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Is Fluency Free-Operant Response-Response Chaining?

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This article briefly reviews behavioral fluency and its 10 products. Fluency development requires three of the four free-operant freedoms: the freedom to present stimuli at the learner's rhythm, the freedom to form the response, and the freedom to speed at the learner's maximum frequency. The article closes with several suggestions that fluent performing is really operant response-response (R-R) chaining, and recommends further controlled laboratory research on free-operant R-R chaining.

Key words: chaining, fluency, fluency products, free operant, frequency, rate of response

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This paper is dedicated to Eric C. Haughton, Harold P. Kunzelmann, and Clay M. Starlin, the pioneer discoverers of fluency. Sadly, their discovering in precision teaching and behavior analysis was extinguished. Harold's and Clay's discovering was extinguished by the ignoring of their effective classroom practices by the public educational establishment (Lindsley, 1992).[1] Eric's discovering was extinguished by terminal liver cancer (Lindsley, 1986).[2] The loss of such brilliant innovators is a major educational tragedy.

As educators we cannot do very much about preventing liver cancer at this time, but we should be able to prevent our public schools from investing their hard-won dollars in appealing instructional fads (e.g., modern math and whole language) when ample research has demonstrated vastly more effective classroom practices (Bateman, 1991; Binder & Watkins, 1990; Engelmann, 1992; K. Johnson & Layng, 1992; Watkins, 1988). Even lawsuits have had little effect (Engelmann, 1991). For the sake of our millions of children being sacrificed on the altar of educational fad, please try to convince your local schools to adopt proven effective curricula. For Eric, for Harold, and for Clay, please try to give our children effective education, now.

FLUENCY

Definitions of fluency and its history will not be repeated here because they are accurately and extensively documented in Binder's article in this issue. I will describe only a brief personal history of fluency experiences and research, and more important, ideas about how and why some conditions are required to build fluency. I collected these ideas gradually over the past 25 years since the discovery of the importance of building fluent performance. The paper gives special reference to the crucial dependence of fluency upon the free operant and on response-response (R-R) chaining. These notions might help readers to understand the surprising power of fluency training, and encourage careful quantitative field and controlled laboratory research into these important and long-neglected behavioral topics.

Fluency is doing things so fast that

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[1] Harold and Clay were not alone in suffering professional extinction. Two thirds of the 40 or so early contributors to precision teaching were also extinguished by our public educational establishment. Four have escaped into public school district central office positions of well-paid impotence. Eight are public school principals, where I trained and placed them, assuming in error that there they would have some curricular power. Five have found handsome financial reinforcement elsewhere by spending their days in the private practice of traditional noncharted psychotherapy.

[2] Two others of our early contributors died of natural causes. Diana Dean (1973) died of stomach cancer, and Nancy J. A. Johnson (1971, 1972) died of multiple sclerosis.

they become second nature and are performed without effort, without error, without distraction, and can be performed for longer periods of time with great resistance to forgetting. The effects define fluency in the same way that the effects define reinforcement (Skinner, 1938). Monitoring response frequency is necessary in developing fluency. Fluent performance is always well above 40 per minute and goes as high as 300 to 400 responses per minute for many behavioral pinpoints. In general, human behavior frequencies are between 60 and 200 per minute. That is where we are comfortable and interested, and where it is fun to perform and fun to watch. Frequencies below 10 per minute produce distressing boredom in most learners.

Members of our culture receive more and more rapid stimulus presentations in movies. Commercial television frequently presents scene changes at above 100 per minute, sometimes with four separate images on a quartered screen that gives viewers a potential stimulation frequency of 400 scenes per minute! It is likely that the more experience viewers have with such rapid stimulus bombardment, the less tolerant they will be of slow (10 per minute) public school curriculum presentation.

Brief Frequency Monitoring

The first steps toward fluency began in 1968 when Haughton moved from monitoring the frequency of all classroom performance (35 to 50 min) as urged by me (Lindsley, 1964) to monitoring only a 10-min sample each day. Haughton (1971) did this initially so that teachers, who were still doing the timings for the students, could time each child during the class session each day (Lindsley, 1992). I had urged the direct technology transfer of direct and continuous measurement from laboratory free-operant conditioning to academic performance in school classrooms. Haughton and his doctoral candidate, Clay Starlin (1970, 1971), soon moved on to several 1-min timings per day for each child, and each timing with different pinpointed performances for each learner. These brief timings were originally called probes, and were used to diagnose functionally in which of several areas a student most needed help. Kunzelmann, in close contact with Haughton,[3] was using 1-min timings once a day for 5 successive days to diagnose learning problems from 13 different basic tool skills, covering six say and seven write behaviors (Kunzelmann, Cohen, Hulten, Martin, & Mingo, 1970, p. 280). These brief timings were considered mainly diagnostic, although one of the three alternative remedies suggested for academic problems was to continue with daily 1-min timings. It was Clay Starlin who first got the proficiency/aim/fluency idea that high frequencies would squeeze out errors and would permit generative curriculum leaps. He supervised practicum students in a remedial reading clinic at the University of Oregon from 1967 through 1970 and urged all the practicum students to try out the proficiency idea in their classrooms.

