teachers often analyze the component skills necessary for success in a composite performance. Using this method, it can be said that increases in complex skills were noted, despite small gains in the frequency of component skills. Precision Teaching utilizes a measurement system designed to detect changes in the development of a skill that will ensure later retention of concepts, even with periods of no practice; endurance over longer and longer periods of time; stability in the face of distraction or frustration; application of basic skills in working through more complex tasks;

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Between Group Post-Intervention Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Participants</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Average of 13 Quizzes*</td>
<td>85.30</td>
</tr>
<tr>
<td>Second Examination*</td>
<td>81.46</td>
</tr>
<tr>
<td>Cumulative Final Examination*</td>
<td>87.02</td>
</tr>
<tr>
<td>Course Grade**</td>
<td>3.28</td>
</tr>
<tr>
<td>Cumulative GPA**</td>
<td>3.41</td>
</tr>
</tbody>
</table>

Note. * = On a scale 0 to 100, ** = On a 4.00 scale
and the generation of new skills through un instructed combinations of different fluent skills (Johnson and Layng, 1992). The frequency-building program provided an efficient and effective means of strengthening the skills necessary for success in the developmental algebra course.

The results of the current study have far reaching implications for educators and administrators in supporting and retaining quality student populations. Universities may find that providing support for student learning and mastery of basic skills will have large payoffs for the development of more advanced skills in a number of subject areas. Such improvements could be made available to a wide array of students with minimal expense to the university. Supported practice such as that provided in the current study could be provided through new student entry programs, tutoring available in student services, or through computerized learning programs.

In addition to demonstrating the effectiveness of the intervention, the current study offers an extension of the data-based instructional practices of Precision Teaching to university students, a population for which limited application of effective practices has been noted (Austin, 2000). Remedial education programs receive criticism from those who advocate increasing standards for program admission. However, to reach the learning goals that we have for our students, we must add to the skills they have at the present time, rather than hoping that they have had more fully developed skills (Hackworth, 1994). As such, we choose to examine how best to bring the skills of these learners up to a level necessary for success. The means of creating more skilled learners will surely involve utilizing teaching methods with demonstrated effectiveness, not being more selective in the population that we choose to instruct. The current study reiterates the finding that Precision Teaching provides a sensitive measure of increases in skill performance and that frequency of responding is key to achieving true mastery. Creating more skilled learners not only increases their success in academia, but also in the social and economic venues for which they are seeking training.

Participants in the study showed improved mastery of basic mathematics concepts. These improvements represented an average increase of between five and eight problems correct per minute across the four mathematics operations. Although this is seemingly a slight increase, development of a basic skill, such as solving addition problems, is a prerequisite component skill for elementary algebra. Thus, even a slight improvement is important. The effect seen by this intervention may have actually been the introduction of systematic practice and measurement for basic skills in a student population who likely found this subject aversive and may have lacked appropriate study skills. This possibility is supported by anecdotal feedback from participants that indicated that participation in this study functioned to model effective student study behavior. It is possible that the habits established during the intervention may have been generalized to participants’ independent study behavior in the elementary algebra and other classes. In particular, the use of short but frequent practice sessions dedicated to increasing speed of certain skills was a useful adaptation to participants’ regular study habits and helped them to emphasize the importance of basic skills.

The reasons that more remarkable gains in the frequency of basic mathematics skills were not observed are numerous. First, it should be noted that the intervention included a maximum of 16 minutes per week of practice developing basic skills outside of the required coursework aimed at producing these learning gains. This is a very striking change in learning for a very minimal effort. These gains were produced outside of class with peer tutors, thus no additional demands were placed on the professor. This procedure should be replicated in future research with the learners managing their own tasks. This could be effected through the use of the computer, or even by adding this work as a homework requirement. As such, future research should pursue additional avenues to increase the use of individualized, frequent basic skill building in larger groups of students, even considering university-wide applications.

