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VARIABILITY: AN AID IN THE ASSESSMENT OF THE EFFECTIVENESS OF TRAINING PROCEDURES¹

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Abstract

Pennypacker, Koenig, and Lindsley's variability procedure was used to illustrate the bounce in performance of eight severely/profoundly handicapped persons when they were trained to assemble two complex vocational tasks via two training procedures (total task presentation and backward chaining). From an analysis of the results, it can be concluded that subjects' correct performance under the backward chaining condition was significantly more variable than when correct responding was controlled by the total task condition. Practitioners are encouraged to quantify and analyze bounce to

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assist in making decisions about the effectiveness of training procedures.

The quantification of behavior change (celeration) and variability (bounce) are two of the many features of the Standard Celeration Chart that have a significant impact on the daily decision-making behavior of practitioners. The relationship between celeration and bounce and to what extent the bounce is due to celeration or uncontrolled variability is an important practical training issue. Frequently, this relationship is not used to its greatest practical utility--an aid in the assessment of the effectiveness of training procedures.

Pennypacker, Koenig, and Lindsley (1972) and White (Note 1) suggest that the more variability that can be explained by the effects of the celeration, the more effective the procedure, and the greater the predictive power of the procedure. In essence, measurement of variability during the treatment phase of a training program can be used to assist in assessing the effects of procedures on learning. The purpose of this paper is to explain Pennypacker et al.'s (1972) procedure for measuring and quantifying variability, and to apply this method to the assessment of the effectiveness of backward chaining (BC) and total task (TT) training procedures with severely handicapped persons.

Method

Subjects and Setting

The subjects were eight severely and profoundly handicapped individuals living in a state residential training facility. The five women and three men ranged in age from 14 to 58 years. Their I.Q.'s as measured by the Stanford Binet ranged from 14 to 27. Six of the subjects were enrolled in a vocational training program where they sorted plastic spoons, while two adolescent subjects were enrolled in an on-grounds school program.

The setting was a 5 by 4 meter room divided by a wall to provide two training rooms. The settings were tailored to be similar.

Apparatus

Two different items, a drain and a gate valve, were assembled by each subject. Each item consisted of seven different pieces. No pieces of the two items were identical or interchangeable. The drain was composed of a 7 cm by 3.5 cm drain head, a .65 cm rubber washer, a 6.5 cm hexagonal lock washer, a 4.5 cm by 10 cm pipe, a 4 cm slip nut, a 4.5 cm

plastic washer, and a 4.5 cm rubber stopper. The gate valve was composed of a 6 cm turn knob, a 1 cm nut, a 2.5 cm cap, a 4 cm by 4 cm valve, a 5 cm plastic washer, a 6.5 cm by 7.5 cm housing, and an 11 cm stem. Each item was placed in a wooden training tray (60 cm by 45 cm) that had seven different compartments. The items were organized in the order described above. Pieces for three drains or three gate valves were placed in each tray.

Procedures

Experimental design. The experimental design was a multielement design (Sidman, 1960; Ullman & Sulzer-Azaroff, 1975). This design is also referred to as an alternating treatments design (Barlow & Hayes, 1979). Figure 1 is a graphic depiction of the display of the design, using Johnston and Pennypacker's (1980) notation of design elements. The independent variables were the backward chaining (BC) and the total task (TT) training procedures. Daily correct and incorrect frequencies were collected for each of the two items and served as the dependent variable. Each subject started in a baseline (i.e., non-training) condition, against which progress in the training condition was evaluated. The baseline condition was also used to empirically validate that the learner could not assemble the item(s) without training. Trials were alternated as outlined in Figure 1. For example, on the first day of baseline, Subject 1 started with Setting 1, Trial 1, gate valve. During that trial the subject was allowed many opportunities to assemble pieces of the item for three minutes. The frequency of correct and incorrect pieces was recorded on a data collection form and a corresponding Standard Celeration Chart. Then, Subject 1 moved to Setting 2, Trial 2, drain. Trial 2 was conducted in the same manner as Trial 1. Subsequent to Trial 2, the subject remained in Setting 2 with the drain and completed Trial 3. After Trial 3, the subject returned to Setting 1 and the gate valve and completed Trial 4. This completed Session 1.

The second day of baseline opened with Session 2, Trial 5 (see Figure 1). Trials 5 and 8 were conducted in setting 2 with the drain, while trials 6 and 7 were conducted in Setting 1 with gate valve. Sessions 1 and 2 were alternated every other day until "steady state responding" (the celerations for the correct and incorrect frequencies were $X1$) was achieved. Data were collected and charted separately for each Trial number.

