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Precision Teaching's Unique Legacy from B. F. Skinner

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Precision Teaching's unique legacy from B. F. Skinner was the monitoring system of rate of response and the cumulative response recorder. This legacy is unique because the other instructional systems derived from Skinner's work do not use his monitoring method exclusively. Rate of response, cumulative recording and their extension to Precision Teaching's standard celeration chart ing are briefly described. In addition, Precision Teaching's nature, history, costs, distribution, inductive data-base, and academic base are briefly described. Skinner's legacy to education was a sound behavioral scientific base and his unique legacy to Precision Teaching was self-monitoring for real time decision making by learners and teachers.

KEY WORDS: Precision Teaching; Skinner; rate of response; cumulative recorder; standard celeration chart.

INTRODUCTION

Precision Teaching inherited "rate of response" and "cumulative response recording" from B. F Skinner. This legacy is unique since Precision Teaching is the only instructional system derived from Skinner's work to use his monitoring method exclusively. Other instructional systems adopted Skinner's descriptive language, reinforcement strategies, response shaping, and stimulus fading strategies, but not his behavior monitoring methods. This is surprising because Skinner considered rate of response

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and the cumulative response recorder to be his major contributions (Skinner, 1976).

WHAT IS RATE OF RESPONSE?

The rate of response can be defined as behavioral events or products per unit time (e.g., number per minute). Rate was the measure of operant behavior used in the animal laboratories (Ferster & Skinner, 1957; Keller & Schoenfeld, 1950; Skinner, 1938). In Precision Teaching the term frequency is used instead of rate because it is more readily understood by non-psychologists. Furthermore in one of his more general books, Skinner (1953, p. 62) himself used the term frequency when describing behavior.

It was Skinner's use of rate of response as a measure of operant behavior that convinced me to switch from research in electrophysiological psychology to study animal and human learning with him. My early undergraduate studies in engineering and biology taught me the power of standard measurement of things on frequency spectra. When we looked at light qualities we accomplished little, but when we looked at light merely as differences on a frequency spectrum, we accomplished wonders of radiance. When we listened to sound qualities, we accomplished little, but when we placed sounds on a frequency spectrum we developed instruments and amplifiers far purer than the best ever crafted by quality artisans. When we puzzled over differences in the qualities of electricity, we accomplished little, but when we sprinkled electrical events over a frequency spectrum, we made great strides in electrical control and discovery.

Skinner often said in classes, "Rate is a universal datum," but he had recorded only the frequencies of lever pressing by rats and key pecking by pigeons. In Skinner's statement, I saw the opportunity for putting all behavior of all organisms on a frequency spectrum, as previously had been done with light, sound, and electricity. In our laboratory research on chronic psychotics, I had recorded the frequencies of human plunger pulling, pacing, talking, looking and listening (Lindsley, 1956, 1960, 1962). Once we had all behaviors plotted on a frequency spectrum, I was convinced major behavioral discoveries would soon follow.

Now, after collecting tens of thousands of records of hundreds of different behaviors, I am convinced that frequency is much more than Skinner's universal datum. I am convinced that frequency is actually a dimension of behavior. When you change the frequency, you have changed the behavior. Just as frequency is a dimension of light, sound, and electricity, frequency is a dimension of behavior. Frequency should not be

Table 1. A Comparison of Cumulative Response Record Grids

Rat speed[a]		Human speed[b]		Pigeon speed[c]	
Degrees	R/min	Degrees	R/min	Degrees	R/min
		80	80	79	180
64	8	64	40	60	60
45	4	45	20	42	30
27	2	27	10	24	15
15	1	15	5		

[a]Skinner (1938). [b]Lindsley (1962). [c]Ferster & Skinner (1957).

considered a mere measure of behavior, it is a dimension of behavior. Yo have not accurately described a behavior until you have stated its frequency. I a recent article, I detailed why and how I went from human laborator research at Harvard into teacher education at Kansas in order to plac frequency recording in classrooms (Lindsley, 1990a). Early appliers o behavior analysis were recording rate of response in their pre-schoo *laboratories,* but recording percent correct in their pre-school *classrooms* They told me that you could not get teachers to record frequencies. Thi was problematic because our laboratory research had shown human be- havior frequencies to be 10 to 100 times more sensitive to changes in pro- cedures than percent correct (Lindsley, 1962). Details of the sensitivity an rationale for frequency have been fully described elsewhere (Johnston & Pennypacker, 1980).

