Breaking the Structuralist Barrier

Literacy and Numeracy With Fluency

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Behavior analysis is an example of a selection science, and behavioral programs that follow the tenets of selectionism, long advocated by B. F. Skinner, can have a large impact on social problems. This article describes the characteristics of selection sciences and their application in the Morningside Model of Generative Instruction, which addresses both adult literacy and children's learning and attention problems. School curricula are analyzed for their key component elements and underlying tool skills. Teaching procedures then establish and build these key components to fluency. New and complex repertoires then emerge with little or no instruction, producing curriculum *leaps that allow students to make rapid academic advancement. Children typically gain more than two grade levels per school year, and adults advance two grades per month.*

> Structuralists and developmentalists tend to neglect selective contingencies in their search for causal principles in organization or growth. . . . The proper recognition of the selective action of the environment will require a change in our conception of the origin of behavior, a change perhaps as extensive as that of our former conceptions of the origin of species. (Skinner, 1981, p. 504)

> Complex forms are often built by a much simpler (often a very simple) system of generating factors. Parts are connected in intricate ways through growth, and alteration of one may resound through the entire organism and change it in a variety of unsuspected ways. (Gould, 1980, p. 42)

As you are reading this article, more than 34 million American adults will not be able to read the warning on a nonprescription medication they are taking, nor will they be able to verify the change they are receiving from a grocery purchase (*Information Please Almanac, Atlas and Yearbook,* 1991; *World Book Encyclopedia,* 1990). Deficiencies in these fourth-grade skills compound to devastating cumulative ignorance for these citizens, creating an extraordinarily costly social burden for the American people. For example, Berlin and Sum (1988) reported that poor basic skills are evident in 69% of all those arrested, 85% of unwed mothers, 79% of welfare dependents, 85% of dropouts, and 72% of the unemployed. Perhaps it is mere coincidence that the continuously accelerating illiteracy in America today parallels the increasing popularity of *structuralist* models of knowledge (Andresen, 1991; Palmer, 1986; H. W. Reese, 1991; Skinner, 1990; Winograd & Flores, 1986) and their "S-process-R" (stimulus-process-response) models of behavior that feature hypothetical constructs defining assumed mental processes (Alexander, Schallert, & Hare, 1991; Chase, 1986; Lindsay & Norman, 1977; Skinner, 1978). Whether coincidental or not, there is little to suggest (e.g., Stahl & Miller, 1989; Watkins, 1988) that these models, the linchpins of U.S. education, hold much promise for providing the rapid improvement in literacy required to resolve this country's educational crisis (Skinner, 1987c, 1990).

Although currently not in the mainstream, an alternative to structuralism has been evolving over the last several years (Lee, 1988). This approach is based on a *selectionist* framework long advocated by B. F. Skinner (1969, 1978, 1981, 1987a, 1987b, 1990). In contrast to structuralism, which emphasizes investigating knowledge structures and processing (Skinner, 1987c), a selectionist approach as applied to the analysis of behavior emphasizes investigating changes in behavioral repertoires over time. This approach shares with evolutionary theory (Gould, 1989) a common commitment to understanding complexity as a function of selection contingencies found in nature (Donahoe, 1986, 1991; R. M. Gilbert, 1970; Holland, 1987; Layng, 1991; Skinner, 1969, 1981, 1990). Moreover, this selectionist perspective is beginning to spread beyond the studies of behavior and evolution to the once structuralist-dominated field of computer science, as evidenced by the emergence of parallel distributed processing theory (McClelland & Rumelhart, 1986; Rumelhart & McClelland, 1986) and adaptive networks research (Donahoe, 1991; Donahoe & Palmer, 1989).

This article describes some of the selection contin-

Authorship of this article is considered equal.

We wish to thank the following teachers, mentors, and colleagues who established certain key component skills in their repertoires and made them fluent enough to recombine into the generative teaching model described in this article: Paul Thomas Andronis, Beatrice H. Barrett, Carl V. Binder, Philip N. Chase, Siegfried Engelmann, Israel Goldiamond, Eric Haughton, Ogden R. Lindsley, Susan M. Markle, J. Gilmour Sherman, Beth Sulzer-Azaroff, and Phillip W. Tiemann. This article is dedicated to their forefather and ours, Burrhus Frederick Skinner. We also wish to thank Joanne Robbins and Prentiss Jackson for their critical comments.

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Vol. 47, No. 11, 1475–1490

gencies responsible for behavioral complexity as they apply to education. We argue that a superior instructional system can be created by combining principles derived from a basic and applied behavior analysis that is selectionist in its approach, principles whose origins can be found in the laboratory, educational, and theoretical work of B. F. Skinner.

Generative Instruction and Fluency

Two critical features of the selectionist approach described in this article are its use of generative procedures, specifically *generative instruction*, and its insistence that skills are built to *fluency*. Generative instruction, which has emerged from both basic behavior analytic laboratory work (e.g., Andronis, 1983; Andronis, Goldiamond, & Layng, 1983; Epstein, 1981, 1985, 1991) and applied behavioral research (Alessi, 1987), focuses on effective teaching to establish key component skills and their underlying tool elements to fluency (Johnson, 1990, 1991). When presented with new environmental requirements, these behaviors can recombine in new ways that correspond to the higher level complex skills shown by experts. For example, basic number writing, addition, subtraction, and multiplication skills are the fluent components necessary to learn how to correctly factor an equation with ease. When these components are fluent, equation factoring is mastered by simply learning which numbers in an equation go in which position within which set of parentheses. Effective paragraph writing requires fluent component elements like basic letter and word writing speed, sentence combining, and sentence sequencing skills. Many structuralist approaches attempt to tackle student problems in thinking and problem solving by directly teaching structurally derived strategies and algorithms of the problem to be solved (e.g., Stepich, 1991). In contrast, generative instruction emphasizes making new or latent repertoires available to the environment, so that new contingencies can select solutions and curriculum leaps that have been adduced from former related and unrelated component performances, rather than explicitly trained, sequenced, or chained. This selectionist approach is thus nonlinear and systemic (Goldiamond, 1975, 1979, 1984). Intervention often targets establishing alternative repertoires or components of repertoires that produce the desired educational result without attending directly to the problem occasioning the intervention in the first place. That is, the problem the student presents is not always the problem to solve.

Fluency is defined as the rate of performance that makes skills not only useful in everyday affairs but also remembered even after a significant period of no practice (Binder, 1987, 1988; Haughton, 1972). In addition, the definition of fluency requires the skill to be available to the selecting environment as a behavior that can be readily linked or combined with other behaviors, thereby allowing students to perform complex tasks and solve complex problems. For example, students may be taught to spell words that follow the rule to double the final consonant before adding an ending that begins with a vowel. Many instructors might stop after students could spell three words per minute with perfect accuracy. The teacher and the students would probably say that the students now "know how" to spell those words, but a fluency-based definition of knowing is more rigorous. It is unlikely that at three words per minute students will (a) spell those words swiftly enough not to lose momentum and disrupt the chain, (b) remember how to spell those words after a significant period of no practice, or (c) spell them correctly when concentrating on a composition theme that uses those words. On the other hand, if students can build fluency to a rate just below the rate at which they can write their name (assuming that skill is fluent), they will be likely to remember and apply the spelling skill. Accurate performance needs to become quick, easy, and automatic to be (a) useful, (b) remembered, and (c) applied.