On the first day of training, Subject 1 started with session 1 in Setting 1 with the TT procedure and the gate valve. That trial consisted of one opportunity to assemble every

piece of that item. Immediately following the completion of Trial 1, Subject 1 moved to Setting 2 and was trained with the BC procedure on the drain. Trial 2 was one opportunity to assemble the last piece of the item. Subsequent to Trial 2, the learner immediately went to Trial 3 which occurred in the same setting and with the BC procedure. After Trial 3, the learner returned to Setting 1 with the TT condition and the gate valve and completed Trial 4. Session 1 was completed with the conclusion of Trial 4.

The second day of training opened with Session 2 which started with Trial 5. In Session 2, the order in which Subject 1 received the item and training procedure was reversed from that received in Session 1. On the third training day, Subject 1 received the sequence reported in Session 1 and on the fourth training day the Session 2 sequence, and so on for each subsequent day in the investigation. As in the baseline condition, data were collected and charted separately for each Trial number.

Training procedures—Backward Chaining (BC) and Total Task (TT). In the BC procedure the subject was presented with a "completed assembly" except for the last piece. When that piece was completed either correctly or incorrectly, the trial and the counting period were over. At the time of the study, the authors could not find published indicators of acceptable frequency aims for similar vocational tasks. Therefore, subjects were required to meet a criterion of six consecutive correct pieces (without assistance) across trials before attempting to learn the "next to the last" piece. On subsequent presentations, the item was presented to the subject with all but the last two pieces completed. The subject followed this progression until s/he was completely assembling an unassembled item.

In the TT procedure, every step was trained every time and the subject started with the first step of the task. When all 7 pieces were completed either correctly or incorrectly, the trial and the counting period were over. A total of six consecutive correct items (without assistance) across trials was the criterion.

Calibration and reliability. The data were collected by two principal trainers. The trainers received approximately 12 hours of training prior to the start of "live" data collection. The key elements of the calibration training were: (a) frequency of correct pieces, (b) frequency of incorrect pieces, (c) recording procedure, and (d) timing procedure. These elements were trained to ensure stability, accuracy, reproducibility, and generality of the record responses (Johnston & Pennypacker, 1980).

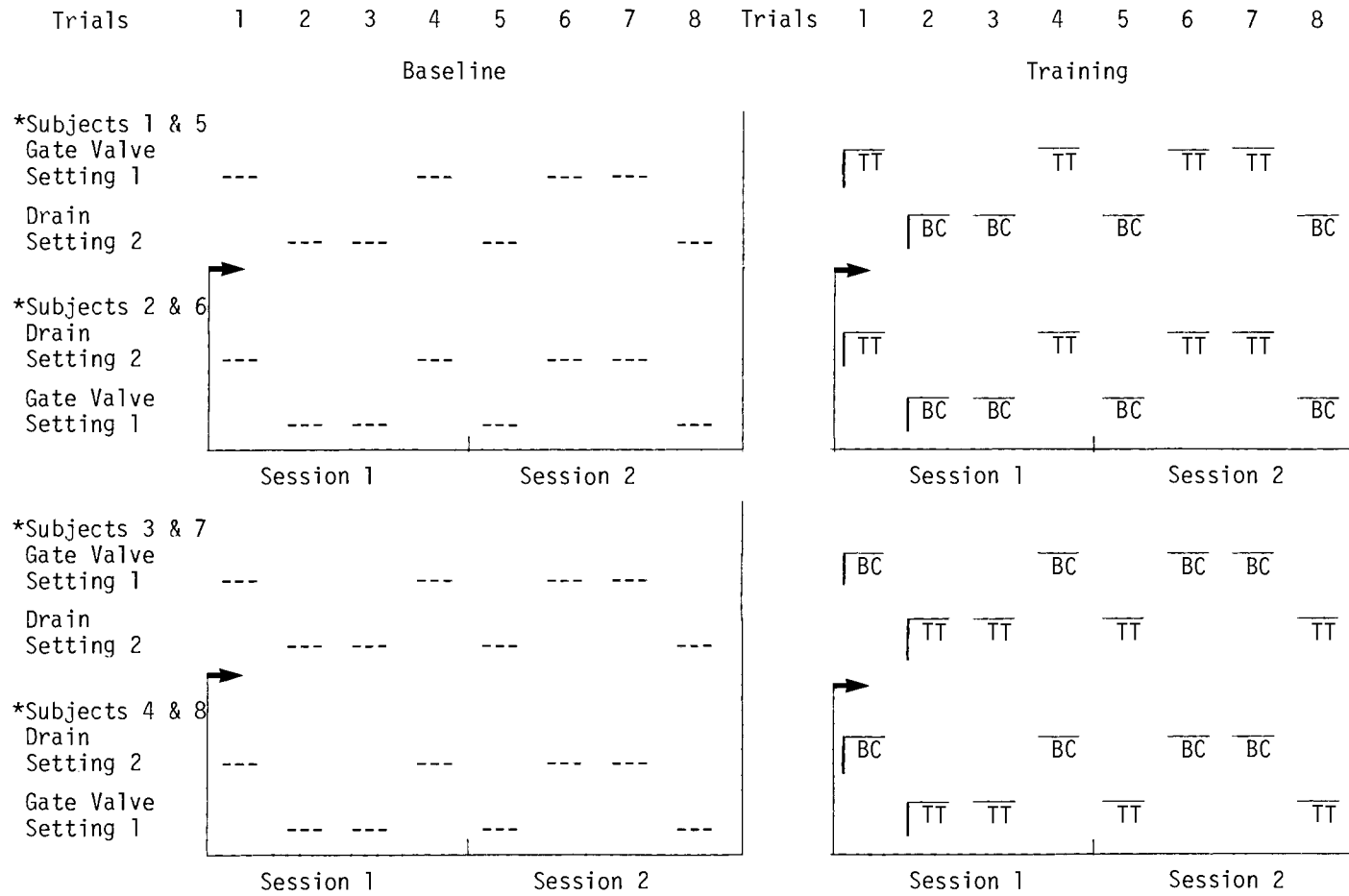


Figure 1. Experimental Design

During simulated "live" training (calibration), the trainers could introduce known sources of variation to provide assurance that the observer was exposed to a full range of possible values. Frequencies were also checked and compared to a mechanically produced record (i.e., videotape). These two calibration procedures are recommended by Johnston and Pennypacker (1980) and were used to ensure accuracy of human recording. When the trainers had trained each other in two consecutive trials without error, the calibration criterion was met.

For this investigation there was no measure of inter-observer reliability. This decision was based on Johnston and Pennypacker's (1980) statement that, "Using two or more observers to detect behavioral events cannot provide any information about the reliability of any one observer's judgment" (p. 163).

Measurement and Quantification of Variability

The variability (bounce) analysis used in the present study was secondary to the original celeration analysis. In the celeration analysis, Spooner (1981) found the TT procedure to be more effective than the BC procedure. After a thorough examination of the variability in the data, it was decided that the variability analysis could be used to help assess the effectiveness of the two procedures.

The procedure described by Pennypacker et al. (1972) is a measure of the total bounce **around** the celeration compared to the total bounce **including** the celeration (see Chart 1). Other investigators have used alternative terms to describe these bounce relationships. For example, Lindsley refers to the total bounce **around** the celeration as the "celeration course" because of the analogy between celeration and its bounce and a river and its banks (Graf, Note 2). Johnston and Pennypacker (1980) call the total bounce **including** the celeration a range coefficient. "The range coefficient is readily visualized as proportional to the distance between the largest and the smallest values displayed on a logarithmic scale" (Johnston & Pennypacker, 1980, p. 360). The ratio of these two measures is the percentage of bounce which is **not** accounted for by the celeration.

Pennypacker, Koenig, and Lindsley's (1972) Procedure

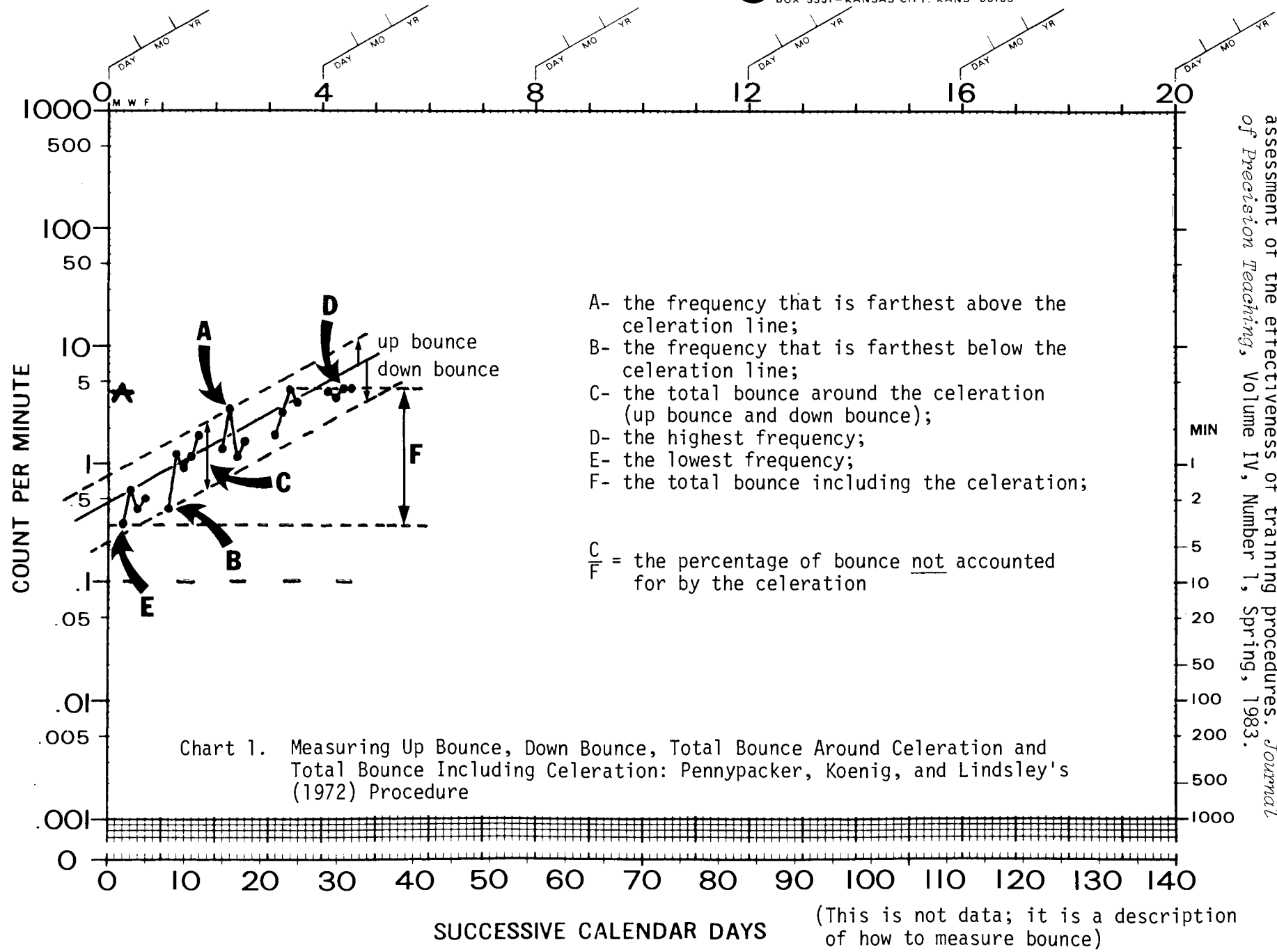
This procedure is a straightforward, powerful way of quantifying variability. It is not a statistical comparison for which a researcher needs a computer to determine the analysis. The procedure is conceptualized in the following format:

1. Measuring "up bounce," "down bounce," and "total bounce" **around** the celeration:
 - a. First, **draw the celeration line.**
 - b. Next, draw a line parallel to the celeration line which passes through the frequency that is farthest **above** the celeration line (see Chart 1, Point A). The distance along any day line from the celeration line to the new line is the up bounce.
 - c. Draw a line parallel to the celeration line that passes through the frequency that is farthest **below** the celeration line (see Chart 1, Point B). The distance along any day line from the celeration line to the new line is the down bounce.
 - d. The total bounce **around** the celeration is the total distance along any day line that is described by the distance of the up bounce and the down bounce (see Chart 1, Point C).
2. Measuring total bounce **including** the celeration:
 - a. Draw a horizontal line through the **highest** frequency in the set (see Chart 1, Point D).
 - b. Draw a horizontal line through the **lowest** frequency in the set (see Chart 1, Point E).
 - c. Measure the total bounce **including** the celeration as the distance between these two lines (see Chart 1, Point F).
3. Finding the ratio of total bounce around celeration to total bounce including celeration:
 - a. Take the measure of total bounce **around** the celeration as found in Chart 1, Point C and place it in the numerator of a fraction.
 - b. Next, place the measure that describes total bounce **including** the celeration, as found in Chart 1, Point F, in the denominator of the fraction.
 - c. Finally, divide the numerator by the denominator. The ratio is the percentage of bounce **not** accounted for by the celeration.

Using Variability as a Measure of the Effectiveness of Treatment Procedures

For the variability (bounce) analysis, the most typical performance for each individual subject was compared across training procedures. This was done by comparing the charts for each of the four trial numbers, calculating the points of least difference and determining the most typical trial. Chart 2 shows a summary of the most typical celeration and the "celeration course" for all 8 subjects in the BC and TT training

CALENDAR WEEKS



- A- the frequency that is farthest above the celeration line;
- B- the frequency that is farthest below the celeration line;
- C- the total bounce around the celeration (up bounce and down bounce);
- D- the highest frequency;
- E- the lowest frequency;
- F- the total bounce including the celeration;

$\frac{C}{F}$ = the percentage of bounce not accounted for by the celeration

Chart 1. Measuring Up Bounce, Down Bounce, Total Bounce Around Celeration and Total Bounce Including Celeration: Pennypacker, Koenig, and Lindsley's (1972) Procedure

Spooner, Fred, and Spooner, Doreen. Variability: An aid in the assessment of the effectiveness of training procedures. *Journal of Precision Teaching*, Volume IV, Number 1, Spring, 1983.

(This is not data; it is a description of how to measure bounce)

SUPERVISOR ADVISER MANAGER BEHAVIOR AGE LABEL COUNTED

DEPOSITOR AGENCY TIMER COUNTER CHARTER

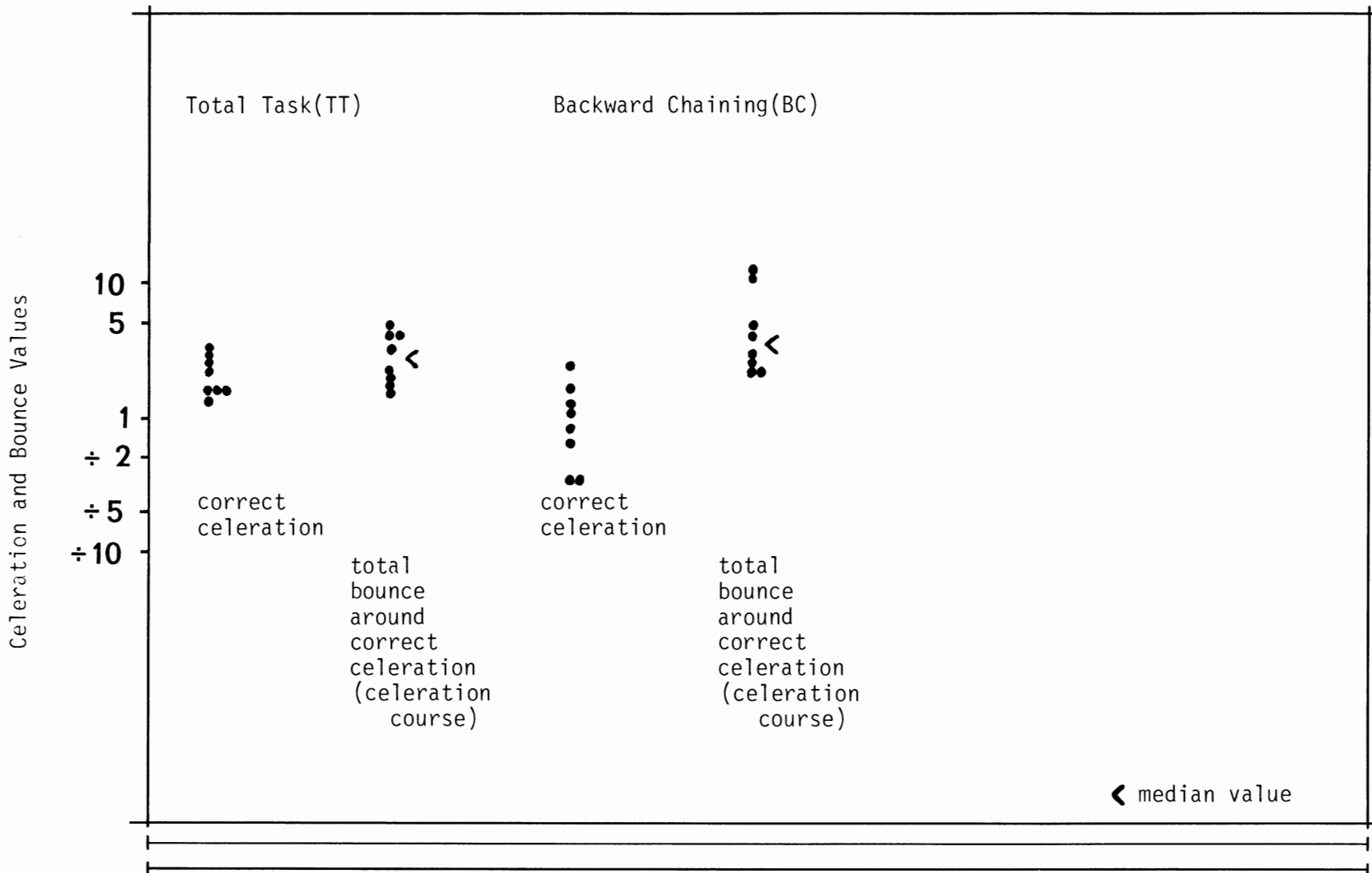


Chart 2. The Most Typical Celeration and "Celeration Course" for all 8 Subjects in the BC and TT Training Procedures.