WHAT IS CUMULATIVE RESPONSE RECORDING?

A cumulative response record plots the cumulative number of re sponses vertically up the left of the chart, against time in minutes alon the bottom of the chart. Cumulative records display changes in rate o response (frequency) as changes in the slope of the curve in real time whil the behavior is in progress (Ferster & Skinner, 1957, p. 725).

Equally important additional features of cumulative recording no usually noted in publications are:

(1). *Self recording.* "All the curves given in this book ... are photographic reproductions of records made directly by the rats them selves" (Skinner, 1938, p. 60).

(2). *Objective and reliable.* "At no point does the experimenter inter vene for purposes of interpretation" (Skinner, 1938, p. 60).

(3). *Slope.* Slope is performance which has 2 dimensions (number per minute).

(4). *Slopes are standard.* The cumulative response recorders were standardized for the three major species studied in free operant conditioning (see Table 1). This was achieved by changing the speed gears that turned the paper drums, thus changing the bottom time lines of the charts. Standard grids were printed for pasting on the cumulative records for publication.

(5). *Displays major changes.* Note that the grids above represent about equal angular changes (12 to 18 degrees) for major changes in frequency (doublings). Skinner often said this keeps you from wasting your time attending to trivial changes in behavior.

(6). *Frequencies displayed on a multiply scale.* Note also that the approximately equal changes in angle represent doublings in the frequencies (rate/min). This means that the cumulative records display frequencies on a times 2 multiply scale. Equal angles of grid lines represent a times 2 scale.

The main advantage of standard slopes is that you eventually learn the value of each slope and do not have to make measurements from charts or refer to grids to see frequencies, assess learning, and estimate the magnitude of change.

A cumulative response record always should be read with a frequency grid calibrating the exact number per minute for different angles of slope. Cumulative records published without grids show that the author is not really reading slopes, but is simply using his/her cumulative record to display total number (up the left) and total time taken (across the bottom). This is using the cumulative record as little more than a graphical table of number and time.

PRECISION TEACHING'S EXTENSION OF CUMULATIVE RECORDING

Precision Teaching took the slope (number per minute) of Skinner's cumulative records and charted it up the left of the standard celeration chart on a logarithmic scale. Calendar days were charted across the bottom, taking 140 days (20 weeks) to cover one school semester. The chart was made to fit landscape form, the horizontal on the 11-inch side of an 8.5 by 11-inch page. The size was designed to fit on the projection stage of overhead projectors and computer display screens.

The frequencies up the left of the chart went from 1 per day through 1 per minute up to 1000 per minute. This covered six times ten cycles (log