Fluency is efficiently achieved only with a measurement system that has both count and time dimensions (Johnston & Pennypacker, 1982). By using Skinner's fundamental discovery of frequency or response rate (Skinner, 1953b; Ferster, 1953) and its first derivative, rate of change, we are beginning to discover important relations among acquisition, retention, problem solving, and other aspects of how contingencies select performances and how repertoires evolve.

The Morningside Model of Generative Instruction and Fluency

Many independent but related behavior analytic efforts contributed to the model presented in this article. All, however, were occasioned by Skinner's (1938, 1953b) discovery of the importance of response rate as a dependent variable, his analysis of verbal behavior (1957), or his work in programed instruction (1954, 1968). These contributions include Tiemann and Markle's instructional content analysis (Markle & Droege, 1980; Tiemann & Markle, 1990); Engelmann and Carnine's analysis of curriculum and instruction (Engelmann & Carnine, 1982; Carnine, 1991); Keller and Sherman's personalized system of instruction (Keller, 1968; Sherman, Ruskin, & Semb, 1982); Lindsley's (1972, 1990, 1991) standard celeration measurement methodology and precision teaching; Haughton's (1972, 1980) fluency concept, and tool skill and channel set analyses for establishing component-skill objectives and fluency aims; Goldiamond's (1975, 1979, 1984) nonlinear contingency analysis; Johnson's (1991, 1992b) precision placement procedures and synthesis of direct instruction, precision teaching, and fluency-building technologies; Chase's analysis of the use of rules to increase as well as restrict response variability (Chase & Danforth, 1991; Joyce & Chase, 1990); Epstein and Skinner's principle of resurgence (Epstein, 1983; Epstein & Skinner, 1980); Epstein's research in generativity theory (Epstein, 1985, 1990, 1991; Epstein, Kirshnit, Lanza, & Rubin, 1984; Epstein & Medali, 1983); Andronis and Layng's formulation of contingency adduction (Andronis, 1983; Andronis et al, 1983; Layng & Andronis, 1984); guidelines provided by Markle (1964, 1969, 1991) and others for empirically validated, highly interactive instructional sequences (Engelmann & Carnine, 1982; Gilbert, 1962, 1978; Holland, Soloman, Doran, & Frezza, 1976); and Thiagarajan (1990) and others' game and simulation exercise technologies (Stolovitch & Thiagarajan, 1980; Thiagarajan & Stolovitch, 1978) to ensure relevant skill application and promote the adduction of separate repertoire elements into newly recombined forms and sequences.

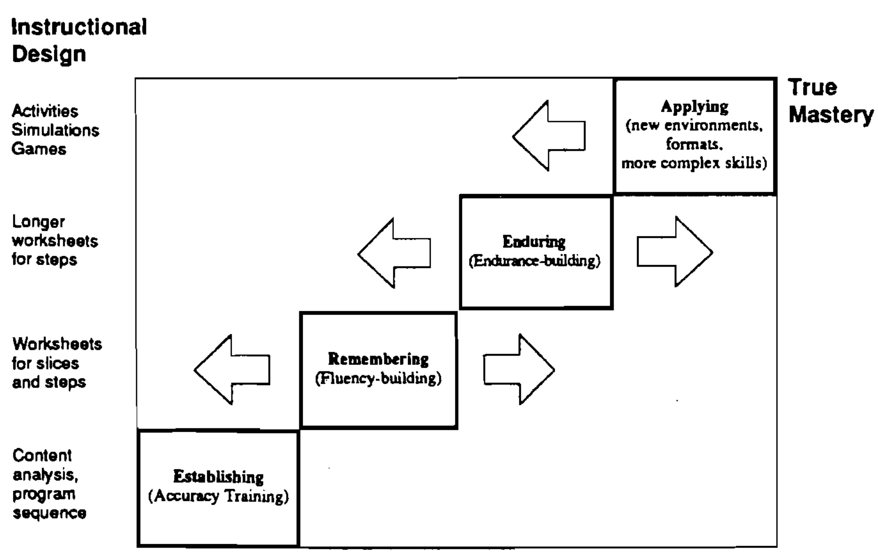
Figure 1 specifies each of the important instructional processes in the Morningside Model of Generative Instruction and their relation to each other.

The model is most efficiently implemented with one instructor and one fluency coach (teacher's aide or advanced student) per 15 students. Other ratios are possible and have been successfully implemented. However, great care has to be taken to group and seat students when the number exceeds 15. Previous teaching experience is not required of either instructors or fluency coaches. Implementation of the model requires about 60 hours of pre- and in-service training.

An important contribution to the model's success may be its use of *precision placement testing* (Johnson, 1992b; Starlin, 1972). There are, for example, 11 mathematics tests: computation with whole numbers; problem solving with whole numbers; fractions computation; problem solving with fractions; decimals computation; problem solving with decimals; computation and problem solving with ratios and equations; advanced number concepts and procedures; informal geometry concepts and procedures; measurement concepts and procedures; and concepts and procedures with tables, charts and graphs. Each test defines a *unit* in mathematics. Each unit has a series of *steps*. For example, the steps in the fractions computation unit include addition of fractions, subtraction of fractions, multiplication of fractions, and division of fractions. The six steps in the problem solving with whole numbers unit include five classes of addition–subtraction word problems and one class of multiplication–division word problems. The items on each precision placement test are the *slices* of each step. Each slice is keyed to a scripted instructional presentation that has been designed according to strict instructional design standards (Englemann & Carnine, 1982; Markle, 1969, 1991; Tiemann & Markle, 1990). For example, problem solving with fractions that involve the division of fractions by other fractions is a curriculum slice in the step that includes all problems involving division with fractions, and it has its own scripted presentation. Students who make errors on these placement test items are prescribed this particular script as part of their personalized instructional sequence.

Students who need instruction gather with a teacher at a horseshoe-shaped table for a 15-minute, highly interactive instructional episode. During instruction, the teacher stands in front of the group before a blackboard. A scripted presentation is placed on a music stand and is referred to when necessary. The script allows the teacher to present empirically validated rules, examples, and nonexamples of concepts, principles, and procedures of problem solving (Carnine, 1991; Englemann & Carnine, 1982; Markle & Droege, 1980; Tiemann & Markle, 1990) to students, who simultaneously respond to the instruction on signal at a rate of approximately 10 responses per minute. Recognition of progress and corrections for errors occur rapidly as well. The volley between teacher and

Figure 1
Morningside Model of Generative Instruction



Note. The large arrows indicate that steps can move horizontally to provide overlapping learning phases. True mastery is the product of the steps.

student responses is very rhythmic, as if a choreographer played a part in the production. Students typically respond loudly and enthusiastically. Many readers will recognize these instructional procedures as part of Engelmann's direct instruction system (Kinder & Carnine, 1991).

