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On Terms

On Terms and Procedures: Fluency

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Fluency is a metaphor for flowing, effortless, well-practiced, and accurate performance. Current practice in fluency building involves increasing the frequency of free-operant performances. Free-operant performance is defined as continuous responding in the presence of discriminative stimuli that are either varied or not varied from response to response. Free-operant performance is also distinguished from discrete-trial performance. Frequency-building procedures are also described, including defining the learning channel and stimulus control topography of a component performance (called a pinpoint), selecting an appropriate timing period, and displaying stimuli so that no performance ceilings occur. During frequency building, frequencies of pinpoints are continuously charted on standard celeration charts. Frequencies are increased to empirically derived performance standards, or aims, that predict retention, endurance, stability, application, and adduction of performance. Frequency is also described as a dimension of performance, not simply its measurement. Frequency building is described as possibly facilitating contingency adduction.

Key words: fluency, free operant, frequency building, contingency adduction, performance standards, component-composite analysis

The term *fluency* is becoming increasingly popular in current behavioral discussions of teaching and learning. The Association for Behavior Analysis (ABA) convention program citations have risen from a handful in 1980 to nearly 100 in 1996. It is time to develop a coherent investigation of behavioral fluency. To do so, it is necessary to have a clear definition, one that shares some characteristics with the more common meaning of fluency and also adds some clear definitional criteria that may be absent in the common usage of the term. Further, the technical definition of the term has undergone some refinement since its inception 20 years ago and continues to be refined. Indeed, discerning readers will note some changes in definition from two of our earlier papers (Johnson & Layng, 1992, 1994).

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Fluency: the Metaphor

Over the last 20 years, the concept of fluency has evolved within the behavior analysis community to describe certain characteristics of behavioral repertoires. The current use of the term retains some of the common features of its more prosaic use; that is, it tacts behavior that is flowing, effortless, well practiced, and accurate. As such, fluency is a tact for certain large segments of behavior, or composite repertoires, as illustrated in Table 1.

Fluency may also tact quick and effortless component sequences of expert composite performance, also illustrated in Table 1 (Barrett, 1977; Gagne, 1970; Resnick, Wang, & Kaplan, 1973; Tiemann & Markle, 1990). Fluency may also tact more mundane but nevertheless important elementary component behaviors, or tool skills (Haughton, 1972), also in Table 1.

The common usage of fluency also captures an important feature of the more technical scientific definition of *behavioral fluency*—its continuous na-

TABLE 1

Three Kinds of Fluency

Composite repertoires	Component sequences	Tool skills
Expert ice skating Jazz improvising Radio sportscasting Museum curating Inventing new medical procedures Quickly and thoroughly solving urban living problems	Catching a fly ball in left field Playing a complicated piece on the piano Writing a review article Reciting certain literature Recalling a lengthy shopping list or bibliography Solving certain math story problems Balancing chemical equations	Rapidly typing and handwriting Quickly recalling phone numbers Saying the meanings of literary abbreviations or road signs Identifying examples of a concept, such as *vehicle* or *reinforcement*, as soon as they occur in everyday life

ture. Free-operant performance rather than discrete-trial responding is a critical feature of behavioral fluency. This should come as no surprise, because the roots of the concept lie in precision teaching, which is inextricably linked to a free-operant measurement system. Accordingly, it is the free operant that sets the foundation for the scientific definition of behavioral fluency (Ferster, 1953; Lindsley, 1964). We shall return to this point shortly.

The technical use of the concept of fluency makes contact with other more empirically determined characteristics of performance as well. It is the elucidation of these characteristics to which the present effort is directed.

Frequency-Building Procedures

Performance definition. Using the metaphor of fluency, we need to specify outcomes that indicate fluent performance, and select a dimension of behavior in time that will indicate that outcomes have been achieved. Current practice in hundreds of precision teaching classrooms throughout the world is to create fluent performance by increasing the frequency of one or more free-operant component performances. Although frequency is only one of several variables that contribute to the development of fluency, this paper will focus upon frequency and fluency.

To begin, we need to examine several terms used in the technical procedures that establish behavioral fluency. By *frequency,* we mean count in time or rate of performance, not simply count alone. By *free-operant performance,* we tact two kinds of events. One is more typical of laboratory investigations; the other is more typical of real-world conditions. In the laboratory, reinforcers are made contingent upon responding by the laboratory subject in accord with a criterion established by an experimenter. No attempt is made to limit the subject's responding; stated otherwise, the subject is free to respond at any time. The discriminative stimulus in these situations is typically not varied; it is held constant. For example, a lever or key is constantly present; a downward press of the lever or peck at the key of sufficient force to close a microswitch will from time to time be followed by a click of the apparatus and the delivery of food. A small number of real-world contingencies, such as the operation of vending machines, illustrate this kind of free operant performance.