It is also likely that students placed in the developmental mathematics course have long-standing and cumulative deficits in their mastery of basic mathematics concepts. Given that participants were adult learners, they may in fact, have been practicing errors for many years, further blocking the acquisition of appropriate skills. Future
research might address this issue by presenting the materials in a format that has little overlap with previous math learning programs. For example, many of these learners had completed worksheets in the course of other math learning programs, but few would have used the computer as medium for such skill acquisition. Computer-based precision learning has not only been demonstrated to be an effective means of increasing mastery of specific tasks and the content of a variety of disciplines, it also has produced significant increases the retention and graduation rates of at-risk college students (McDade and Goggins, 1993; Kulik and Kulik, 1991). As such, presenting information in a format that does not evoke the learner’s history with respect to the concepts may allow educators to work around these histories of failed mastery. Also, new and innovative ways to present materials have the possibility of creating a better match with the learning style of the student, given that use of typical formats (e.g., worksheets) in the past were unsuccessful.

These deficits in basic mathematics skills may have produced a second effect. That is, a great amount of emotional behavior was also observed in the practice sessions. These behaviors ranged from extreme anger and frustration to resignation that the learner just could not master these skills. Anxiety was common to all of the participants. This was reported both in the practice sessions, in class, and in other settings where the student engaged in math-based activities. These emotional reactions could have further interfered with the acquisition of skills, as they are not optimal conditions under which to learn (Craig, 1998; Goolsy, Dwinell, Higbee, and Bretscher, 1994). Although these emotional reactions decreased dramatically over the course of our sessions, the addition of relaxation exercises may have further reduced this source of interference. Even a few minutes of physical or thought-based exercises in which the learner has demonstrated success could change the tone of the learning sessions. The concept of behavioral momentum best illustrates this point. Behavioral momentum is the relation between the persistence of behavior and the rate of reinforcement for that behavior in a given setting (Mace, 1996, p. 557). The application of behavioral momentum to teaching of mathematics in the future studies could include interspersing a number of brief exercises where learners have a high probability of success, followed by a brief, but more challenging mathematics skill building exercise. In such a scenario, the probability that the learner readily engages in the more challenging activities is increased since a high density of reinforcement has been previously established in that setting.

Finally, it is possible that characteristics of volunteers differed from those who did not volunteer in ways that affected our results. Because the participants were freshman or transfer students and had no available academic history on which they could be compared, we chose to match students on their in-class test scores, their attendance during the class, and considered placement test scores. These measures ensured equal preparation in the subject matter prior to the course and equal exposure to the material during the course, but did not control for differences in study skills, time management, motivation, or other important differences in the effectiveness of these students.

The addition of just 16 minutes of practice for six weeks improved course outcomes in mathematics a whole letter grade above non-participating peers. Research should continue to address ways to increase the efficiency and effectiveness of different methods of accelerating learning and promoting transfer to relevant settings.

REFERENCES


SC: National Resource Center for the First Year Experience and Students in Transition.


Mrs. Red Elk, Leaf, and I wrote this chart share article in four parts. I wrote the introduction on Precision Teaching in education. Mrs. Red Elk describes how she got involved with Precision Teaching. Leaf says why he started to do the vocabulary timings differently from the way Mrs. Red Elk, his teacher, had initially told him. Finally, I give a summary of Leaf’s remarkable achievement and Michael Fabrizio closes with a commentary.

Precision Teaching Background
Abigail B. Calkin

In the early 1950s, Ogden Lindsley became the first person to measure human behavior continuously, and he continuously measured and researched its frequency and growth. He took lessons learned from pigeons and rats in Skinner’s operant laboratories into his home and continuously recorded the toy playing behavior of his infant daughter, Kathy (Babe in a Box, 1952). He also began to measure the behavior of schizophrenics at Metropolitan State Hospital in Waltham, Massachusetts, and coined and first published the term “Behavior Therapy,” in 1954 in the Boston telephone directory: Studies in Behavior Therapy (Lindsley, 1999). In 1965, he developed what was first called the Standard Behavior Chart, now more accurately described as a family of Standard Celeration Charts—five standard measurement charts for human behavior in minute, daily, weekly, monthly, and yearly time period formats. Its primary use continues to be charting learning and change in public and private education, preschool through university.