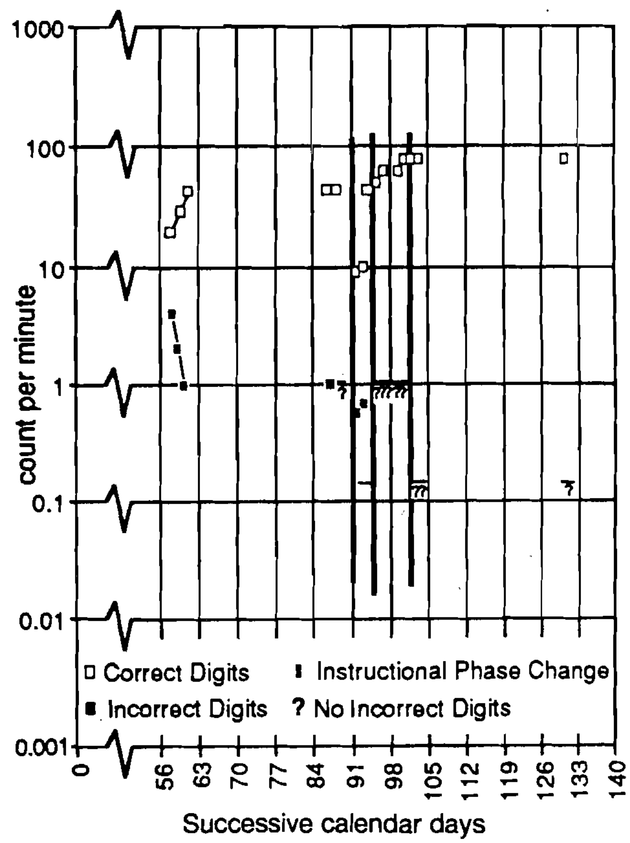
Student progress is monitored using Lindsley's (1972, 1990, 1991) *standard celeration chart.* Its logarithmic, count-per-minute scale "up the left" (*y*-axis) enables students to measure and chart data on frequencies of correct responses as well as on frequencies of errors. Each data point is equivalent to the average of one minute of responses in a cumulative record slope (Ferster & Skinner, 1957; Skinner, 1938). Accordingly, as data points increase in value over time, they indicate increasing rates of change. Because growth is proportionate to previous growth, the chart's ratio scale produces straight accelerating lines if the student's rate of change is being maintained. Curves indicate faster or slower rates of change. Because rate of change, not absolute frequency, is used as the critical property of progress, the chart makes it easy for students and teachers to make quick, daily, timely decisions about whether a student is progressing to fluency (Binder & Watkins, 1990; Lindsley, 1990, 1991). Many readers will recognize this dimension of the Morningside Model as precision teaching (Binder, 1991; Lindsley, 1990, 1991). The Morningside Model requires that students maintain a slope that indicates a doubling, or "times-two," increase in performance frequency per week. If a slope indicating a times-two increase is not obtained for three consecutive days, then the instructor, fluency coach, and student change the learning procedures or material to be learned. By working directly with an instructor and the standard celeration chart, students become their own fluency coaches and precision teachers. They quickly learn how to improve their performance through daily practice, self-monitoring, decision making, and self-correction.

The model's standards for progressing through curricula are based on functional criterion frequencies that facilitate three important learning processes that should result from initial learning: remembering, enduring, and applying. Haughton (1980) referred to this multicriterion focus as REAP/S: retention, endurance, application performance standards. When a learner meets the multiple criteria, "true mastery" has occurred (Binder, 1988) and a "permanent repertoire" has been established (Johnson, 1990, 1991, 1992a, 1992b). For example, to show true mastery of the identification of faulty logic in argumentation, the student must first demonstrate the skill after a significant period of no practice. To ensure remembering, students must practice the skill until they can identify faulty logic almost at their silent reading rates. We have found that an approximation to this standard can be obtained by dividing the student's reading rate per minute by 1.2 and positioning several instances of faulty logic in that amount of text. The students' goal is to identify all of the faulty logic in the passage in one minute. This practice procedure helps assure that identification will occur immediately upon reading it. When this fluency aim is achieved, an assessment following a month of no practice will verify remembering.

Second, the learner also must be able to identify faulty logic at a rate that does not decrease when the passage length is extended. Endurance (Binder, Haughton, & Van Eyk, 1990) can be ensured by doubling then tripling the amount of text and the timing interval for practice after a student reaches the remembering fluency aim.

Figure 2 illustrates the sometimes complex relations between remembering, endurance, and fluency. It shows the need to adjust remembering aims to build endurance. When Marie built her rate of long multiplication answer digits to 50 per minute on Day 59, her rate remained unchanged when measured on Day 89, one month after no practice. However, when she was given a five-minute timing on Day 92, her rate dropped to 10 per minute and errors recurred. When her 1-minute rate was then built to 70 per minute, achieved by Day 96, it remained at 70 per minute when tested for five minutes on Days 101 and 102. On Day 131, after one month without practice, she

Figure 2
Marie's Progress



Note. Standard celeration chart of Marie's rate of long multiplication answers, in digits, during fluency building and endurance building. Solid lines below the 0.2 count-per-minute line indicate five-minute timings. All other timings were one minute.

was still performing at 70 per minute with zero errors for five minutes.

Not only must students be able to remember skills and perform them with persistence, they must also be able to apply the skills in various contexts. The goal is for students to be able to apply the skill in new or more complex situations than previously encountered in instruction or practice. The teacher's task is to determine what skill frequency accelerates composite skills of which it is a component. As with endurance, one can begin with the remembering fluency aim. Verification that the remembering fluency aim is sufficient for successful application can be achieved by creating new environmental contexts for engaging in the skill (Tiemann & Markle, 1990). For example, after a student can identify instances of faulty logic in long passages of text for long periods of time, after significant periods of no practice a student might engage in a formal debate with an instructor or coach in front of an audience. During the debate, the coach could break each of the various logic rules, making sure the student can catch them all.

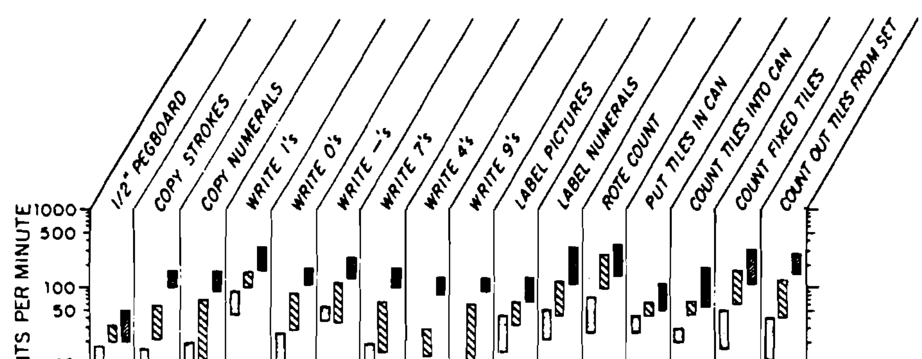
The arrows next to the boxes in Figure 1 indicate that the boxes can move horizontally. Some learners can begin fluency building simultaneously with accuracy training, others need to be fully accurate before they can profitably build rate, and still others are between the two extremes. Likewise, some learners can begin endurance building as soon as they begin to build rate; others need to reach remembering fluency first. Some can begin applying skills almost as soon as they are taught. Discovery learning or adduction activities, often in the form of games and simulations, are used to encourage the application and recombination of firmly established skills. The steps in the model may need to be rigorously programmed for some learners, whereas others profit from a less rigorous sequence.