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8 subjects assemble pieces of gate valve and drain

procedures. Using the median "celeration course" for each training procedure, it is evident that the BC procedure is 1.5 times more variable than the TT procedure. The percentage of bounce not accounted for by the celeration, for each subject's most typical BC trial, was compared with the percentage of bounce not accounted for by celeration for each subject's most typical TT trial (see Table 1). The range in bounce not accounted for by the celeration with TT procedure is 16% - 68%, with a median of 41%. The range in bounce not accounted for by the celeration with the BC procedure is 28% - 96%, with a median of 76%. In all but one case (Subject 8), the percentage of bounce not accounted for by celeration was less for the TT procedure. Charts 3 and 4 show Subject 2's most typical TT and BC performance (Trial 6). In the TT procedure (Chart 3), 16% of the bounce is not accounted for by the celeration. On the other hand, for the BC procedure (Chart 4), 85% of the bounce is not accounted for by the celeration.

Table 1

The Correct Celeration and the Percentage of Bounce not Accounted for by Celeration

Subject	Procedure	Correct Celeration	Percentage of Bounce Not Accounted for by Celeration
1	TT	X1.4	31%
	BC	X1.4	51%
2	TT	X1.5	16%
	BC	/1.05	85%
3	TT	X3.2	31%
	BC	X2.9	48%
4	TT	X1.6	51%
	BC	/1.4	83%
5	TT	X2.7	62%
	BC	/2.4	72%
6	TT	X2.4	16%
	BC	X1.3	85%
7	TT	X3	68%
	BC	X1.9	96%
8*	TT	X1.6	51%
	BC	/2.6	28%

*This is the only case in which the percentage of bounce not accounted for by the celeration is less for BC than for TT.

Discussion

Variability is a measure that may be used to assist in the assessment of the effectiveness of training procedures. Data in this study were used to illustrate Pennypacker et al.'s (1972)

procedure as a useful quantification tool when researchers are interested in more than just "estimating" variability. The median total bounce around celeration was 1.5 times greater for the backward chaining (BC) procedure than for the total task (TT) procedure. In all but one of eight cases, the percentage of bounce not accounted for by the celeration for the BC procedure was greater than the percentage of bounce not accounted for by the celeration for the TT procedure.

The results of this investigation call the researcher's attention to variability (bounce) as a measure of the effectiveness of training procedures. The relationship between celeration and bounce and to what extent that bounce is due to celeration is an important practical training issue. If bounce **around** the celeration is small and the bounce **including** the celeration is large, then a greater proportion of that bounce is accounted for by learning. The training procedure is also exerting greater control over subject responding. On the other hand, if the bounce **around** the celeration and the bounce including the celeration are both large, then a greater proportion of that bounce is not accounted for by learning. In this case, the bounce is attributed to uncontrolled sources and less control is exerted on responding by the training procedure. If the bounce is accounted for by learning, then the practitioner should continue to observe responding and continue with the training procedure. If the bounce is not accounted for by learning, then it would be necessary to plan a program change.

The findings of this study and Spooner's (1981) previous work challenge the continued use of the BC procedure. With this procedure, learning is likely to be less and unaccounted variability greater when compared to the total task procedure. Practitioners should consider using the total task procedure because of its effects on both celeration and bounce.

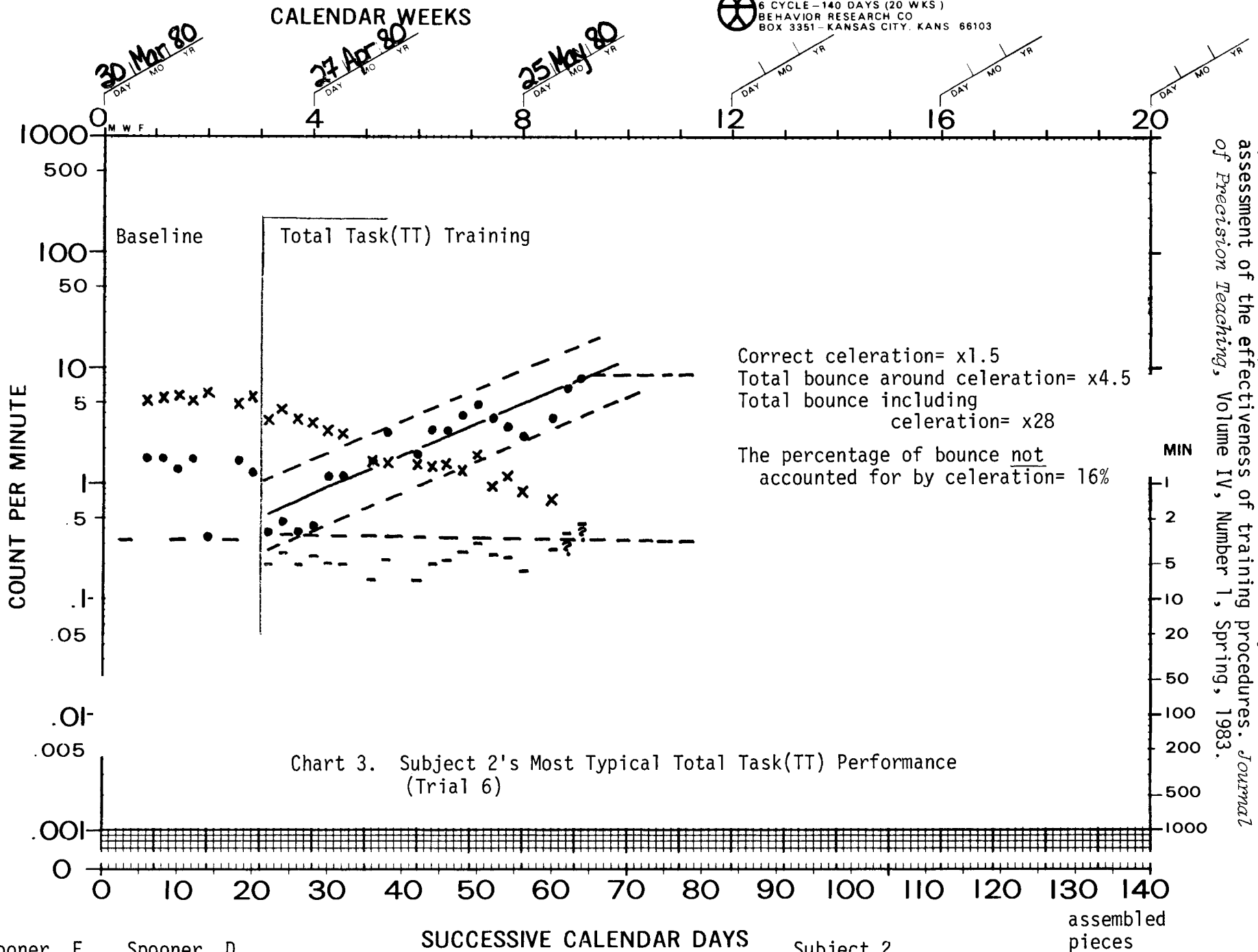
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Spoooner, F. SUPERVISOR
 Spoooner, D. ADVISER
 MANAGER

SUCCESSIVE CALENDAR DAYS

Subject 2 BEHAVIOR
 AGE LABEL COUNTED
 of a 7-piece drain assembly

DEPOSITOR AGENCY TIMER COUNTER CHARTER

CALENDAR WEEKS

30 Mar 80
 DAY MO YR

27 Apr 80
 DAY MO YR

25 May 80
 DAY MO YR

DAY MO YR

DAY MO YR

DAY MO YR

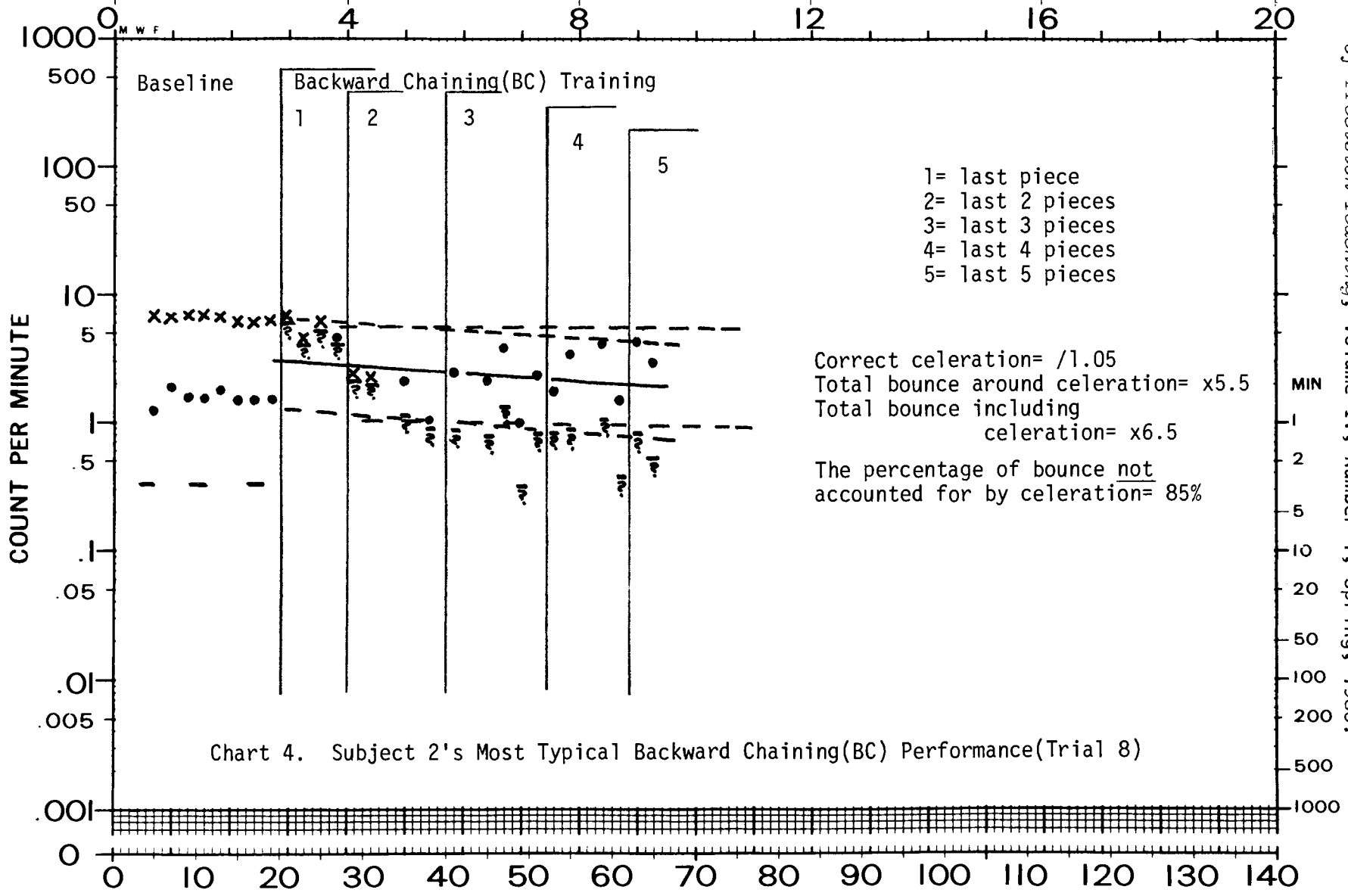


Chart 4. Subject 2's Most Typical Backward Chaining(BC) Performance(Trial 8)

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Spooner, F. Spooner, D.
 SUPERVISOR ADVISER MANAGER

 DEPOSITOR AGENCY

SUCCESSIVE CALENDAR DAYS

 TIMER COUNTER

Subject 2
 BEHAVIOR AGE LABEL COUNTED

 CHARTER of a 7-piece gate valve assembly

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Chart-sharing

A COMPUTERIZED MATH DEFICIT REMEDIATION

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Paul is a twelve year old learning disabled student. He came to the North Marion Middle School resource room for daily instruction over a three-month period last winter until his family moved out of the school district.

In assessing his math skills, we found that Paul was proficient in basic addition and subtraction facts. He understood the concept of multiplication, but made many errors in see-say multiplication facts.

We had access to Radio Shack's TRS-80 hardware and John Trifiletti's Spark 80 Computerized Courseware for Instruction in Mathematics. This software program presents basic math skills in a Precision Teaching format. Individual skills are timed, with the number of correct and incorrect digits typed per minute recorded. When an incorrect answer is typed, the student is instructed to try the problem again. If a second incorrect answer is typed, the machine flashes the correct answer.

Paul had access to the computer for an eight to ten minute time period four days per week. He was put on the random X2 drill in January. As seen on Chart 1, Paul began in the acquisition stage of learning, completing 29 digits correctly with 12 errors in one minute. After four days with no sign of improvement, an intervention was made: Paul was told that he could earn "computer game time" if his corrects went up and his incorrects went down. Over four weeks, Paul's corrects accelerated at the rate of X1.3 per week to 50 digits per minute. This correct frequency was almost exactly the same as his multiplication tool movement frequency. His incorrects decelerated during the first week and "leveled off" at about three per minute.

We are very excited by the results of computerized instruction skill drills. Precision Teaching programs can take a student to proficiency if the prerequisites for learning the specific skill exist. Perhaps best of all, students enthusiastically approach each computer session.

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SELF-COUNTING IN THE TREATMENT OF GILLES DE LA TOURETTE SYNDROME

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Gilles de la Tourette syndrome is characterized by a high rate of involuntary physical tics and utterances which are often vulgar. The subject in this investigation was a 12 year old student who suffered from this condition. His classroom behavior was adversely affected by a high rate of utterances of an expletive. As indicated on Chart 1, an observer recorded the number of times this word was said during a 50 minute class period. An initial baseline phase was