Most real-world examples of free-operant performance retain the feature of free responding, but with each response comes a new or different discriminative stimulus. Examples include the changing sounds of chords played during a jam session, the changing text of a recited poem, the verbal stimuli produced while writing a research review or balancing chemistry equations, different math facts on a fluency sheet, and the changing terrain of social interactions, some of which illustrate reinforcement. Expertly responding to constantly changing discriminative stimuli during a performance run, like a driver steering through an obstacle course, illustrates the fine-grained repertoire (Ferster, Culbertson, & Boren, 1975) of most fluent real-world performances. These performances may be a combination of separately or concurrently established operants, including psychomotor or verbal repertoires, concepts, principles, and others.[1] What is critical is that no teacher- or experimenter-defined interval is imposed between the once-separate operants that now comprise the targeted skill performance, or repertoire. Laboratory procedures should be governed by similar considerations.

It is important to the definition of fluency that free-operant performance be distinguished from discrete-trial performance. In discrete-trial responding, the experimenter controls the occurrence of the discriminative stimulus; a stimulus is presented and a response occurs, which occasionally is followed by a reinforcer. The reinforcer, in turn, is followed by an interval of time under experimenter control before the next discriminative stimulus is presented. Conversely, current procedures used to make performance fluent increase the frequency of free-operant but not discrete-trial performance. We encourage those engaged in the formal study of fluency to adopt current practices, at least as comparisons, or experimental findings may not be relevant to current practice. Laboratory investigations that use current practice as a baseline may find new frequency-building procedures to replace current practice.

Fluency-building procedures have been designed to increase the frequency of component, not composite, performances. Composite performances are analyzed for their key component elements; the frequencies of these elements are then increased to some predetermined *frequency aim* (Haughton, 1972, 1980; Johnson & Layng, 1992, 1994). Increased frequency of composite performances is an indirect product of establishing fluency on the component performances. For example, the component performance, see and catch then shoot basketballs, involves rapidly presenting basketballs to a learner from a variety of angles, each of which must be rapidly shot through the hoop. See math facts/write answers involves writing numbers to changing math facts on a page.

Conventionally, the statement of a *learning channel* (Haughton, 1972, 1980) such as see/write, hear/say, see/mark, or touch/do, specifying the sensory dimensions of the discriminative stimuli and topographical dimensions of the responses accompanies the specification of each stimulus control topography. Together, the learning channel and stimulus control topography are called a *pinpoint* (Lindsley, 1972). Table 2 lists examples of pinpoints for frequency building from education, industry, business, therapy, and institutional settings.

Timing. Notice that every occurrence of a certain pinpoint has the same duration. In fact, precision teachers used to call these repeating pinpoints *movement cycles* to connote their similar execution time. Technically, we say the repeating pinpoints must be calibrated (White & Haring, 1976).

Once a pinpoint is specified and calibrated, a timing period is selected (White & Haring, 1976). Most often the timing period is 1 min, during which at least 20 performances are capable of occurring, and perhaps 200 or more performances will occur as the learner increases performance frequency. Larger component performances may require from 2- to 5-min timing periods, to make the occurrence of 20

[1] Interested readers should refer to Tiemann and Markle (1990) for a description of some of the complex operants that may be programmed.

TABLE 2

Pinpoints for Frequency Building

Area	Skill	Pinpoint	Frequency aim (count per minute)	Celeration aim
Education	Reading	See/say words (lists)	80–100 words	×2
	Math	See equations/write and solve for *x*	100–110 answer digits	×2
	Writing	See two or more sentences/write and combine to one sentence	130–150 letters	×2
	Spelling	Hear/write words	130–150 letters	×2
Therapy	Tourette syndrome	Say expletive	0	÷2
	Speech	Hear/say sentence	30–35 words	×2
	Depression	Say negative self-statements	0	÷2
Developmental disabilities	Fine motor skills	See/twist object	200–400 twists	×2
	Dressing	See/snap buttons on coat	75–125 buttons	×2
Business and industry	Safety	See/do • check machine temperature	0.01 checks	×10
	Product knowledge	/Say details about product	40–60 details	×2

or more performances in the timing period possible.