The first daily Standard Celeration Chart, then called the Standard Behavior Chart, began regular use in the public schools in 1967. Eric Haughton in Eugene, Oregon first came up with the idea and use of the 1-min timing (H. Kunzelmann, personal communication, October 10, 2004). Since 1968, the 1-min timing has come into common use in the school environment. With the development of the Timings Chart, the use of the 30, 15, or 10-sec timing has also become frequent in special and regular education classrooms.

Riverside Indian School in Oklahoma, and Morningside Academy in Seattle, Washington work together to provide improvement in reading at Riverside.

Leaf is an eighth grade student in Mrs. Red Elk’s reading class. There are also sixth and seventh graders in the class. Mrs. Red Elk had her students doing 1-min timings of See Say prose in the Scott Foresman reading series and 10-sec timings with vocabulary words. The students wrote the vocabulary words on flash cards, then practiced reading and defining them in two separate timings. Such flashcards are called SAFMEDS, an acronym for Say All Fast Minute Every Day Shuffled.

One day in December 2002, Mrs. Red Elk asked me if it was all right to do the timing in a different way. Of course!, I said. It seems Leaf was not happy with his frequency of words defined per minute.

Morningside Reading
“How It Has Invaded My Classroom”
Cheryl Red Elk

I am not a reading teacher and have never had a desire to be one. The work is too hard and the responsibility too great. I am a math teacher (just the facts, ma’am). However, our school has incorporated this program and I have had to deal with a new situation which has not been a personal favorite of mine. I love to read for pleasure. I read as many books as time, or the eyesight, will allow. But to have the rigorous design of this reading program placed in my lap, has been quite a trip.

My students are among the highest reading group in our section. When working on the see/say word timings, students began to complain that they could not turn the cards over quick enough. I told them to improvise. One student laid his cards all on the table and read them as he was being timed. He did quite well. It is easier to facilitate and let them devise their own techniques. Many other techniques had to be revised to fit me, (as I may be old and set in my ways). The charting is done by the counselor
recited them to get a higher score. The program has really helped my reading and vocabulary skills improve. The program has really helped me.

Leaf’s Chart
Abigail B. Calkin

Figure 2 shows Leaf’s Timings Chart. The timings were 10 seconds long. During two of the nine sessions, session one and session seven, Leaf read words in a list. His frequencies ended up well over the aim of 80-100 words read per minute. Sessions two through six and sessions eight and nine are See Define, where Leaf would see the word and say the definition.

What makes this chart noteworthy is the steepness of the celerations, at least six of the nine celerations.

Sessions 1 and 7 are words read per minute in a list. As such, they do not belong on the SAFMEDS vocabulary Timings Chart. However, because Mrs. Hamilton, the manager of the project, put them on this chart, they remain there. As an academic curriculum technician at Riverside Indian School, she was in charge of the charted learning in the classroom. (In other school districts, her position is often called paraprofessional or educational aide.) Indeed, the academic
curriculum technicians are that—highly trained technicians in charge of supporting the classroom academic curriculum.

Leaf’s chart jumped out of hundreds of other Timings Charts because his celerations were consistently steeper than most others I had seen. The slope of his See Say prose words is x8 and x3, good for consecutive timings, tripling from an initial timing of about 55 words per minute to about 160 words per minute in about 20 school days, and exceeding the aim of 80-100 per minute.

As Leaf stated in his comments above, during his reading of the SAFMEDS his partner turned his cards too slowly. It is better for the person reading the cards to turn them himself because he can judge better when to turn the card. However, Ken did one even better: he laid the cards out in front of himself so there was no possibility of even that delay. The celerations of sessions 3 and 6 are not particularly steep, no greater than x1.4. The celerations of sessions 2, 4, 5, 7, 8, and 9 are definitely steep, ranging from x3 to x5.