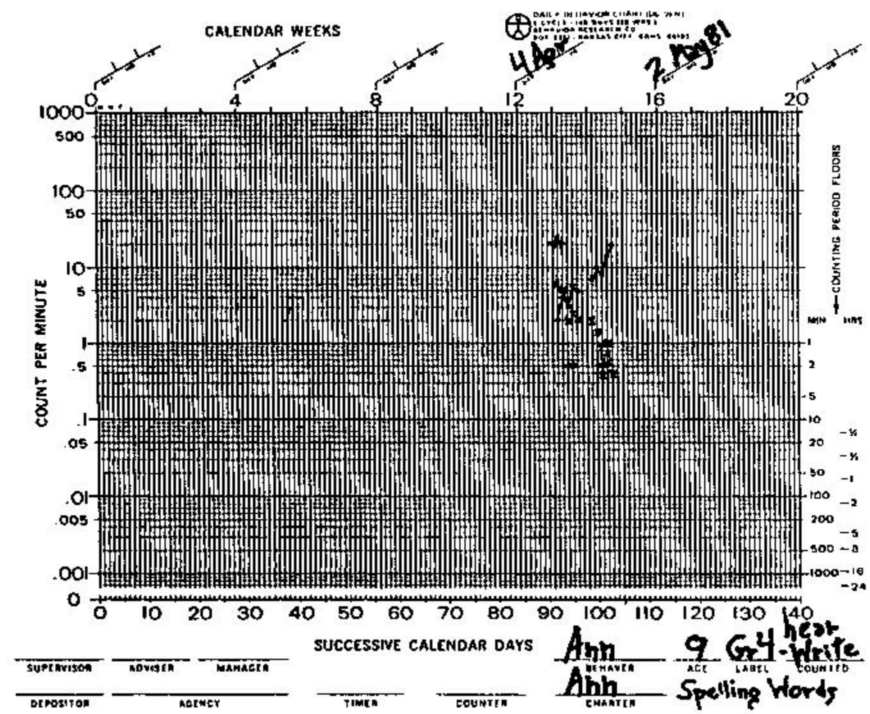

Fig. 1. Sample standard celeration chart. Ann's daily chart of her learning to hear-write her spelling words correctly over two weeks of practice.

cycles) on the chart. The size was adjusted so that a line from the lowe left corner to the upper right corner (an angle of 34 degrees) represented a doubling in frequency every seven days. This is a celeration of times 2 pe week. The reason we call the charts standard celeration charts is because a diagonal corner to corner slope is times 2 and 34 degrees on all the charts The standard is in the meaning of the slope just as was the case with th cumulative record. In fact, the cumulative record would more properly hav been called the standard frequency record, describing it by its slope rathe than by its vertical scale.

As an example, Figure 1 displays Ann's standard celeration chart fo her 40 spelling words from lessons 3 and 4 of her spelling book (from Mc Greevy, 1981). Ann is 9 years old, in 4th grade, and calls this "my learning picture chart." Her aim is 40 words spelled correctly in 2 minutes. He daily countings began Monday, and were as follows: Mon.-4 correct anc 12 incorrect; Tue.-8 and 10; Wed.-6 and 4; Thur.-12 and 5; Fri.-10 and

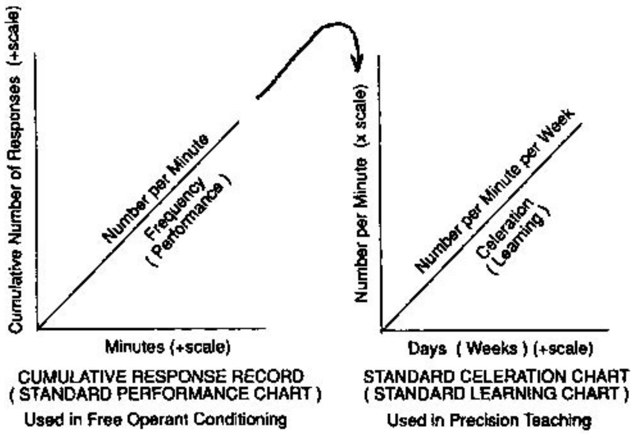

Fig. 2. Schematic diagram of the extension of free operant conditioning's cumulative response record to Precision Teaching's standard celeration chart.

4; Mon.-14 and 4; Tue.-20 and 3; Wed.-16 and 0; Thur.-31 and 2; and Fri.-40 and 0.

Standard charting symbols are used in the figure. The dates at the top of the chart at two of the wider Sunday lines synchronize the days with the calendar. The "A" symbol indicates her aim with the point located on the Monday line on which she set her aim. The elongated arms of the "A" rest on the frequency line of her set aim of 20 words correct per minute. The number of words written correctly per minute is charted with a "dot" on each day of practice. The number of words spelled incorrectly each day is charted with a small "x" on the day line. The duration of the practice sessions is indicated by a horizontal dash drawn between the Tuesday and Thursday line of the week at the frequency of one in that practice period. This is called the "record floor," and in this case of 2 minutes of practice the floor is on the 0.5 per minute line. Ann wrote her name, age, grade, practice subject (spelling words), and channel used (hear-write) on her chart for identification.

Ann's learning picture is called "Jaws Crossover" (All, 1977). Since her chart shows she can learn rapidly when entering a curriculum with only 1 correct for every 3 incorrect (25% correct), she knows that she has the courage to leap up the curriculum. Ann has broken the bounds of "accuracy addiction" which cripples the majority of our public school teachers and students. Accuracy addicts cannot enter curricula at accuracies below 4 correct for every 2 incorrect (60% correct).

Another way to look at the relationship between cumulative records and standard celeration charts is that the charts are the first derivative of cumulative records. The slope of a cumulative record is number per minute. It has two dimensions and records performance. The slope of a standard celeration chart is number per minute per week. It has three dimensions and records learning.

Figure 2 diagrams the extension of Skinner's legacy, the cumulative record, to its derivative, the standard celeration chart.

Both scales of the cumulative record are add scales, that is, equal distances represent equal additions or subtractions on the scale. The horizontal time scale on the standard celeration chart also is an add scale but the vertical scale on which frequencies (number per minute) are charted is a multiply scale. Equal distances on this scale represent equal multiplications or divisions. The frequencies are plotted on a multiply scale so that the celeration slopes will project as straight lines (Koenig, 1972).

If we could locate environments interested in maximizing learning, and could generate high celerations over and over again in the same learners, we would be in a position to study and display the learning of learning. Then, we would need the second derivative of cumulative records which would be the first derivative of standard celeration charts. The slope of the standard celeration chart, number per minute per week, would be up the left of the chart, and months or years along the bottom of the chart. The slope of this standard celeration of celeration chart would have four dimensions: number per minute per week per month.

There is so little current interest in major learning gains in public schools, however, that we can't even get the standard celeration chart in wide use (Watkins, 1988). Interest in producing large performance gains is also weak in the scientific literature. The pay-off to the academic scientist is number of pages published rather than magnitude of behavior change produced. Indeed, even the standard cumulative record has disappeared from behavioral journals (Barrett, 1987; Skinner, 1976). Therefore, it will probably be a very long time before we see a need for four dimensions on standard celeration of celeration charts.

WHAT IS PRECISION TEACHING?

Precision Teaching is adjusting the curricula for each learner to maximize the learning shown on the learner's personal standard celeration chart. The instruction can be by any method or approach. For example, the most effective applications of Precision Teaching have been when it is combined with Direct Instruction (Johnson, 1989; Maloney & Humphrey, 1982). The materials are derived from Direct Instruction and the curricular change decisions, fluency aims and one-minute practice sessions are from Precision Teaching.

The precision comes from making curricula changes based on changes in the weekly learning of each student. The weekly learning changes are seen on standard celeration charts. The frequencies of correct and incorrect responses of each subject are recorded daily on separate standard charts. Because of the normal daily variation in performance frequency, it takes one to two weeks (5 to 10 daily frequencies) to project a learning course and to determine a change in learning. Details of Precision Teaching techniques, timing and charting have been described extensively in previous publications (Binder, 1988; Lindsley, 1990a, 1990b; McGreevy, 1981; Pennypacker, Koenig & Lindsley, 1972; West, Young & Spooner, 1990; White 1986) and in a special issue of *Teaching Exceptional Children* (spring, 1990), and will not be repeated here.