Tool Skill Applications and Other Component–Composite Relations

Nowhere has the importance of setting application standards been more dramatic than in the case of basic *tool skills.* Tool skills are the most basic elements of more complex skills. For example, in order to build fluency in oral reading, one must be able to say sounds and words quickly. In order to build fluency in composition, one must be able to copy letters and words quickly. Although early studies in perceptual–motor learning demonstrated that fluency in task parts makes fluency on complex tasks that contain these parts easier to achieve (e.g., Gagne & Foster, 1949), it was not until the late 1960s that Eric Haughton studied such relations in education. Haughton (personal communication, August 1978) found that college students having trouble in calculus could improve their performance by building fluency on very basic elements, such as saying and writing numbers and math facts. Haughton (1971, 1972, 1980) reported that a program of tool skill building improved underachieving students' math performance to the level of their competent peers, whereas an arbitrary reward system, increasing the potency of consequences, and extensive practice in math at the students' grade levels all failed to improve their performance. Again, the presenting problem is not always the problem to solve.

Barrett's (1979) data, presented in Figure 3, illustrates some quantitative relations between tool *component skills* and the *composite skills* of which they are a part.

Figure 3
Component–Composite Relations



Note. Standard celeration chart comparing frequencies of some basic tool skills among three groups. The higher the frequency of a component skill, the smaller the ratio between component skill frequency and composite skill frequency. The height and position of each symbol indicate the range of performance. Data is from a pilot study conducted at the Fernald School, Waltham, Massachusetts, by Beatrice H. Barrett and her colleagues. From "Communitization and the Measured Message of Normal Behavior" (p. 313) by B. H. Barrett, 1979, in *Teaching the Severely Handicapped* (Vol. 4), Columbus, OH: Special Press. Copyright 1979 by Beatrice H. Barrett. Adapted by permission.

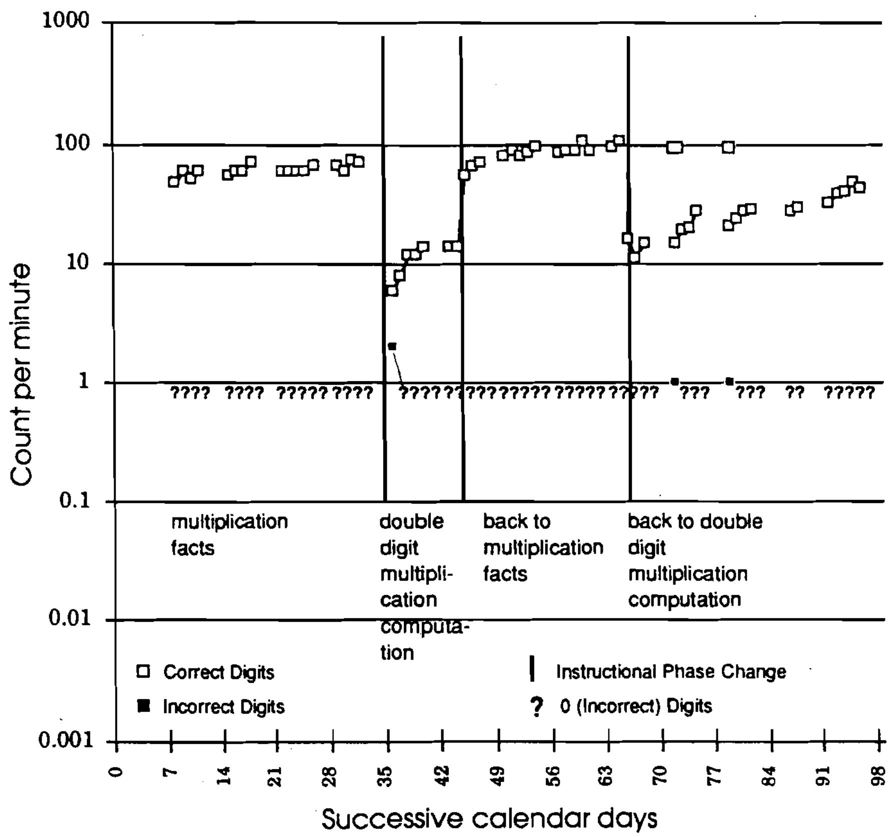
For example, writing the number 1 is a component skill in writing a 4. Nonretarded adults who wrote a series of 1s at an average rate of 210 per minute could write 4s at an average of 100 per minute, or about one half as fast. Barrett also measured a group of developmentally disabled students performing the component skill, writing 1s. They averaged only 60 per minute. Their composite skill performance, writing 4s, was only 5 per minute, or about one twelfth of their component rate. This ratio suffers in comparison with the adults' composite–component relation of one half. Other similar component–composite relations are shown in the figure. They all support formally investigating the validity of the assertion: The higher the frequencies of component behaviors, the greater the acceleration of their composite or more complex behaviors.

Although the relation between component and composite skills can be complex and many interactions must be taken into account, our data support the practice of building component skills to high rates, much higher than the rates necessary to be useful in daily life. Figure 4 demonstrates a typical relation between component and composite performance rates. When Laurie's multiplication math facts rate was only 70 per minute, the teacher attempted to build her fluency in complex multiplication computation. The student quickly leveled off at 15 correct digits per minute, a rate that would never guarantee remembering or enduring (Johnson, 1990, 1991, 1992a, 1992b). Instead of intensifying the practice efforts, the teacher stepped back in the curriculum and built the student's component tool skill, multiplication math facts, to 100 per minute. When the complex multiplication computation fluency building exercise was reintroduced, the student's rate steadily rose to 50 correct digits per minute. Notice that the initial composite performance of 15 digits per minute is less than one fourth of the initial component skill rate of 70 per minute. However, the later composite performance of 50 digits per minute is one half of the 100-per-minute component skill. Progress in complex tasks depends on high prerequisite skill performance. Our charts show us again and again that the higher the prerequisite skill rates, the faster a complex skill will be learned.

Fluency: Overlearning Rediscovered?