At first I resisted this departure of my students from the continuous measurement of the laboratory free operant towards what I believed was merely a sampling or testing procedure. I also reacted negatively to the term *probe,* which seemed to imply that the timing was just an indicator of some underlying behavior and not the performance itself. Soon Haughton and Kunzelmann and their students produced such excellent learning results from 1-min daily practice sessions that I admitted my error in resisting the 1-min timings. At this point I was proud of the fact that my students made major discoveries in just a few years out of graduate school. I learned from my students and gave them the highest compliment by rapidly adopting their discoveries and dis-

[3] Kunzelmann and Haughton often created together as a team, even though they usually published as separate authors.

tributing them nationwide in symposia and workshops.

Free-Abbreviate Timings

In the spring of 1972 I used 1-min timings at the start and end of workshops and university classes to measure the participants' gain in knowledge in a way that would be comfortable and have meaning. All first timings should be with fluent performances and therefore fun and not threatening, so I had participants freely abbreviate facts about themselves for 1 min. Then the participants corrected their facts by sharing what their abbreviations meant with their neighbor. This is a great warm-up exercise, and it also teaches how to abbreviate, how to count abbreviations, and how to structure facts for fluent abbreviation. Next, I had the participants free-abbreviate facts about the day's class topic. This provided the before-teaching baseline and demonstrated to the participants that pretesting need not be unpleasant—it can be fun! At the end of the session, a closing 1-min free-abbreviate of the class daily topic was run to determine how much each participant learned in the class session. I displayed these before-and-after frequencies on a Standard Celeration Chart at the overhead projector to show the participants how their performance compared with others in the class. The frequency distributions also showed how much the class middle frequency had shifted up (always a doubling and often times five). The distributions also showed the participants that group distributions are spread normally—the same distance up from the middle frequency as down on a multiply-divide scale; the Standard Celeration Chart normalizes performance distributions. Haughton and Kunzelmann called these think-write timings, but I renamed them free-abbreviate.

SAFMEDS, Essay, and Lecture Timings

In the fall of 1975 at the University of Kansas I started using 1-min timings with both flash cards and practice sheets. Students in my graduate class in the supervision of instruction charted their performances on daily Standard Celeration Charts. By the fall of 1978 I used flash cards practiced to fluency in all of my graduate classes. I called them SAFMEDS ("say all fast a minute each day shuffled"). This name was designed to prevent students from making the most common errors in building fluency with cards. "Say" to prevent silent card viewing.[4] "All" to prevent learning the 75-card deck 25 cards at a time. "Fast" to prevent the common error of starting slow and accurate and then later trying to build speed. "A minute" to prevent the common error of starting with longer timings. "Each day" to prevent skipping weekend days and then trying to catch up with extra timings on Monday. "Shuffled" to prevent the common error of first trying to learn the cards in the same order, then after "knowing them," shuffling to try different orders. SAFMEDS was used both as a learning aid and a grading criterion. Soon all of the student tasks for all my courses included 1-min fluency timings, 10-min essay timings, and 10-min lecture timings. For example, the learning tasks and grading criteria for my graduate course in the Supervision of Instruction for the spring semester, 1979, are summarized in Table 1. To get the letter grade at the bottom of a column the student had to perform at or above the number of facts listed in each of the six timings in that column. No performance averages or medians were permitted. The students could stop and start over in their final check-out grading timings with their instructor and

[4] My wife, Nancy Hughes, took my graduate course in projecting educational futures. When she was ready for her final timing at over 75 cards said correctly per minute, her timing with me was only 22 cards said correctly. When I asked what was the matter, because she couldn't have been that anxious, she said, "this is the first time that I have said them out loud!" Her misunderstanding of how to practice the cards prompted me to create the preventive name.

TABLE 1

Learning tasks and grading criteria for Lindsley's course in the Supervision of Instruction, Spring 1979

Performance	Timing (duration in minutes)	Grading Criteria (count per minute correct)		
Learning picture facts				
See-say SAFMEDS	1	8	25	40
Free-write essay	10	2	6	8
Free-say-lecture	10	2	8	12
Supervision of instruction facts				
Free-write abbreviate	1	10	35	50
Free-write essay	10	2	6	8
Free-say lecture	10	2	8	12
Letter grade earned for the course		C	B	A

could repeat timings as often as they wished to earn a higher grade. They were permitted even to take an incomplete grade for the course and after they had more practice, the next semester could earn a higher grade. Most students earned As in the course and the number of facts required was gradually increased each semester until by 1989 the criteria for an A was 75 facts in 1 min for Learning Picture see-say SAFMEDS and 100 facts in 1 min for Supervision of Instruction free-abbreviate facts.