Commentary
Michael A. Fabrizio

On February 10, 2003, while driving between client appointments in the Seattle area, I phoned my friend Abigail Calkin. I knew Abigail was traveling away from her home while she consulted with schools for Morningside Academy, and I thought she might like to hear a familiar voice while on the road for business. During my conversation with Abigail, she told me of some of the work she had been doing while on her trip, and she read me Cheryl Red Elk’s thoughts on using the Standard Celeration Chart as part of the Morningside Model of Generative Instruction. As I listened to Abigail read Cheryl’s statement, two things struck me: as a teacher, Cheryl was less than enthused about teaching reading, but even given this reluctance the Standard Celeration Chart proved a powerful ally for Cheryl. While she may not have embraced teaching reading with open arms, Cheryl displayed one of the most important characteristics that any teacher can display—she was willing to change what she was doing based on her students’ performance data. In her description of how her students modified the way they practiced their vocabulary SAFMEDS, we see Cheryl’s willingness to adapt how she taught to fit the needs of her students, and to do all of this based on student performance data. My congratulations to Cheryl Red Elk and all of her (very lucky) students!

REFERENCES
Babe in a Box. (1952, May 2). Newsweek, 97-98.

Figure 2. Ken's (Leaf's) chart of SAFMEDS vocabulary words.
Journal Description

The Standard Celeration Society publishes the *Journal of Precision Teaching and Celeration* (JPTC) two times a year. JPTC provides a forum for research, practical applications and discussions of Precision Teaching and Celeration technology. JPTC has dedicated itself to the promotion and diffusion of Precision Teaching and Standard Celeration technologies.

Journal Sections:

Authors may submit their original contributions to one of five sections of JPTC:

I. **Application Articles**: “Application articles” require:
   1. Use of Standard Celeration Charts;
   2. Use of basic charting conventions; (See the JPTC guidelines for guidance on the “basic charting conventions”);
   3. Description of variables or procedures supporting the interpretation of the data.

   “Application articles” usually represent data from applied settings such as schools, clinics, human service agencies.

II. **Research Articles**: “Research articles” require:
   1. The use of Standard Celeration Charts;
   2. Descriptions of the collection and analysis of data;
   3. Use of basic and advanced charting conventions and analysis; (See the JPTC guidelines for guidance on the “basic” and “advanced” charting conventions and analysis);
   4. Description of variables or procedures supporting the interpretation of the data;
   5. Control for extraneous variables or report of their influence.

III. **Discussion Articles**: “Discussion articles” offer explanations, reviews, and extensions of Precision Teaching and Standard Celeration concepts.

IV. **Chart Shares**: “Chart shares” contain data displayed on Standard Celeration Charts along with brief descriptions of the performer, what occurred, and other relevant observations. [Note: We encourage performers (e.g. students, clients, patients) to submit their own charts to the chart share section.]

V. **Technical Notes**: Brief technical descriptions clarifying, elaborating, or reporting upon Precision Teaching and Standard Celeration concepts.

Submission Guidelines:

To submit a manuscript authors must conform to the following guidelines:

1. If submitting by postal mail*, submit three typewritten, doubled spaced copies of the manuscript without author’s names or affiliations. If submitting by email, send to rmk11@psu.edu.
2. If submitting electronic manuscripts, we recommend OpenOffice Writer (v3 or higher), Word Perfect (v4), Apple iWork, or Microsoft Office 2003. We discourage Microsoft Office 2007 and will not accept pdfs.
3. Follow the format outlined in the Publication Manual of the American Psychological Association (5th edition, 2001);
4. Do not exceed 20 words in the article title;
5. Include an abstract and do not exceed 250 words in the abstract (Technical Notes do not require an abstract);
6. Select 3 to 5 key words that describe the manuscript;
7. Secure permission for use of copyrighted materials;
8. Send all charts and graphics in vector format or as 600 dpi bitmapped images, uncompressed;

*Dr. Richard M. Kubina Jr., The Pennsylvania State University, Department of Educational and School Psychology and Special Education, 231 CEDAR Building, University Park, PA 16802-3109
Editors reserve the right to edit all material accepted for publication.
## BASIC CHARTING CONVENTIONS for the DAILY STANDARD CELERATION CHART

<table>
<thead>
<tr>
<th>TERM</th>
<th>DEFINITION</th>
<th>CONVENTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. CALENDAR SYNCHRONIZATION</td>
<td>A standard date for starting all charts.</td>
<td>The synchronization date begins on the first Sunday before Labor Day. The second chart begins 20 weeks after the synchronization date. The third chart begins 40 weeks after synchronization date. Three charts cover a full year.</td>
</tr>
<tr>
<td>2. CHARTED DAY</td>
<td>A day the charter records and charts a behavior.</td>
<td>1. Chart the behavior frequency on the chart on the appropriate day line.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Connect charted days.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. <em>Do not</em> connect charted days across phase change lines or no chance days.</td>
</tr>
<tr>
<td>a) ACCELERATION TARGET FREQUENCY</td>
<td>Responses of the performer intended to accelerate.</td>
<td>Chart a dot (●) on the appropriate day line.</td>
</tr>
<tr>
<td>b) DECELERATION TARGET FREQUENCY</td>
<td>Responses of the performer intended to decelerate.</td>
<td>Chart an (x) on the appropriate day line.</td>
</tr>
<tr>
<td>3. NO CHANCE DAY</td>
<td>A day on which the behavior had <em>no chance</em> to occur.</td>
<td>Skip day on daily chart. (Do not connect data across no chance days).</td>
</tr>
<tr>
<td>4. IGNORED DAY</td>
<td>A day on which the behavior could have occurred but no one recorded it.</td>
<td>Skip day on daily chart. (Connect data across ignored days).</td>
</tr>
<tr>
<td>5. COUNTING-TIME BAR (aka Record Floor)</td>
<td>Designates on the chart the performer’s lowest possible performance (other than zero) in a counting time. Always designated as “once per counting time.”</td>
<td>Draw solid horizontal line from the Tuesday to Thursday day lines on the chart at the &quot;counting-time bar.&quot;</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>TERM</th>
<th>DEFINITION</th>
<th>CONVENTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. ZERO PERFORMANCE</td>
<td>No performance occurred during the recording period.</td>
<td>Chart on the line directly below the &quot;counting-time bar.&quot;</td>
</tr>
<tr>
<td>7. PHASE CHANGE LINE</td>
<td>A line drawn in the space between the last charted day of one intervention phase and the first charted day of a new intervention phase.</td>
<td>Draw a vertical line between the intervention phases. Draw the line from the top of the data to the &quot;counting-time bar.&quot;</td>
</tr>
<tr>
<td>8. CHANGE INDICATOR</td>
<td>Words, symbols or phrases written on the chart in the appropriate phase to indicate changes during that phase.</td>
<td>Write word, symbol and/or phrase. An arrow (↑) may be used to indicate the continuance of a change into a new phase.</td>
</tr>
<tr>
<td>9. AIM STAR</td>
<td>A symbol used to represent: (a) the desired frequency, and (b) the desired date to achieve the frequency.</td>
<td>Place the point of the caret...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acceleration Target</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deceleration Target</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>A</strong> for acceleration data</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>V</strong> for deceleration data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>...on the desired aim date. Place the horizontal bar, —, on the desired frequency. The caret and horizontal line will create a &quot;star.&quot;</td>
</tr>
<tr>
<td>10. CELERATION LINE</td>
<td>A straight line drawn through 7 to 9 or more charted days. This line indicates the amount of improvement that has taken place in a given period of time. A new line is drawn for each phase for both acceleration and deceleration targets. <em>(Note: For non-research projects it is acceptable to draw free-hand celeration lines.)</em></td>
<td><strong>Acceleration Target</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Deceleration Target</strong></td>
</tr>
</tbody>
</table>
BASIC CHARTING CONVENTIONS

1. Calendar synchronization
2. Charted days
3. No-chance day
4. Ignored days
5. Counting-time bar or Record Floor
6. Zero performance
7. Phase change line
8. Change indicator
9. Aim star
10. Celeration line

The name of the person who works with the performer on a daily basis.
The name of the person who advises the manager or performer on a weekly basis.
The name of the person who sees the performer's chart on a monthly basis. The person may give advice to the Adviser or Manager.
The name of the person whose performance appears on the chart.
OPTIONAL: The age of the performer when the chart begins. If not filled in, draw a line through the space.
A clear description of the performer's counted behavior. Use a learning channel and active verb and noun (e.g., Seesays counts block).

The name of the person who times the performer.
The name of the person who counts the performer's behavior.
The name of the person who charts the performer's counted behavior.
OPTIONAL: Any additional information relevant to the performer or chart. If not filled in, draw a line through the space.

The name of the division of the organization.
The name of the organization where the counted behavior takes place.
### ADVANCED CHARTING CONVENTIONS for the DAILY STANDARD CELERATION CHART

<table>
<thead>
<tr>
<th>TERM</th>
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<tbody>
<tr>
<td><strong>Tools:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CELERATION FINDER</td>
<td>A translucent tool (often Mylar) with celeration lines or calibration lines used for computing celeration line values. One edge of the celeration finder has the vertical axis of a Standard Celeration Chart, called a frequency finder, to assist in plotting frequencies and other common charting practices, including alternate techniques to compute celeration line values.</td>
<td>Bought commercially. For a frequency finder, one can copy and cut out part of the vertical axis on the Standard Celeration Chart.</td>
</tr>
<tr>
<td><strong>Calculations:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. CELERATION CALCULATION (Quarter-Intersect Method)</td>
<td>The process for <em>graphically</em> determining a celeration line (aka &quot;the line of best fit&quot;). Divide the frequencies for each phase into four equal quarters (include ignored and no chance days), locate the median frequency for each half, and then draw a celeration line connecting the quarter intersect points.</td>
<td>See advanced charting conventions sample chart.</td>
</tr>
<tr>
<td><strong>Frequency:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. FREQUENCY CHANGE (FC) (aka frequency jump up or jump down)</td>
<td>The multiply &quot;x&quot; or divide &quot;/&quot; value that compares the final frequency of one phase to the beginning frequency in the next phase. Compute this by comparing the frequency where the celeration line crosses the last day of one phase to the frequency where the celeration line crosses the first day of the next phase. E.g., a frequency jump from 6/minute to 18/minute. FC = x 3.0.</td>
<td>Place an &quot;FC =&quot; in the upper left cell of the analysis matrix. Indicate the value with a &quot;x&quot; or &quot;/&quot; sign (e.g., FC = x 3.0).</td>
</tr>
<tr>
<td><strong>Celeration:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. CELERATION CHANGE (CC) (aka celeration turn up or turn down)</td>
<td>The multiply &quot;x&quot; or divide &quot;/&quot; value that compares the celeration of one phase to the celeration in the next phase (e.g., a celeration turn down from x1.3 to ÷ 1.3. CC= ÷ 1.7).</td>
<td>Place a &quot;CC =&quot; in the upper middle cell of the analysis matrix with the value indicated with a &quot;x&quot; or &quot;/&quot; sign. (e.g., CC = ÷ 1.7).</td>
</tr>
<tr>
<td>TERM</td>
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</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>4. PROJECTION LINE</td>
<td>A dashed line extending to the future from the celeration line. The projection offers a forecast that enables the calculation of the celeration change value.</td>
<td>See advanced charting conventions sample chart.</td>
</tr>
<tr>
<td>5. BOUNCE CHANGE (BC)</td>
<td>The multiply &quot;\times&quot; or divide &quot;\div&quot; value that compares the bounce of one phase to the bounce in the next phase. Computed by comparing the total bounce of one phase to the total bounce of the next phase. (e.g., a bounce change from ( \times 5.0 ) to ( \times 1.4 ), BC = ( \div 3.6 )).</td>
<td>Place a &quot;BC=&quot; in the upper right cell of the analysis matrix with the value indicated with a multiply &quot;\times&quot; or divide &quot;\div&quot; symbol (e.g., BC = ( \div 3.6 )).</td>
</tr>
<tr>
<td>6. CELERATION FAN</td>
<td>The nine-blade celeration fan shows nine reference celerations used to quickly provide a visual estimate of any celeration value by using modifiers of &quot;equal to,&quot; &quot;greater than,&quot; or &quot;less than.&quot;</td>
<td>Celeration fans are printed on all commercial standard celeration charts.</td>
</tr>
<tr>
<td>7. CELERATION COLLECTION</td>
<td>A group of three or more celerations for different performers relating to the same behavior over approximately the same time period.</td>
<td>Numerically identify the high, middle and low celeration in the celeration collection and indicate the total number of celerations in the collection.</td>
</tr>
<tr>
<td>8. ANALYSIS MATRIX</td>
<td>The analysis matrix provides the numeric change information regarding the effects of the intervention(s) on frequency, celeration and bounce between two phases.</td>
<td>Place the analysis matrix between the two phases being compared. For acceleration targets place the matrix above the data. For deceleration targets place the matrix below the data.</td>
</tr>
</tbody>
</table>
4. **Projection Line**
   A dashed line extending to the future from the celeration line. The projection offers a forecast that enables the calculation of the celeration change value. See advanced charting conventions sample chart.

5. **Bounce Change (BC)**
   The multiply "x" or divide "÷" value that compares the bounce of one phase to the bounce in the next phase. Computed by comparing the total bounce of one phase to the total bounce of the next phase. (e.g., a bounce change from x 5.0 to x 1.4, BC = ÷ 3.6). Place a "BC=" in the upper right cell of the analysis matrix with the value indicated with a multiply "x" or divide "÷" symbol (e.g., BC = ÷ 3.6).

6. **Celeration Fan**
   The nine-blade celeration fan shows nine reference celerations used to quickly provide a visual estimate of any celeration value by using modifiers of "equal to," "greater than," or "less than." Celeration fans are printed on all commercial standard celeration charts.

7. **Celeration Collection**
   A group of three or more celerations for different performers relating to the same behavior over approximately the same time period. Numerically identify the high, middle and low celeration in the celeration collection and indicate the total number of celerations in the collection.

8. **Analysis Matrix**
   The analysis matrix provides the numeric change information regarding the effects of the intervention(s) on frequency, celeration and bounce between two phases. Place the analysis matrix between the two phases being compared. For acceleration targets place the matrix above the data. For deceleration targets place the matrix below the data.

---

**Celeration Fan**

- **High:** x 2.35
- **Middle:** x 1.45
- **Low:** x 1.05

**Celeration Collection**

1. Cluster celeration collections at their actual frequencies.
2. Label:
   - 1. The steepest celeration
   - 2. The middle celeration
   - 3. The least steep celeration

**Celeration Calculation**

- **Frequency Change (FC):**
  - **High:** x 2.35
  - **Middle:** x 1.45
  - **Low:** x 1.05

- **Bounce Change (BC):**
  - **High:** x 3.7
  - **Middle:** x 2.6
  - **Low:** x 1.9

**Celeration Change (CC):**

- **High:** x 2.82
- **Middle:** x 3.25
- **Low:** x 1.15

**Total Bounce:**
- **High:** x 2.6
- **Middle:** x 2.2
- **Low:** x 1.8

**Frequency Change:**
- **High:** x 1.65
- **Middle:** x 1.22
- **Low:** x 1.05

**Celeration Change:**
- **High:** x 2.82
- **Middle:** x 2.2
- **Low:** x 1.15

**Bounce Change:**
- **High:** x 1.63
- **Middle:** x 1.42
- **Low:** x 1.22