A BRIEF HISTORY OF PRECISION TEACHING

We began Precision Teaching, in 1965, in self-contained special education classrooms of the Children's Rehabilitation Unit at the University of Kansas Medical Center (Lindsley, 1964, 1966). The first pupil behaviors that were self-monitored were mostly the handicapping conditions selected for rehabilitation (Koenig, 1967; Slezak, 1969). These projects were so successful that soon the teachers were working on the special education children's primary and elementary academic skills (Edwards, 1969; Fink, 1968).

In the early 1970s, mostly through the work of Eric Haughton and his students at the University of Oregon, self-monitoring of academic products moved into class-wide regular elementary classrooms (Haughton, 1972; Johnson, 1971; Starlin, A., 1971, 1972; Starlin, C. M., 1970).

In the middle 1970s, large scale district- and state-wide projects attracted federal government funding and trained large numbers of teachers in Precision Teaching (Beck, 1976; Sokolove, 1978; Willis, 1974). The projects moved up through high school and state-wide and nation-wide dissemination projects (Beck, 1981).

HOW COSTLY IS PRECISION TEACHING?

By 1984, Precision Teaching was well established in many kindergarten through 12th grade regular education classrooms. Albrecht (1984) surveyed 10 Precision Teaching programs and found that 276 (57%) schools out of 477 in the sample were using Precision Teaching. Of the teachers, 848 (8%) out of 10,540 were using Precision Teaching. Of the pupils, 15,085 (8%) out of 178,434 were using Precision Teaching. The costs for the first training year ranged from $25 to $8000, with a median of $300 per year per teacher. The costs for subsequent years ranged from $5 to $400, with a median of $60 per teacher per year, or only $3.50 per pupil per year (Albrecht, 1984).

HOW WIDESPREAD IS PRECISION TEACHING?

Some estimates indicated that from 2,000 to 20,000 teachers and 34,000 to 340,000 pupils internationally have used Precision Teaching (Beck, 1981). A. Starlin (1986) surveyed 15 principals previously well-trained in Precision Teaching to see if they were still charting and whether they had introduced Precision Teaching into their schools. Seven (47%) had discontinued charting, and seven (47%) had one or more of their teachers charting. Only one had a building-wide program with all teachers and all students charting. The principals who charted reported significantly ($p = .02$) more rewards from staff and parents for student learning than those principals that discontinued charting (A. Starlin, 1986).

The currently most effective state-wide Precision Teaching program is in Utah. Because of its low tax base, Utah has fewer dollars per student for education than other states, yet its students perform better on national tests than most other states. The most secure Precision Teaching programs are located in four private for-profit schools. The Learning Center, Belleville, Ontario; Morningside School, Seattle, Washington; Ben Bronz Academy, Hartford, Connecticut; and the Haughton Learning Center, Napa, California, all have comprehensive Precision Teaching programs. According to the administrators of these private schools, it takes about 2 years to establish a stable referral base in the community. They found that the best start was through a summer school catch-up program, and later including full-time elementary grades. The best advertising was local weekly newspapers combined with word of mouth recommendations from parents of successful students.

Private Precision Teaching schools seem able to charge the highest tuitions in their region because they regularly produce four times greater student gains than the other local private and public schools. Most promise money back if students do not gain at least two years in performance in one year at the school. Private schools can give learning commissions to pupils, teachers, staff and parents when pupils reach their aims. Further they also can develop their own curriculum and are free to exceed the lock-step scope and sequence of public school curricula.

Computer-based Precision Teaching programs require high frequency operation (above 60 per minute) to reach fluency aims. They also require separate recording of both the number correct per minute and the number incorrect per minute. To date, 17 Precision Teaching-based computer programs are available: five are authoring systems, five are tutorials, four are teaching aids, and three are classroom management aids (Spence & Maloney, 1990).

PRECISION TEACHING'S INDUCTIVE DATA BASE

Skinner's (1950, 1956) laboratory research on free operant conditioning was data-up to conclusion (inductive) rather than theory-down to data (deductive). Skinner's three research areas (free-operant conditioning with rats, schedules of reinforcement with pigeons, and programmed instruction with humans) were all data-up or inductive.