TEN PRODUCTS OF FLUENCY

In 1981 Haughton coined the acronym R/APS (retention/application performance standards) to state that performance frequency aims must be set by determining the frequencies that insure both retention and application of skills. Haughton (1981) soon expanded his acronym to REAPS (retention, endurance, application, performance standards), giving four fluency products. By then I had 6 years of experience building fluency in 30 offerings of my graduate classes. Each class had about 25 students, and each student learned two decks of 75 to 100 SAFMEDS for a total of 50 fluency learnings per class. The 30 classes yielded 1,500 SAFMEDS learning charts with graduate-level adult learners. Several products not stressed by Haughton in his REAPS acronym jumped out of these data.

Stability

First, as an aviation cadet in World War II, I daily practiced repeating my army serial number, the names of my company officers and Army Air Corps generals, the names of both friendly and enemy fighters, the words to Air Force marching songs, and other verbal chains until they could be recited perfectly at 100 to 300 words per minute any time on call from an upperclassman. Similarly, repeated high-speed practice of emergency aircraft exit drills and field disassembly and assembly, while blindfolded, of the Army 1911A1 automatic pistol in 1 min was part of the official military training. The Air Corps believed that repeated high-speed practice produced performance that could be accomplished under the stress of battle or in emergencies without error. The same stability and resistance to distraction occurred when my graduate students approached fluency in their 1-min SAFMEDS practice sessions. Only the beginners who made the mistake of starting at slow frequencies had their pace broken by the noise of the other students saying SAFMEDS and slapping their cards down on the chair arms close by. This prompted me to convert the S in Haughton's REAPS to stability—a fifth product of fluency.

Fun

In workshops and university classes, it became clear that fluent performing was fun. Participants often laughed and giggled when comparing their frequencies correct after a fluent timing, and fluent timings are such fun that they can be used as "ice breakers." Grumbling, groaning, and critical comments always occur with adults when asked to perform a task in which they are not fluent, so I learned to start workshops and class sessions with timings of fluent performances (e.g., abbreviating facts about themselves) and to close with a similar fluent timing (e.g., facts about the town or university). This is similar to band directors and athletic team coaches starting practice sessions with fluent performance and closing them with fluent performance to keep up team spirit. Fluent timings are so exhilarating and so much fun that they can be used at any time in a lecture or workshop to perk up participants when they are beginning to doze, gossip, or look uncomfortable. The correcting of a timing with a neighbor is always fun, so during the correction period I let participants talk it all out until the room quiets down, taking about 10 to 15 min after a 1-min timing.

Understanding

My graduate classes met one evening a week for 3 hr. Each semester the students' first assignment was to make their own deck of SAFMEDS from a list of words for the front and back of each card.[5] In the second class meeting, students said their cards as close to 60 per minute as they could, but they typically produced low correct frequencies and high error frequencies. I did not explain the meanings of the words and symbols on the list and cards. One by one, students demanded to know what some particular word meant. The rote learning of the cards produced a strong need to know meaning. Some students always figured out on their own what some cards meant, and told the meanings to others. The push of rote learning to fluency produced the best interest in understanding that I had ever witnessed in my classes. Even when I had tried "teaching to understanding" I could not produce such interest in the content.

As a result of this experience, I began urging teachers to build fluency first, and then students will take care of developing their own understanding. Building fluent performance first and then answering students' questions was maximally efficient because the teacher used no valuable classroom time instructing what students already knew or what they could learn on their own.

No Cheating

The eighth fluency product, no cheating, seemed obvious to anyone who has taught or practiced a performance to fluency. Other teachers, who continuously fussed with the problems of student cheating, did not realize that fluency assessment totally eliminates cheating. Teachers do not need to use different versions of practice sheets and tests or separate students with empty chairs during group timings. There is just not enough time for a student to peek at another's practice sheet and also give answers fluently. Peeking at another's sheet slows the learner down; sneaking looks at a crib sheet slows the learner down. There is no way a student can bring another student's behavior to a grading validation session. Students can fake their charts, but cannot fake their fluent performances. The acronym fluency REAPS FUN, describing eight products of fluency, was used in workshops and classes throughout the 1980s (Lindsley, 1992).

Confidence

I formalized the ninth product of fluency development in 1993. In the late 1960s I urged the teachers of learners with developmental delays to continue practice sessions even after the learners had reached a normal frequency range for that skill. I urged the teachers to practice their learners far above normal frequencies to championship levels, because this would develop learner

[5] Stephen A. Graf (1994, 1995) has used SAFMEDS extensively in all of his large undergraduate classes. Ready-made SAFMEDS card decks are provided through the Youngstown University bookstore.

confidence. Because the delayed learners' charts seldom leveled off, the students could build up speed to fluent frequencies beyond normal adult range. When a disabled person can write letters, or do basic addition facts, or count items faster than their brothers, sisters, parents, and teachers, they gain real confidence—a confidence that no amount of verbal stroking could achieve. Binder (1990) called attention to confidence as a benefit of fluency in the title of an article describing fluency to industrial trainers.

Generativity

K. Johnson and Layng's (1992, 1994) excellent recent articles on generative instruction prompted me to formalize what precision teachers for years had called curriculum leaps (Stromberg & Chappell, 1990), and add the 10th product of generativity.

These 10 products of fluency (Lindsley, 1995) are the benefits of teaching and learning to fluency. The acronym for these 10 products is REAPS FUN CG (retention, endurance, application, performance standards, stability, fun, understanding, no cheating, confidence, and generativity). Research supporting these fluency products is detailed in Binder's article in this issue; my purpose is to comment on the research presented by Binder and to suggest areas for potential laboratory research.

FLUENCY AND CHAINING

Skinner introduced chaining in 1938, and it held free-operant conditioners' attention through the 1950s. He devoted 10 of the 457 pages in his classic text (Skinner, 1938) to chaining. He introduced the process of chaining as follows: "The law of chaining: The response of one reflex may constitute or produce the eliciting or discriminative stimulus of another" (p. 32).

Keller and Schoenfeld (1950) introduced their chapter on chaining with the following quotation.

> In learning [the Lord's Prayer] we repeat it: that is we pronounce the words in successive order, from the beginning to the end. . . . *Our* suggests *Father*, *Father* suggests *which*, *which* suggests *art*, and so on, to the end. How remarkably this is the case, any one may convince himself by trying to repeat backwards, even a passage with which he is as familiar as the Lord's Prayer. (p. 197)

Keller and Schoenfeld went on to define chaining by saying one response commonly produces the stimulus for another.

Diagrams

Skinner (1938) diagrammed chaining as a series of stimulus–response (S-R), S-R, S-R, each R being not only a response but also the stimulus for the next response. This is functional description rather than topographical and applies the strong S-R law that all behavior follows the S-R linkage, even response chains. It was hard for Skinner to give up the stimulus and its central position in reflex theory. For example, he called rewards that follow the behavior *reinforcing stimuli*, trying to make the point that they were just as much a part of the reflex as the stimuli that come before the behavior. This use of the word *stimulus* to describe a consequence created confusion with the general public.

Keller and Schoenfeld followed Skinner's functional logic that each response is the stimulus for the next response, and they diagrammed a chain as follows (1950, p. 200): $S^D4—R_4—S^D3—R_3—S^D2—R_2—S^D1—R_1$. Most recent chaining diagrammers (Goldwater & Acker, 1995) take the same strong S-R position and diagram it similarly to Skinner and Keller and Schoenfeld, with each R being the S for the next R, and so on.

In the fall of 1951, while I was a graduate student in experimental psychology at Harvard in Skinner's portion of the proseminar course, I disagreed with Skinner's diagram of behavior chains and asserted that all we observed and recorded were a series of chained responses. Why not just admit that response–response linking occurs and recognize that it is a little different from discrimination learning, which clearly is controlled by environmental stimuli? This touched a tender point in Skinner, and I quit trying to have Skinner admit that chaining was simply R-R linking. However, I did not give up this notion; I just gave up trying to convince Skinner. Recently, Michael and Shafer (1995), in their state notation system for teaching, have dropped out the S, diagramming chaining as simply R1 and R2. This simplification of chaining diagrams clarifies the process for their students and adheres more closely to the observed facts, in that only linked responses are recorded.

Recently my experience with workshop practice sheets shows that learners who point to the next item on the sheet learn quicker than learners who do not point (Lindsley, 1994). Pointing to the next item is not only necessary but is highly specific, because pointing with a pencil point produces quicker learning than pointing with the finger. The finger partially obscures the view. This need to overtly respond to each question is one of the many things that make us think that when a performance becomes fluent it is then chained. It is not merely see-say or S-R. The see must be physically responded to for maximum fluency building. Therefore it is point-see-say, clearly an R-R-R chain.

If songs and poems were simply S-R, S-R, then every word in the series would be the stimulus for the next word as diagrammed by Skinner, Keller and Schoenfeld, and Goldwater and Acker. When given any word in the series, one can come up with the next word, but most of us cannot do this. We have to go back to a phrase beginning and "get a running start." Then we listen as we sing, to hear which word we sing after the questioned word. This looks more like R-R-R-R-R than S-R, S-R, S-R, S-R, S-R.