Now and again, certain behavioral scientists have described the relevant correlation between frequency and

Figure 4
Laurie's Progress



Note. Standard celeration chart of Laurie's rate of long multiplication answers, in digits, as a function of her multiplication math facts rate. All timings were one minute in length. The data illustrate a component skill dysfluency that stops a composite skill from becoming fluent.

future probability of action. Unfortunately, however, until recently these descriptions have been shrouded by hypothetical constructs or have concentrated on repetition or amount of practice. For example, Guthrie (1952) traced the so-called law of frequency from observations made by Aristotle to sources of his day. Henmon (1911) noted a relation between visual discrimination frequency and visual ability. Several psychometricians at various times have noted the relation between IQ test completion frequency and overall intelligence (McFarland, 1930; Tinker, 1931; Wolf & Stroud, 1961). An entire literature exists in what has been called *overlearning* (Kling & Riggs, 1971, chaps. 17, 20, & 21) that examines the effects of practicing beyond an accuracy criterion. Tinker (1934) told of the relation between frequency of problem solving and percentiles on a test of problem-solving ability. Laberge and Samuels (1974) have discussed what they call *automaticity*, reporting that building reading speed makes verbal associations automatic, thus obviating the need to pay attention. They observed higher reading comprehension scores in subjects who increased their reading speeds and concluded that training beyond the accuracy criterion must be provided if the association is to occur without attention. The dimension that we are stressing, however is not simply repetition or practice beyond accuracy but the *rate* of performance, typically measured as a count per minute, that will predict remembering, endurance, and application after a significant period of no practice (Haughton, 1980).

Binder (1987) demonstrated the importance of response rate to fluency, endurance, and distractibility in a series of laboratory and classroom studies. In one experiment, children learned to say specific numbers when presented with specific Hebrew letters. The students learned the paired associate task, number correlated with each Hebrew letter, to 100% accuracy. Although they were well practiced beyond the point of 100% accuracy, the students could say numbers on presentation at only very low rates. While wearing headphones, the students were then asked to "add" pairs of Hebrew letters. At certain times the children heard a voice saying random digits while they added. When the children's rate of saying numbers on presentation was low, the random number voice completely disrupted their adding performance. However, when the students became fluent at number–Hebrew letter pairs, they were able to perform the adding task at a consistent pace, despite the distracting voice. Similarly, recent data (Binder, Haughton, & Van Eyk, 1990) suggest that fluency building may reduce the high distractibility characteristic of the behavior of students diagnosed as having an attention-deficit disorder (ADD). ADD students who were given extensive endurance training on a variety of tasks were able to greatly increase their attention span. Training began with 20-second timings, which were gradually increased to longer timings until students met criterion.

Instruction and Fluency Intertwined

The Morningside Model does not simply apply modern instructional design principles to instructional sequences that are then followed by periods of timed practice to certain fluency criteria. The procedures used here integrate *repertoire establishment* with rate-building. By repertoire establishment we mean occasion–behavior relations (Goldiamond, 1974) or stimulus control topographies, not merely behavior in the presence of any occasion (Ray & Sidman, 1971). When a repertoire is established, an occasion or stimulus is reliably accompanied by a behavior, without extraneous prompts, hints, or aids. The integration of repertoire establishment with rate building creates a self-correcting mechanism in the Morningside Model, assuring that (a) fluency building procedures correct repertoire defects established during instruction and (b) subsequent instruction expands or relocates any occasion–behavior relations that drifted during previous fluency building. Accurate establishment alone may not guarantee maintenance of the relation or its availability for adduction by new environments. Similarly, rate building alone may not guarantee that targeted occasion–behavior relations will be established.

Several procedures in the Morningside Model illustrate the intertwining of instruction and fluency. Only when establishment and rate-building procedures are intertwined, resulting in a built-in system of checks and balances, can we have any confidence that a repertoire will be selected by the educational contingencies and retained. For example, all instructional scripts have both accuracy and rate criteria, requiring that students achieve a minimum of 0.8 times the rate of 8–10 responses to the teacher per minute. In addition, fluency building involves increasing not only the rate of completing tasks presented during instruction but also the complexity of the problems, until they resemble those encountered in daily life. For example, the tasks presented during fluency building of story problems with whole numbers gradually incorporate larger numbers, more advanced vocabulary, and more irrelevant details or distractors—information not needed to solve the problem. Below are two subtraction problems that students encounter as they build fluency. They are both in the class of problems that take the algebraic form $X - Y = Z$, where X and Z are known. The problems represent ends of the continuum from simple to complex:

Betty had six pieces of candy. She gave some of them away. Then she had four pieces left. How many pieces did she give away?

Barbara came into a windfall of money for her birthday. She received $729 and decided to spend $29 on cassette tapes of rap music. She took her $729 and went shopping at Marshall Fields. By the time she was done she had depleted her supply to $539. How much did she spend?

The variable attributes of tasks are held constant during instruction and initial fluency building. Once control by the critical attributes is established and behavior in the presence of its occasion made fluent, task variation is expanded while fluent rates are maintained. If errors begin to occur, teachers identify the changes in the variable properties that are causing performance breakdown and use them to correct student errors (Tiemann & Markle, 1990).

Instruction and fluency building are also intertwined during initial fluency-building exercises, called *sprints*. All sprints are accompanied by carefully designed procedures for catching and immediately correcting student errors. Instructors and coaches also use correction procedures during endurance timings. Student performance is sampled, and when errors occur the timing is interrupted and errors are corrected. If the endurance tasks do not lend themselves to error detection during ongoing student performance, fluency coaches conduct error-pattern analyses (Tiemann & Markle, 1990) after the student completes the endurance timing and then implement the appropriate correction procedure. Endurance timings and corrections continue until the student has reached the prescribed fluency aim with no errors for the timing interval.

Two Examples of the Implementation of the Morningside Model

Two programs, one begun at Morningside Academy, Seattle, Washington, 12 years ago and one launched in January 1991 at Malcolm X College, Chicago, Illinois, illustrate the Morningside Model of Generative Instruction for both children and adult learners. Children diagnosed as learning disabled, who have never gained more than half a year in any one academic year, typically gain between two and three years in each academic skill per year. Adults below the U.S. government-defined eighth-grade literacy level advance at the rate of two academic years for every 20 hours of instruction in each skill. Skills taught at Morningside Academy and Malcolm X College include the basics: mathematics computation and problem solving, reading decoding and comprehension, grammar, spelling, writing, critical thinking and reasoning, and organizing and studying. No homework is required for either program.

The program at Morningside Academy has produced an instructional system that offers parents two money-back guarantees. The first is that a child who is behind two or more grade levels will advance at least two grade levels in one year. The second is that children independently diagnosed with so-called attention-deficit disorder will increase their time-on-task endurance from their typical 1–3 minutes to 20 minutes or more—an attention span longer than that of the average college student (E. P. Reese & Johnson, 1975)—within the time it takes to achieve peer grade level parity.

The program at Malcolm X College is likewise performance- and accomplishment-based (Gilbert, 1978). The primary accomplishment is straightforward: Underprepared high school graduates will acquire the skills necessary to maintain a B or better average in college-transferable courses in two academic semesters or less, provided the students attend sessions on a regular basis and participate as the program requires. Over 40% of all Malcolm X College students with high school diplomas score below the nationally defined eighth-grade level literacy standard, as measured by the Nelson-Denny Reading Test (1981). About 30% of these students test below sixth-grade reading levels. Without the program, underprepared Malcolm X College students with such entering behaviors typically take as long as three years to build their precollege skills to a point where they can qualify for college transfer courses. The demands of adult living assure that most do not persevere that long.