Precision Teaching follows Skinner's data-based laboratory research strategies. This research was perhaps the richest body of inductive behavioral research conducted since Pavlov. We can assign numbers to the ratio of induction by dividing the number of records that were collected by the number that were published.

The need to maintain thousands of charts that provide many teachers and scientists ready access to valuable data prompted a computerized data base. Beginning in 1967, the Behavior Bank collected information on precise management projects. The projects were recorded on five optical character read forms and deposited in a main frame computer. The information included: individuals involved in projects, behaviors recorded and their frequencies, situations in which the projects took place, improvements in performance, and procedures used in the projects. The students were identified by social security numbers and/or initials and full names (Koenig, 1971).

The Behavior Bank provided scientists access to a standard data bank from which they could obtain effective procedures and check out ideas on each other's data. It also tested the observation that all behavior performance frequencies lived in the multiply world. The spread of performance frequencies within groups of learners was approximately the same multiple, independent of the behavior. The up-spread of a distribution of frequencies within a school classroom was an equal multiple to the down-spread of the class. Daily frequencies bounced by equal multiples, and frequencies accelerated and decelerated by multiplying. These data justified charting behavior frequencies on standard celeration charts with a multiply (logarithmic) scale. A summary of the Behavior Bank data base from 1967 through 1971 was published as the Handbook of Precise Behavioral Facts (Lindsley et al., 1971).

The major conclusions from the data stored in the Behavior Bank were:

(1). Behavior frequencies celerate, bounce and spread in multiples, and should be charted on multiply scales (Koenig, 1972).

(2). A split-half check of the reliability of the data showed that little more was found by doubling the size of the data base from 6,000 projects to almost 12,000. Therefore, there was no need to further enlarge the data base to make these general conclusions.

(3). The results based on the 11,436 directly banked projects were similar to those based on 511 journal projects. This showed that the banked projects were as valuable as the refereed journal data and 35 times more numerous.

(4). Many different programmed and arranged procedures were equally effective on the same behavior. There were no best stimuli and no best rewards. This stopped our search for the ideal procedure for a particular behavioral problem, and sparked our axiom "different strokes for different folks."

PRECISION TEACHING'S ACADEMIC BASE

In the 25 years that I taught at the University of Kansas, School of Education, I have advised 44 doctoral dissertations, 28 Ph.D.s and 16 Ed.D.s. Of these, 38 (86%) related to Precision Teaching or standard celeration charting. Of the 38 chart-related doctorates, 15 (39%) are now charting.

Doctoral and Masters degrees, specializing in Precision Teaching, can be obtained from over ten major universities, including East Tennessee State, Florida, Florida State, Fullerton State, Jacksonville State, Kansas, Lincoln, North Carolina, Ohio State, Oregon, Utah State, Victoria BC., Washington, Western Washington, West Virginia, and Youngstown State.

Research on Precision Teaching is published in the *Journal of Precision Teaching,* as well as in other journals. This journal has published 158 articles on Precision Teaching to date. Precision Teaching's scientific literature contains 45 doctoral dissertations and 423 published references (Eshleman, 1990). Precision Teaching has held annual international conferences for the past twelve years, with 300 to 500 participants. Over the past 25 years, a total of 799 presentations have been made, with 368 at the Association for Behavior Analysis conventions and 381 at the International Precision Teaching Conferences (Eshleman, 1990).

SUMMARY

B. F. Skinner's legacy to education was a sound behavioral scientific base in place of philosophical conjecture and fads. His unique legacy to Precision Teaching was rate of response and the cumulative response recorder. The self-charted cumulative recorder displayed performance (number per minute) on standard slopes for real time decision making. Precision Teaching continued the exclusive monitoring of performance frequency, and extended cumulative response recording to standard celeration charting. The self-charted standard celeration charts display learning (celeration or number per minute per week) on standard slopes for real time educational decision making by learners and by teachers.

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