Carly Simon stammered as a child but could easily sing without stammering (Brenner, 1995). Do stammerers have trouble with S-R performance but not with R-R chaining? Maybe we should train stammerers to talk fast and in rhythm, thus sing-talking their stammer away. Would talking at speeds above 40 words per minute squeeze out the stimulus steps in S-R, S-R, S-R and go to direct, smooth R-R-R performance? I believe these questions are fascinating, and provide a rich area for both field and laboratory research.

Popularity

Chaining has been very popular. Many psychology departments had a performing rat or pigeon that did an elaborate chain of responses on command. These demonstrations impressed the students, public, and press, but produced little research on the process. Chaining and its related topic, shaping, have had little study and little writing. In the author's topic count of 17 of Skinner's books and four other operant classics, only 551 pages of over 5,000 described chaining. Ten of these pages were in Skinner's (1938) *The Behavior of Organisms,* and 34 pages were in Keller and Schoenfeld's (1950) *Principles of Psychology.* Only 41 pages of the 5,000 were devoted to shaping. John Cooper (personal communication, October 26, 1995) counted the pages devoted to shaping and chaining in the six most-used textbooks in applied behavior analysis and found, in Alberto and Troutman (1995), 11 of 522 pages; Cooper, Heron, and Heward (1987), 35 of 651 pages; Malott, Whaley, and Malott (1993), 30 of 468 pages; Martin and Pear (1996), 24 of 455 pages; Sulzer-Azaroff and Mayer (1991), 26 of 644 pages; and Walker and Shea (1995), 7 of 384 pages. The total number of pages on shaping and chaining in these six popular textbooks is 133 of 3,124 pages. This proportion (1 of 23) is five times higher than the proportion of 1 of 100 found in the earlier classics, demonstrating a fivefold increase in popularity. Shaping and chaining have been further popularized in the popular press by professional animal trainers (Pryor, 1975, 1984; Wilkes, 1994).

It is surprising that so little research has been done on shaping and R-R chaining because much of the reputation of operant conditioning and behavior analysis is based on its power for building chains and shaping behavior. Chaining, along with shaping, was perhaps free-operant conditioning's greatest selling point and attention gatherer (Skinner, 1951). In the 1950s, a free-operant conditioner could get instant acclaim by shaping a new organism.[6] Teaching an elaborate and interesting chain also produced acclaim. I received some acclaim for teaching the weightlifting rat Samson.[7] The ping-pong playing pigeons were also a popular class demonstration in Skinner's Harvard undergraduate Natural Science 114 course.[8] If Skinner had named his pigeons Ping and Pong, perhaps they would have been even more popular.

Few laboratory researchers experimented with chaining and shaping animals to perform different skilled acts through the 1960s, 1970s, and 1980s. The laboratory research on shaping contained only a few studies on autoshaping of key pecking (e.g., Brown & Jenkins, 1968). Laboratory research on chaining was usually limited to operanda or schedule chaining (e.g., Kelleher, 1966). Marian and Keller Breland, who with Norman Guttman had trained pigeons to guide missiles during World War II (Skinner, 1960), stayed on at General Mills in Minneapolis to train animals for advertising and entertainment at state fairs. At first, they were about the only two to maintain a strong interest in topographical shaping and chaining. They not only maintained an interest, they made a living at it. They went on to establish Animal Behavior Enterprises in Arkansas and at one time employed over 75 trainers who produced advertising and state fair acts. They consulted with and initiated the trainers at the Sea Life Parks and the trainers of the whales and dolphins for United States Navy undersea rescue and patrol. The Brelands received a lot of press coverage but published little in scientific journals. I looked up to the Brelands as minor gods, not only because they tried to use the free operant to help win World War II but because they were making a living at selling behavior, and they were almost single-handedly keeping alive two of the free operant's most powerful methods.

Breland and Breland published an article (1961) that described "instinctive drift" (e.g., chickens shaped to dance by lifting their feet straight up gradually drift back to their instinctive scratching, which did not impress farmers at all). Most laboratory operant conditioners did not appreciate the instinctive drift article because it made operant conditioning appear to be weak compared to instincts and ethology. Yet, the facts were exactly the opposite. The Brelands had shown that shaped chains of behavior were extremely durable, enduring for years without practice. It was only the form

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[6] Joe Brady shaped cats at Walter Reed. Charlie Ferster shaped chimps at Orange Park. I shaped dogs at Boston University Medical School. One summer there was a rumor that Peter Dews had shaped an octopus in Italy! I was working with a praying mantis and had developed a paper-clip operandum when the mantis drowned in its bottle-cap drinking cup.

[7] At Columbia in 1952, Thom Verhave trained a rat to do an elaborate 10-response chain of behavior (Donald A. Cook, personal communication, March 29, 1996). In 1957 at Barnard College, and then later at Brown University, Rosemary Pierrell and Gil Sherman trained a rat named Barnabus to climb a staircase, push down a drawbridge, cross the bridge, climb a ladder, climb hand-over-hand up a chain to a car, pedal the car through a tunnel, climb another flight of stairs, run through a tube, step into a waiting elevator, and finally raise a university flag up a pole; this started the elevator down to the ground floor, where he pushed a lever and received one pellet of food. This 11-member chain brought Rosemary and Gil instant recognition, and generations of Barnabus continued to entertain and amaze at Brown for many years (Pierrel & Sherman, 1963).

[8] The notes for this course were later published as *Science and Human Behavior* (Skinner, 1953).

of the carefully shaped response that would change, and then only when it was very close to stronger behavior that the animal had engaged in since birth. The *permanence* of shaped and chained performance that the Brelands developed impressed me.

Later, Karen Pryor (1975, 1984), a skilled former dolphin trainer from Hawaii's Sea Life Park, published two very well-written books, portions of which describe shaping and chaining. However, these were written for the general public, and because most free-operant conditioners did not know they existed, they did not spark academic interest. Pyror has regularly attended conventions of the Association for Behavior Analysis since 1990, and she and Gary Wilkes (1994) sparked enough interest among trainers and behavior analysts to form a Trainers' Special Interest Group. *Trainer* has become the term for those who make a living by shaping and chaining animal behavior. The field is rich with subtle new techniques refined by trainers over the decades since 1950.

The myth that only laboratories can discover basic variables is not true. It is true that only the laboratories can *isolate* variables, but basic variables and procedures are often discovered in application. Fluency (Haughton, 1972; Starlin, 1970) and its products were discovered in application of the free operant in precision teaching classooms. The Brelands discoverted "targeting" with a target stick in shaping their show animals. Wilkes (1994, 1995, 1996) has recently discovered the use of the word "wrong" to signal the animal that the response was close to the target response, but not yet close enough. "Wrong" is like "good try" and helps the learning animal to widen its response class. The training field is rich with subtle techniques refined by trainers since 1942. I hope the contributions made by trainers will renew interest in more laboratory research on these important but neglected topics. I have long suggested (Lindsley, 1964), and still hope, that someone will systematically use real shaping and chaining to improve the motor and social skills of our developmentally delayed citizens.

Chained Motor Learning Endures

Karen Pyror (1984) stated in *Don't Shoot the Dog*, "Muscles 'learn' slowly but well; once something has become part of your movement patterns it is hard to unlearn" (p. 133). It is not necessary to relate here all the anecdotes that motor chains once learned are never forgotten. For example, bicycle riding, guitar playing, and other gross and fine motor skills endure for a lifetime with very little practice. However, to be maintained at peak championship fluency, they must be practiced daily.

I trained our stallion Jack donkey, the Silver Butte Jack, (a) to run after a basketball, carry it to a basket, and toss it in; (b) to stand on a box and ring a school bell and then stamp his foot the correct number of times to "answer" simple arithmetic questions like, "Silver, what's 2 times 3?"[9]; (c) to open a mail box and put in a wooden "letter"; (d) to carry a pick in his mouth in parades and circle on command in front of the judges' stand; (e) to pick up dropped gloves, neckerchiefs, or tools; and several other chained skills (Henderson, 1980). During the first year or so of training, my wife and I ran Silver through all his tricks almost every day, because we thought he would forget them if we didn't. Silver was evicted from our backyard in town, and we found him a barn and corral in the country. Driving to Silver's barn and running him through his tricks took

[9] The trick used was to very slightly move the index finger of my right outstretched hand (both hands were outstretched) immediately after the stamp that Silver should stop at to correctly answer the question. Of course, a few times I stopped Silver one stamp early or one stamp late so that he would make a small error to enhance the deception. I got the idea for this training from the classic case of Kluge Hans, the genius horse from Germany, who picked up almost imperceptible cues from his handler.

close to an hour each day. Eventually, we stopped daily practice because our response cost was too high! Months and even years have gone by without Silver performing one of his tricks (e.g., standing on a box and ringing a school bell held in his mouth). When the bell and box are brought out and Silver is signaled, he takes the bell in his mouth, jumps up on his box, and shaking his head rings the bell loudly. He runs off his chain perfectly without error even after months without practice. This fits with stories from Marian Breland Bailey, Karen Pryor, and Gary Wilkes. These motor chains are extremely durable. The endurance product of fluency is clearly demonstrated here.

Understanding after Fluency

"Figuring it out" makes a performance associative or S-R. Is it possible that trying to understand a performance before performing it fluently not only delays fluency building but sets an S-R association ceiling at about 30 to 40 per minute? This associative ceiling appears to delay the start of fluency building and also to impede and slow the performance. In building my graduate students' SAFMEDS fluency, I found that those students who used elaborate memory aids to learn the cards had ceilings around 30 correct responses per minute. What I called their "cushion shots" likely produced the ceilings. For example, (a) a student learned that the capital of Illinois was the same as a town in Massachusetts west of Boston, (b) a student learned the name of the learning picture (correct and error celerations displayed on a Standard Celeration Chart) with correct responses accelerating and errors decelerating was "jaws." Rather than learn the name of the learning picture with correct responses decelerating and errors accelerating directly as "snow plow," the student used a memory aid to learn that the "snow plow" picture is the opposite direction of the "jaws" picture. Understanding often associates an answer with a web of other answers, all of which slow up emitting the point-see-say chain. Perhaps it is better to rote-learn the chain and not to relate it to other things until it is fluent. Understanding might make it S-R and set its ceiling at 30 per minute, thus not only delaying but also putting a low ceiling on performance frequency.

S-R Switches to R-R?

Is the magic 40 per minute the rate at which S-R switches to R-R chaining and the products of fluency really begin? It is clear that this notion has not been proven. It is merely a strong hunch, and that is why it is in the from of a question. Possibly performances with frequencies above 40 per minute move from S-R control (cortical stuff) to direct R-R chaining control (cerebellar stuff).[10]

A clear plateau or leveling off for a week or two at about 30 cards correct per minute appears on a small number of SAFMEDS learning charts (1 to 3 out of 10). Students complain at this time, saying there is no way they can go above 30 per minute. This is where we tried the regular pacing methods at 60 per minute, which only disturbed them more. Some students admitted that they had to give up the memory aids that were holding them up, and that unlearning them was very hard to do. It is possible that these learners display the point at which their associative learning has to give way to direct R-R chaining to reach the higher fluent frequencies.

Figure 1 displays one such working Standard Celeration Chart. I had it photographed as Ann K. made it. Ann

[10] From 1946 through 1950 I was a physiological psychologist studying with Carl Pfaffman at Brown University. My master's thesis (Lindsley, 1950) was determining the conduction velocities and diameters of the "c" fibers of the chorda tympani nerve of the rat. The chorda tympani nerve runs across the basilar membrane (providing an ideal recording opportunity) to the anterior two thirds of the tongue where it conducts taste sensations. So, you can permit me a bit of reminiscent physiologizing.

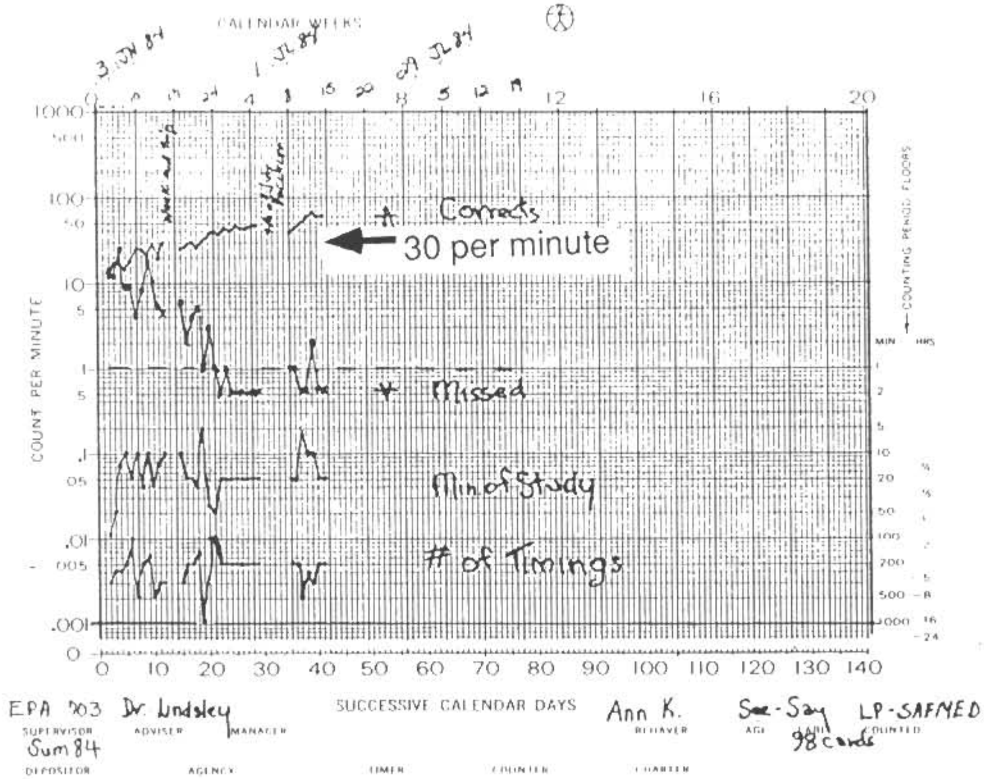

Figure 1. Ann K.'s working Standard Celeration Chart of her daily Learning Picture facts SAFMEDS 1-min fluency practice sessions. The arrow points to 30 per minute, which is the plateau frequency that she had to break through to go on to fluency at 70 cards correct per minute. Is this where her performance went from S-R, S-R, S-R to R-R, R-R, R-R chaining?

was a student in my Supervision of Instruction course, and she charted her see-say learning of Learning Picture Facts SAFMEDS (98 cards in the deck). Her chart covers daily SAFMEDS performances from June 3 through July 15, 1984, from left to right. A frequency of one per day (0.001 per minute) is at the bottom of the chart. One per minute is halfway up the chart, where Ann has drawn a dashed line indicating the counting period floor, which means that she was practicing her SAFMEDS in 1-min daily timings. The top of the chart is 1 million a day (1,000 per minute).

The bottom line charted by Ann plots the number of separate 1-min timings that she practiced each day. The timings bounce from one a day to 10 a day with the middle around five. The second charted line up from the bottom is the number of minutes that Ann spent studying the course in addition to and including her timings. The minutes are read on the right side of the chart, and go down in size as they go up the chart. The time that Ann spent studying bounces from 100 min on June 5 (her first day when she made her own cards) to 5 min on June 22 when she did only one timing.

The third charted line up from the bottom is Ann's frequency of her missed cards. The misses are charted as little x's, representing the total of the number she said "go" to or said incorrectly that day. The misses are the ones that pair with the timing with the highest correct frequency for that day. Ann's misses were once as high as 26 per minute and decelerated by four per week to reach 0 per minute by the fourth week on June 25.

The top charted line is the number of correct responses per minute during the timing with the highest number of correct responses for each day. Ann's correct responses accelerated from about 12 per minute to around 30 in 1 week from June 5 to June 13, and stayed at 30 correct or below until June 23. This is the kind of plateau that might occur in the switch from S-R to R-R chaining. True, there was a weekend trip in there, with no practice, but there still is a clear flat place at 30 per minute in Ann's chart. Once that barrier at 30 per minute was broken, her frequency easily accelerated up through 50 per minute on July 1, and on up to 70 per minute on July 12. Ann reached her fluency aim in 6 weeks.

Learning Native Languages

Native languages are always learned at normal talking speed. The child's family members do not speak slowly so the children can learn. Children start babbling about 60 to 100 babbles per minute. Most of the babbles are incorrect words, so the correct word frequency is very low. Gradually the frequency of correct words increases and the frequency of incorrectly pronounced words decreases. I believe that native language is acquired as an R-R chain using nursery rhymes, alphabet songs, children's songs, and other repeated rhythmical verbal chains. Understanding of what each word means comes after fluent usage in context. Native language is learned very much as we teach fluency. The only missing things are the 1-min timings and the Standard Celeration Charts.

BASIC DISCOVERY IN APPLICATION

The discovery of fluency and its products in precision teaching classrooms shows that basic discoveries can be made in application, and often are. Discoveries from applications in the behavioral sciences are similar to discoveries in the physical sciences. Carefully measured engineering (aircraft design) can teach things to aerodynamics in physics. Empirically discovered medical treatments can focus physiological and pharmacological laboratories on entirely new research vistas. In exactly the same way, carefully measured classroom instruction (precision teaching) has brought new basic concepts to behavior analysis. The catch is that discoveries from the field cannot be carefully and parametrically researched in the field. They need the fine physical control and ability to isolate variable combinations that are provided by well-conducted laboratory research.

Perhaps the notion that the field should apply basic discoveries made in the laboratories is in the wrong direction. Perhaps laboratory research is so detailed and the controls so expensive that it cannot rapidly screen new ideas as fast as can an innovative field practitioner. Perhaps the laboratories should refine and polish some of the new basic ideas that have been demonstrated in the field.

THE TITLE IS A QUESTION

The reason that the title of this article is a question rather than a bold statement is that this is a very strong hunch rather than an experimentally proven fact. The evidence for this is indirect. It is circumstantial evidence. There are many circumstances compelling this hunch, and in the past most of my hunches of this strength have proven true under laborious laboratory labor. So, you few noble laboratory laborers, here's a very strong hunch by a proven huncher, hot from a powerful new field of application for you to dress up, superprove, refine, and further discover!

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