Morningside Academy's kindergarten-through-eighth-grade students gain an average of from two to three grade levels per year, as measured by two different national standardized achievement tests, the California Achievement Tests (CAT; 1978) and the Metropolitan Achievement Tests (MAT6; Prescott, Balow, Hogan, & Farr, 1986). These gains are presented in Table 1. Morningside has never had to refund tuition for failure to meet its money-back guarantees in the seven years since the assurances have formally been in place.

In the fall of 1987, Morningside Academy began a comprehensive adult literacy program in reading, mathematics, and writing for agencies eligible for federal monies dispersed by the Job Training and Partnership Act (JTPA; 1985), a revival of Lyndon Johnson's Great Society CETA program coauthored by the unlikely partnership of Senators Edward M. Kennedy and J. Danforth Quayle, this time with business and community agencies as partners. Morningside proposed that all payments be performance-based. That is, Morningside agreed to be paid only for participants who progressed at least two grade levels in two skills. The duration of the contract was 21 months.

The first JTPA project consisted of 32 African-American male youths and young adults at risk, aged 16–26 years, who were enrolled in the Seattle YMCA Metro Center's job preparation program. These participants entered with skills between second and eighth grade as mea-

Table 1
Morningside Academy Children's Mean Standardized Achievement Test Grade Level Gains

Year	*N*	Reading *M*	Reading *SD*	Language arts *M*	Language arts *SD*	Math *M*	Math *SD*
1981–1982	11	2.4	0.51	1.6	0.56	2.1	0.97
1982–1983	43	2.3	0.57	1.9	0.73	1.9	0.65
1983–1984	75	2.4	0.86	1.9	0.65	2.0	0.73
1984–1985	54	2.5	0.75	2.7	0.97	2.2	0.56
1985–1986	28	2.0	0.72	3.0	0.83	2.5	0.62
1986–1987	24	2.3	0.84	2.3	0.70	1.9	0.77
1987–1988	27	2.3	0.70	3.5	0.84	2.2	0.83
1988–1989	32	2.5	0.83	3.0	0.72	2.7	0.70
1989–1990[a]	11	2.8	0.77	3.3	0.75	2.4	0.84
1990–1991[a]	21	2.2	0.62	3.8	0.86	3.9	0.72

[a] Metropolitan Achievement Tests (MAT6). All others: California Achievement Tests.

sured on the MAT6 (Prescott et al., 1986). Many were homeless, had criminal records, and, in a few cases, were in and out of jail during the course of the program. The participants were given street cleaning jobs in the Metro Center's Clean City Enterprise Program in the mornings o learn job-related skills such as attendance, cooperation, and productivity. In the afternoons, they attended Morningside Academy for academics.

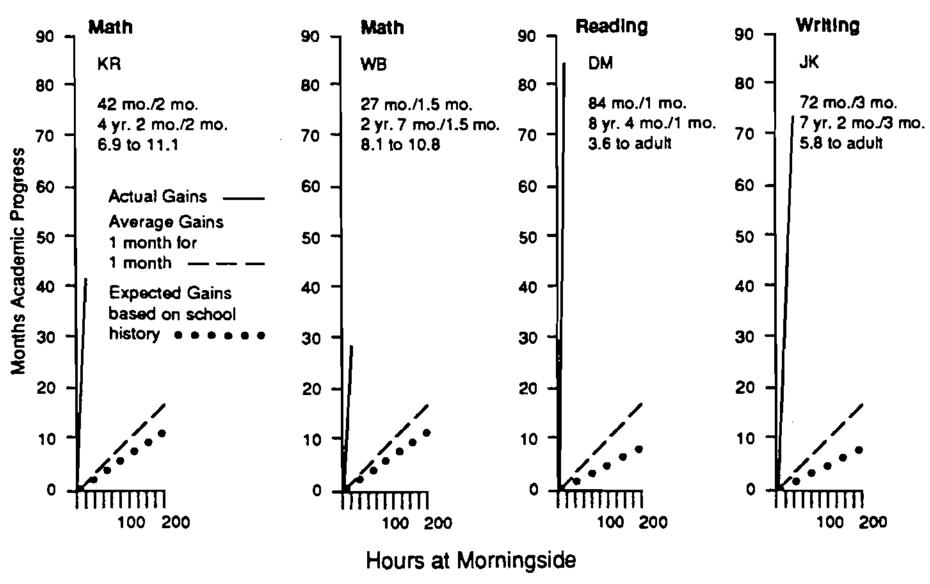
Each participant attended Morningside Academy Monday through Friday between 1 and 3 p.m. One teacher, trained in the Morningside Model of Generative Instruction, taught the students. Each student selected two skill areas for improvement and received approximately one hour of instruction in each skill per day. Students could enter and exit the program at any time during the first 12 months of the federal contract. Because of the staggered nature of the enrollment, the average number of students attending on any given day was 12.

Twenty-nine of the 32 students successfully completed the program, that is, exited with skills at or above the national eighth-grade level literacy standard. Their average attendance was 3.8 days per week. Their average progress was 1.7 grades per month (20 hours of instruction) in each skill, or two grades for 24 hours of instruction as measured on the MAT6 (Prescott et al., 1986). With full attendance, the participants' progress could have been two grades for 18 hours of instruction. Such progress is in stark contrast to the U.S. government standard of one grade level per 100 hours of instruction (Comprehensive Adult Student Assessment System, 1987).

Thirteen months later, a group of 20 Asian-American women aged 25–40 began their matriculation at Morningside. Their agenda was to learn prerequisite mathematics, reading, spelling, or writing skills as needed for office and computer-related occupational skills training programs offered throughout the city. These participants entered with skills between the fifth and eighth grades. None were homeless or had criminal records. Nineteen of the 20 students successfully completed the program, that is, exited with skills necessary for successful entry into their chosen occupational skills training program. Their average attendance was 3.9 days per week. Their average progress in each skill was 2.1 grades per month, or two grades per 19 hours of instruction as measured on the MAT6 (Prescott et al., 1986). With full attendance, the participants' progress could have been two grades per 16 hours of instruction.

Figure 5 illustrates the progress of four representative individuals in the adult literacy program. The dotted lines in each graph represent the individuals' predicted gains, which were calculated by dividing their entering grade level performances by the number of years they spent in school. The dashed lines drawn on the diagonal of each graph represent the standard progress expected of students in school: one year of progress for one year of schooling. The solid lines represent the individuals' gains in the Morningside program as measured on the MAT6 (Prescott et al., 1986). In each case the participants' actual progress far exceeds both the standard and predicted progress. To quote one student, James, displaying well deserved pride in a recent Seattle newspaper article on Morningside Academy, "I'm getting things accomplished

Figure 5
Progress of Four Adults



Note. Representative gains of four adults in Morningside Academy's adult literacy project, expressed as months/years of academic progress as a function of hours/months of instruction. Twenty hours equals one month of instruction. Actual data are reported under each student's initials as months progress/hours instruction, years–months progress/hours instruction, and grade level entry to grade level exit.

now. I'm going to live the good life, the way life is supposed to be lived."

A pilot project based on the Morningside Model was undertaken at Malcolm X College in the summer of 1991. Thirty-three students ranging in age from 9 to 48 years and 10 Malcolm X College tutor-trainees participated in the pilot mathematics program based on the Morningside model, Monday through Thursday, 9 a.m. to 12 p.m. for six weeks. An afternoon program that emphasized oral reading rate and study skills ran from 1 p.m. to 3 p.m.[1]

The summer program constituted a natural multiple-baseline experiment in the implementation of the Morningside Model. After establishing four days of baseline level performance through precision placement testing (Johnson, 1991), students were divided into five groups: one with low level skills in working with whole numbers; one with higher level whole number skills but no fractions skills; one with low level fractions skills; one with higher level fractions skills but no decimal skills; and one with decimals, ratios, equations, and other prealgebra skills. The latter group did not need intensive instruction on any of the objectives in the math sequence but did need brush-up work and fluency building throughout the sequence.

During the first week of teaching, it became clear that although the tutors of the two fractions groups and the prealgebra group were correctly implementing the model, reaching the goal of 25 objectives per student per week, the tutors of the two whole numbers groups were making significant errors, such as not requiring simultaneous responding during script presentation and not immediately following instruction with fluency sprints. As a result, at the end of the first week, students in the two fractions groups had achieved many more objectives in the sequence than students in the two whole number groups, who averaged 9.2 and 14.6 objectives respectively. After the third week, the tutors of one of the whole number groups began to correctly follow the model and increased the number of objectives each student accomplished that week to 25. By the last week of teaching, the tutors of the other whole number group were on track, increasing their rate of accomplishment to the levels achieved earlier by the other three groups.

At the end of the summer term, the two fractions groups, who started out at the 5th-grade level, completed over 107 objectives and gained over six years in mathematics computation and two years in mathematics problem solving and concepts. The two whole number groups, who started out at the 4th-grade level, together completed over 43 objectives per student and gained one year in mathematics computation, 0.9 years in mathematics problem solving, and 0.6 years in mathematics concepts. The advanced group, who started at the 10th grade level, received brush-up work, tool skill development, and fluency building. They gained 1.9 years in mathematics computation, three years in mathematics problem solving, and 2.2 years in mathematics concepts. Pretest and posttests were conducted using Forms L and M respectively of the MAT6 (Prescott et al., 1986) achievement test. All students had approximately 33 hours of combined mathematics instruction and practice.

Reading vocabulary and comprehension, as measured by the Nelson-Denny Reading Test increased 1.1 years in approximately 20 hours of timed practice. The goal of the practice was to increase oral reading rates to match spoken reading rates, thereby increasing comprehension. The results from the timed practice essentially replicated earlier experimental work (Tenenbaum & Wolking, 1989) on the comprehension effects of increasing oral reading rate.

The pilot program served as the foundation for a new Precollege Institute, which began in the fall of 1991. The Precollege Institute was established for students with high school diplomas who attempt to register at Malcolm X College but have reading or math skills below the sixth-grade level. The main purpose of the Precollege Institute is to offer an accelerated approach to building precollege skills, to prevent students from dropping out before they achieve college level status, and to help ensure student success in college level courses. The Precollege Institute now instructs students in precollege mathematics, reading decoding and comprehension, written and oral communication skills, group and individual study skills, and critical thinking. No homework is required; all practice is provided as a part of instruction. The Precollege Institute is staffed by specially trained tutors, many of whom are current or former students at Malcolm X College. The Precollege Institute students now routinely average two grade level gains for every 20 hours of combined instruction and practice in a skill. This is even more remarkable because all but three of Malcolm X College staff members, including supervisors, instuctors, and coaches, are undergraduate students.

A Day in the Life . . . A Closer Look at the Morningside Model

What do adult learners come in contact with in the Morningside Model that results in academic gains of at least two grade levels a month, given that their initial foray with academic learning contingencies produced so little progress? Let us examine the process through the eyes of a hypothetical student, Carter. Carter could be a student at either Morningside Academy or Malcolm X College. Although mathematics is the skill area discussed in this example, we have analyzed all the basic skills we teach, scripted the necessary instruction (e.g., Johnson, 1992a, 1992b; Layng, Jackson, & Robbins, 1992) or purchased it (e.g., Englemann, Johnson, Becker, Meyers, Carnine, & Becker, 1978; Englemann, Meyers, Johnson, & Carnine, 1978), and developed fluency exercises. These

[1] The summer pilot project at Malcolm X College, one of the city colleges of Chicago, was supported by a Special Populations Grant from the Illinois Community College Board. The Precollege Institute owes its existence to the support of the administration, faculty, students, and staff of Malcolm X College and to the Office of Academic Affairs, the district management team, and the board of trustees of the Central Office of the City Colleges of Chicago.

other skill areas include critical-scientific thinking, reading, and writing.

Carter's program entry begins with an interview and orientation. He then completes the three mathematics sections of the MAT6 (Prescott et al., 1986). These results provide external validation of progress but do not help us place Carter in the Morningside mathematics instructional sequence.

Carter's placement begins with precision placement tests in math (Johnson, 1991). Carter starts his precision placement testing with whole number computation and its companion, problem solving with whole numbers. Of the 56 slices constituting four steps in computation, Carter makes scattered errors with no particular clustering in any given step. On the problem-solving test, Carter makes no errors on the addition–subtraction items but several errors on the multiplication–division items. Carter's teacher returns the computation test to Carter and asks him to try to correct the errors without any assistance. He corrects all but two, indicating a need for fluency building but not instruction.

Carter's final work this first day is most fundamental. The teacher assesses Carter's rate of completing three tool skills, those most basic elements of successful mathematics progress. These include number writing, number reading, and math facts. The teacher, in fact, notices that several of Carter's errors in whole number computation are due to math fact errors. Seventeen minus 9 is not 6, nor does 9 times 8 equal 69. The teacher begins by asking Carter to read a series of single digit numbers as quickly as he can in one minute. The fluency aim that predicts progress in learning mathematics is reading 200–250 digits per minute. Carter counts in at 125 digits. Because this first timing is a snapshot that typically underestimates what the response rate will be after several warm-up timings, the teacher gives Carter four more timings. His best timing is 140 digits per minute, far below the necessary tool skill frequency.

Next, the teacher asks Carter to write the digits in order from zero to 9 as many times as he can in one minute. The fluency aim for this skill is 160–180 digits per minute. Carter's snapshot counts in at 95 digits, and his best rate after five timings is 107 digits per minute, again far below the necessary tool skill aim. Carter reads and writes numbers so slowly that he has no momentum to stay with the computation tasks, and he falls out of more complex computational chains. Carter's gloomy face indicates that math work is very tedious as well. Carter's math facts performance is even more dismal. His rate is 25 per minute, less than one third the standard fluency aim of 80–100 facts per minute. Carter's rate is not atypical, however.

What is the teacher's final analysis? The teacher explains the tool skill problems to Carter and goes into great detail about the ramifications of fluent tools. Carter is to devote 30 minutes a day to tool skill work. Carter also needs fluency building in computation with whole numbers; even though he eventually answered 54 of the 56 problems correctly, he completed them very slowly. The teacher also tells Carter that he needs instruction in multiplication–division problem solving because he could not self-correct his placement errors. Then he will be ready for fluency building on that skill step. For the next day, 30 minutes of tool skill building and computation fluency building is scheduled, followed by the appropriate scripted instructional presentation in problem solving.

After two weeks, Carter is fluent in whole number computation and problem solving, so the teacher assigns a bit of fluency maintenance work in these areas each week. His tool skill performance has doubled each week as well. The teacher administers the companion fractions computation and problem-solving precision placement tests. This time much more instruction is needed, but in our experience not nearly as much as would have been indicated had Carter taken these placement tests before the work in whole numbers. A partial repertoire in fractions was adduced when some of its key component elements in whole number mathematical behavior were made fluent.

Carter's instruction has not been a one-to-one interaction with a teacher. He is one of several students, as many as 12 to 14 on a given day. Teachers complete summary sheets of the instruction and fluency-building needs of all of their charges and group students together accordingly. They then proceed to pull subsets of students for instruction throughout the day.

The next day Carter receives group instruction in multiplication–division problem solving along with the 11 students who are present. Soon the participants are responding at approximately eight correct responses and two errors per minute; they then proceed with fluency building to make their new repertoires automatic and permanent. The teacher gathers the fluency coaches, who are aides and other students at more advanced levels in the curriculum sequence, together with the students just instructed and begins timed firming exercises or sprints on the skill just taught. After 10 minutes or so, the students and coaches are on their own. The teacher then calls the subset of students who need the next script in the sequence to the instruction table. A student who was engaged in the first instructional episode may also participate in the second. This was not true for Carter; he needed only one script that day.

The remainder of Carter's day is spent building useful and permanent computation and problem-solving skills through fluency-building procedures. Mastery is defined not by percentage of tasks performed correctly immediately following instruction but rather by the pace at which a skill is performed. Carter may learn to solve one multiplication-division story problem in five minutes during instruction, but it is unlikely that he will be able to (a) solve such problems in a reasonable amount of time when they present themselves in real life, (b) remember how to do this kind of problem after a significant period of no practice, or (c) apply these skills to solve more complex multistep problems.

During fluency building, Carter gets coaching from the teacher's aide, or fluency coach, as well as from more advanced students who are not participating in small-group instruction with the teacher. Today Carter and his junior fluency coach, a peer in the program who is mastering early algebra, begin with a 20-second timing on the skill just taught, multiplication-division story problems, to determine the frequency with which Carter can perform the task. On subsequent days, they first determine Carter's current rate and then build the rate toward an established fluency aim: that empirically determined frequency that predicts remembering after a significant period of no practice. Beginning with successive timings of 20–30 seconds, Carter gradually builds his problem-solving frequency into the range of his reading rate plus his number-writing rate divided by 1.2, or approximately three to nine problems per minute, depending on the length of the problem.

After a few days, Carter is fluent at problems that approximate the complexity of those encountered in daily life. He then builds his endurance in problem solving, maintaining his one-minute frequencies for five minutes.

Carter's computation practice proceeds in a similar manner, from fluency building with problems containing smaller numbers vertically aligned in columns, to problems with larger numbers presented horizontally, into the frequency range of 31–36 answer digits per minute. Once fluent, Carter proceeds with endurance timings.

Whereas the instructional episodes resemble academic singing and dancing, the fluency-building sessions resemble an academic gymnasium, complete with sprints that function as "warm-ups" for firming skills established during initial instruction, and "long-distance runs" or endurance timings of five minutes or more after the student has learned all of the steps in an academic unit. Within a few days, Carter is fluent at whole number computation and problem solving. He completes his own endurance runs easily and will likely never forget how to perform these tasks, much as he never forgets how to ride a bicycle or spell his name.

In the first day of fluency building on addition–subtraction math facts, Carter's standard celeration chart shows no progress across a sequence of timings. He and his coach note when and where hesitancies and errors occur during timings. Whenever facts have numbers bigger than 4 in them, hesitancies occur. Whenever facts have numbers bigger than 8 in them, errors occur. The coach also notes that the three numbers that recombine into four addition–subtraction facts (e.g., 6, 7, and 13 produce $6 + 7 = 13$, $7 + 6 = 13$, $13 - 6 = 7$ and $13 - 7 = 6$) do not occur automatically: Carter uses his fingers to count from one number to the next. The coach adjusts the coaching accordingly, by explaining the number families concept to Carter. They then slice back from the full set of addition–subtraction facts to just those facts that produce hesitancies and errors, learn the number families, and build rate from there. If Carter still makes no progress, they may step back to previous steps in the curriculum and make prerequisite skills such as number reading and writing more fluent. Coaches and students make slicing back, stepping back, and other instructional decisions every day. Charts do not stay flat for even three days. When Carter is fluent at a curriculum slice, he will move to the next slice in the step. When he is fluent at a step, he will step up in the curriculum unit.

The final step in Carter's regimen with whole number mathematics is the application of his skills to real-world contexts. Applying means engaging in a variety of activities with teacher and classmates, solving problems by combining fluent component skills in a manner that was never directly taught. Several days after Carter begins his work with whole numbers, he is composing his own story problems from broad, real-world contexts supplied by his peers and teacher. For what good are fluent rates in story problem solving if Carter cannot see the makings of story problems as they occur in his life and compose them with the relevant properties? Application after fluency building is key. By building skills to rates that make them useful and automatic, and then using the skills in real-world contexts, student remembering and applying is dramatically increased.

In conclusion, Carter's progress is dependent on two elements. First is the *program,* the instructional and fluency-building sequences designed either to establish key educational repertoires or to build existing repertoires to fluency. The program comprises a validated series of stimulus elements (Markle, 1967) whose sequence is determined by what is to be taught or built to fluency (Englemann & Carnine, 1982; Markle, 1991; Tiemann & Markle, 1990). The *reinforcement contingencies* that maintain Carter's participation in the program constitute the second element (Goldiamond, 1974). The reinforcement contingencies are provided by Carter's progress in the program (Goldiamond, 1974) and his success in reaching his fluency aims. As Goldiamond has pointed out, reinforcement does not establish new skills; rather it maintains behavior through a program that establishes or sharpens the skills. Stated differently, reinforcement can only select occasion–behavior relations or stimulus control topographies that have occurred; it cannot make them occur (Ray & Sidman, 1971; Sidman, 1978; Stoddard & Sidman, 1971).

A Selectionist Perspective and the Analysis of Behavior: Implications for Educational Practice

Skinner (1981) suggested that the task behavior analysts face when examining complex behavior is not unlike that faced by the evolutionary theorist. Can an understanding of behavioral selection based on behavioral variation lead to an understanding of behavioral complexity (Donahoe, 1986, 1991)? What is more, can we do what is only rarely done in evolution research, that is, can we control the three critical features of the selectionist position—variation, selection, and retention—to produce predictable outcomes and, in so doing, build better educational practices? