The Use of Precision Teaching Techniques to Increase Mathematics Skills in Adults with Schizophrenia

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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).

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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

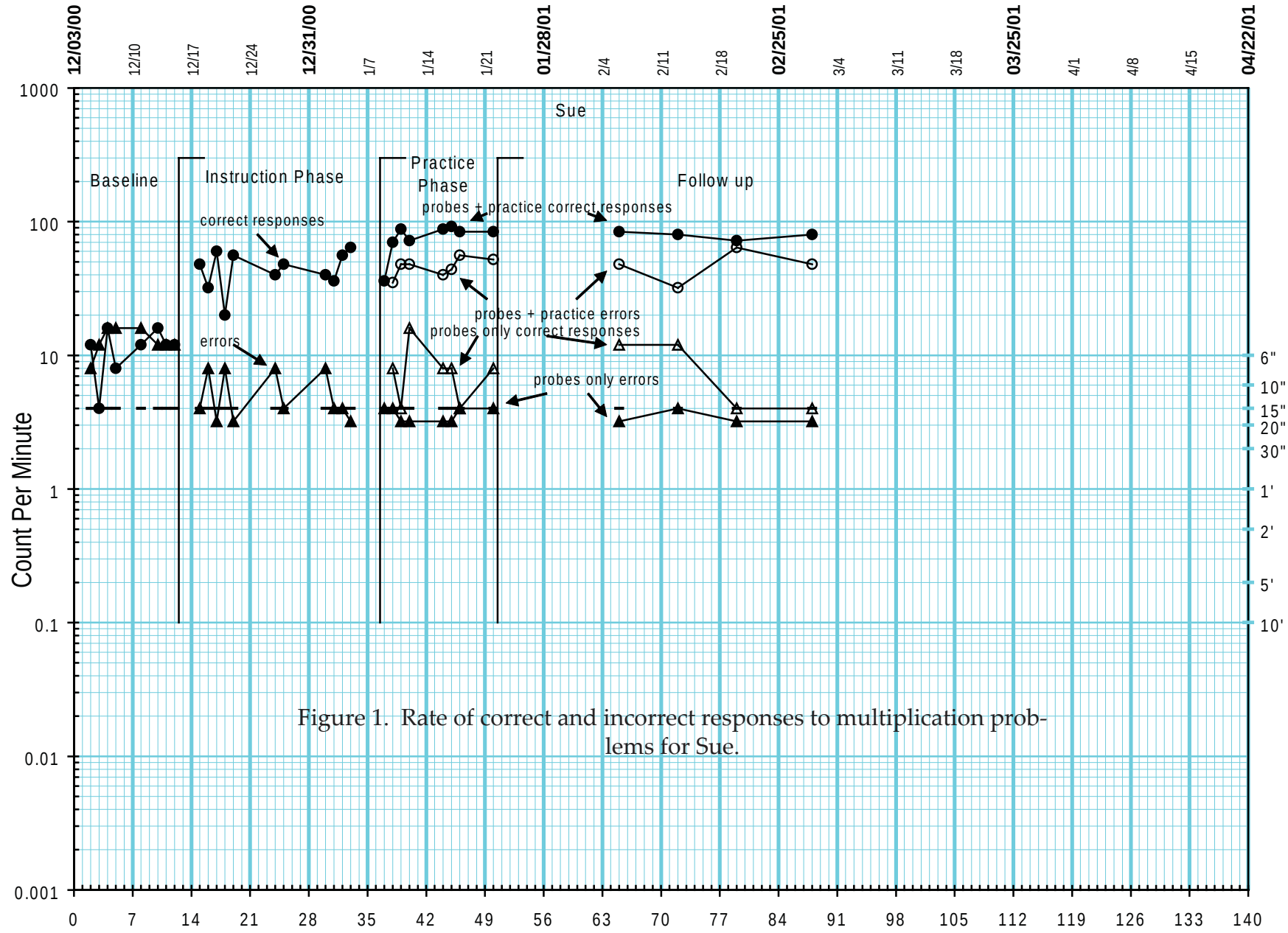

Figure 1. Rate of correct and incorrect responses to multiplication problems for Sue.