During the timing period the learner responds to stimuli presented by the teacher or experimenter. It is important that these materials be designed so that free-operant performance can occur. An array of stimuli on a page or computer screen should contain more stimuli than the learner can possibly respond to. This will guarantee that the teacher is not putting a ceiling on the learner's performance frequency (White & Haring, 1976). Teachers and researchers should avoid trials procedures, such as successive stimulus presentations on a screen, or teacher-presented flash cards; and should avoid free operant procedures that deplete the supply of stimuli to respond to before the timing period is finished.

Charting. As learners build their frequencies of a component pinpoint, they chart the number they complete across successive timings. Accurate and inaccurate performances are charted separately. Most often, performances are charted on the Standard Celeration Chart (Lindsley, 1972). Because applied programs can both increase and decrease the rate of relevant free-operant behavior, the shortened term *celeration* was developed to refer to both acceleration and deceleration of frequency of responding. Regardless of the direction of change, the use of daily charts is essential to evaluation of timings.

Practice. As we mentioned earlier, frequency is not the only variable that needs to be considered in the production of fluency. At least eight other variables are crucial to the promotion of fluency. Procedures for teaching learners how to practice are very important, as is the total amount of scheduled practice. Practice needs to be massed at first, to solidify the performance, but then it needs to be spaced in increasing intervals. In fact, the spacing effect is one of the most robust phenomena reported in experimental psychology (Dempster, 1988). Sequences of practice exercises also need to be designed so that learners cumulatively practice the successive component skills they are learning. A good learning hierarchy of skills, tasks appropriate to the skill being learned, and appropriate reinforcement are all very important in the promotion of fluency. A discussion of all of these variables is beyond the scope of this paper.

In precision teaching, 70% or more of any hour of education or training is devoted to frequency building. This is in stark contrast to the current fashion of excluding practice from the daily regimen of teaching and learning. It appears that the cumulative effect of developing repertoires of high-frequency component skills greatly helps to fulfill the prophecy that less instruction in composite skills is needed as one moves up the curriculum ladder. With fluency building, learning appears to get easier as subject matter gets more complex. We will return to this important point.

Once component behaviors and sequences are fluent, practice in linking fluent component performances into composite performances is scheduled. Composite practice typically does not involve precise timing periods, but may require the performance to be executed in or repeated for approximately 10 min, 20 min, 1 hr, 1 day, and so on.

In sum, fluency is a metaphor for the goals and outcomes of increasing and charting the frequency of one or more calibrated, free-operant, stimulus control topographies, called pinpoints, using certain sequences of practice tasks and timed practice procedures.

Performance Standards (Aims)

How does one determine the frequency aim for a certain component performance? In the early days of precision teaching, at least three norm-referenced approaches were used to set aims, or performance standards (Haughton, 1972, 1980). Let us use the pinpoint, see math facts/write answers, to illustrate the three norm-referenced approaches. One fifth-grade teacher who wanted a math facts performance standard used the average frequency of math facts answered per minute by all students in the fifth grade at the school district as a performance standard. Another teacher based the aim on the performance of students who had been judged to be truly competent. He found the average frequency of math facts answered correctly by all children in the fifth grade at the school who scored above the 90th percentile on a standardized achievement test. Another based the frequency aim on the average performance of people who chose a career that requires frequent use of math facts—all tellers at the neighborhood branch of U.S. Bank.

No matter what sample is selected to measure, there is no guarantee that performance standards derived through norm-referenced procedures will produce frequency aims in the fluency range; indeed, comparison of norm table revisions across successive editions of standardized achievement tests from 1963 to 1990 illustrate decreasing standards of average competencies.

To move beyond a mostly metaphorical use of the term fluency, we need to specify outcomes that indicate fluent performance and select dimensions of behavior in time that will indicate that fluency has been achieved. Five functional fluency criteria have evolved over the last 20 years. These fluency standards have been empirically linked to various frequency aims, depending upon the task. The frequency aims allow few, if any, errors, and are selected to predict that learners will (a) *remember* and perform the skill, at the frequency aim, after a significant period of no practice (a month or more); (b) show performance *endurance,* that is, perform the skill at the frequency aim for periods of time that are longer than the timing period used during practice; (c) perform the skill with *stability*, that is, performance will not be easily distracted; (d) easily *apply* the skill as a prerequisite or component of a more complex performance to be learned; and (e) demonstrate increasing capacity to learn skills instantly, and on their own, as they move through a subject matter. In fact, increasing problem-solving orientation and creativity become readily apparent. These behavioral aspects are a function of *contingency adduction,* which we describe in detail below.

For example, our teachers could set a fluency aim or performance standard that would predict that after a month of no practice, students could (a) still answer math facts at the frequency aim with no errors, (b) maintain their rate of math fact answers when the 1-min timing period is doubled or tripled, (c) continue to answer math facts at the frequency aim even in a noisy or otherwise distracting environment, (d) apply their math fact skills in learning new component and composite sequences, such as long multiplication or long division, without having to pause to recall math facts, disrupting completion of the new learning tasks, and (e) use math facts in performing a novel skill not previously taught (contingency adduction). When a frequency aim meets these criteria, we call it a fluency aim. To establish such a functional fluency aim for math facts, the teacher would increase the frequency of math fact answers until students met the conditions specified above. Investigation of math facts fluency would reveal that the frequency aim that predicts retention, endurance, stability, application, and adduction of performance for most students is 80 to 100 answers per minute (Haughton, 1972; Johnson & Layng, 1992).

The acronym RESAA is a mnemonic for the multiple learning processes that are affected by frequency building and that are required for a performance to be considered fluent: retention (R), endurance (E), stability (S), application (A), and adduction (A). Behavioral fluency is a product of certain frequencies of performance that predict RESAA criteria will be met.

The history of mnemonics for the multiple products of fluency began in the late 1970s when Eric Haughton coined the acronym, RAPS (retention-application performance standards), as a challenge for teachers to help learners retain and apply the skills they taught. After Binder's (1988, 1993) demonstration of increased endurance as a function of higher frequency aims, the acronym switched to REAPS (retention-endurance-application performance standards). Still later, Lindsley and Johnson redefined REAPS to include the increase in performance stability that occurs at higher frequency aims (retention-endurance-application performance standard stability). No doubt the acronym for the products of high-frequency performance will continue to evolve with new discoveries. Whatever the acronym, fluent performance will remain the functional definition of true mastery (Binder, 1988).

Contingency Adduction

Certain arrangements or sequences of instruction and frequency building show promise for instructional efficiency and generativity of composite repertoires. By building composite repertoires from the bottom up, beginning with essential tool skill frequencies, and then moving on to other component behaviors, then to component sequences, then to composites, a teacher may discover that certain component and composite repertoires may occur along the way with little, if any, instruction, and may need little practice. We use the term *contingency adduction* to indicate those instances when the occurrence of novel performance meets new instructional criteria as a function of training its parts and prerequisites (Johnson & Layng, 1992, 1994). Technically speaking, contingency adduction refers to the process of recruiting behavior patterns or combinations of patterns (repertoires) by consequential contingencies that are different than the contingencies that shaped the original patterns (Andronis, 1983; Johnson & Layng, 1992, 1994; Layng & Andronis, 1987). Current iterated contingency requirements may rearrange existing repertoires, through processes of variation and selection, to produce an organism's first instances of behavior (cf. Donahoe & Palmer, 1994; Ferster et al., 1975). Early indications are that frequency building—in the context of a systematic program of massed, spaced, and cumulative practice—may make contingency adduction more likely to occur. In a selectionist account, such frequency building may make component performance more probable and thus more likely to be prompted and selected by current contingencies.

For example, we found that students at Malcolm X College needed no instruction in a task usually found to be very difficult for students to master: fractions story problems. When we built whole-number problem-solving and fraction-computation skills to fluency, they combined to produce fraction word problem solving simply when presented the contingency, "Can you solve these problems?" (Johnson & Layng, 1992). In a recent case, after key component skills such as finding the area of a rectangle and writing its formula were made fluent, students at Morningside Academy discovered themselves writing the formula for the area of a triangle with no instruction. Every day we see new and complex sentence constructions in students' written English compositions that are well beyond the students' peer grade levels. Upon inspection of the sentences, we see new recombinations of sentence components that the students had previously practiced to a frequency aim. Frequency building to establish fluency may prove to be a key element in the development of creative and problem-solving repertoires of all kinds. Similarly, Elizabeth Haughton, one of America's premier precision teachers and pioneers of fluency technology, notes that meeting fluency standards also increases creativity, creates high energy, increases time management, and is the best natural reinforcer for all it makes possible (personal communication, 1992).

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