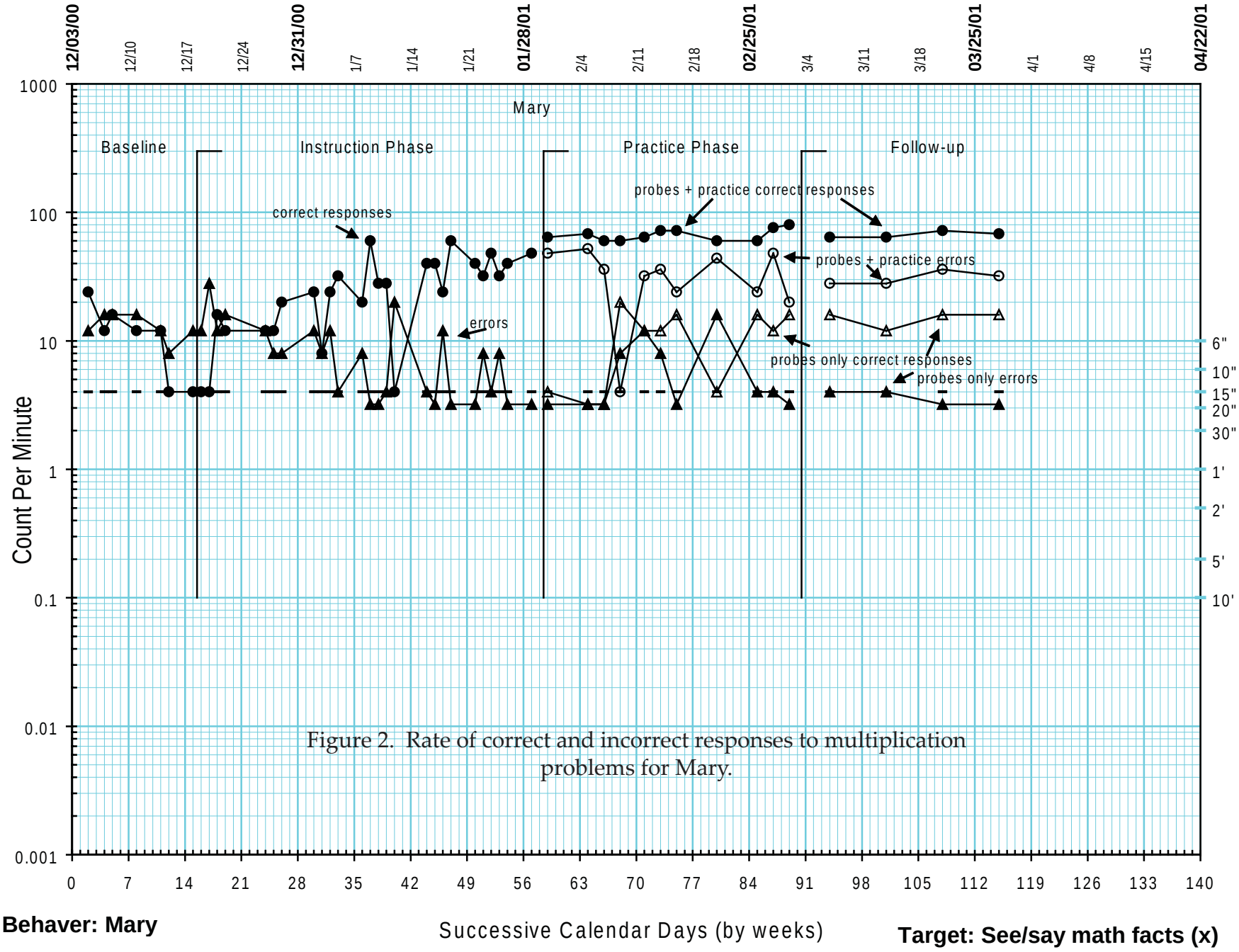

Figure 2. Rate of correct and incorrect responses to multiplication problems for Mary.

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

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.

Beck, R., & Clement, R. (1991). The Great Falls precision teaching project: An historical examination. *Journal of Precision Teaching, 8*, 8-12.

Binder, C. (1996). Behavioral fluency: Evolution of a new paradigm. *The Behavior Analyst, 19*(2), 163-197.

Bucklin, B. R., Dickinson, A. M., & Brethower, D. M. (2000). A comparison of the effects of fluency training and accuracy training on application and retention. *Performance Improvement Quarterly, 13*, 140-163.

Dilk, M. N., & Bond, G. R. (1996). Meta-analytic evaluation of skills training research for individuals with severe mental illness. *Journal of Consulting and Clinical Psychology, 64* (6), 1337-1346.

Haughton, E. (1972). Aims-Growing and sharing. In J. B. Jordan (Ed.) & L. S. Robbins (Ed.), *Let's Try Doing Something Else Kind of Thing: Behavioral Principles and the Exceptional Child* (pp. 20-39). Arlington, VA: Council for Exceptional Children.

Lindsley, O. (1990, Spring). Precision teaching: By teachers for children. *Teaching Exceptional Children, 22*, 10-15.

Lindsley, O. (1992). Precision teaching: Discoveries and effects. *Journal of Applied Behavior Analysis, 25*, 51-57.

Olander, C. P., Collins, D. L., McArthur, B. L., Watts, R. O., & McDade, C. E. (1986). Retention among college students: A comparison of traditional versus precision teaching. *Journal of Precision Teaching, 6*(4), 80-82.

Roder, V., Jenull, B., & Brenner, H. D. (1998). Teaching schizophrenic patients recreational, residential, and vocational skills. *International Review of Psychiatry, 10*(1), 35-41.

Shirley, M. J., & Pennypacker, H. S. (1994). The effects of performance criteria on learning and retention of spelling words. *Journal of Precision Teaching, 12*, 73-86.

Skinner, B. F. (1976). Farewell my lovely! *Journal of the Experimental Analysis of Behavior, 25*, 218.

Starlin, A. (1972). Sharing a message about curriculum with my teacher friends. In J. B. Jordan (Ed.) & L. S. Robbins (Ed.), *Let's try doing something else kind of thing: Behavioral principles and the exceptional child* (pp. 13-19). Arlington, VA: Council for Exceptional Children.

Vargas, J. S. (1977). *Behavioral Psychology for Teachers.* New York: Harper & Row.

West, R. P., Young, R. K., & Spooner, F. (1990, Spring). Precision teaching: An introduction. *Teaching Exceptional Children, 22*, 4-9.

White, O. R. (1986). Precision teaching, precision learning. *Exceptional Children, 52*, 522-534.

Vargas, J. S. (1977). *Behavioral psychology for teachers.* New York: Harper & Row.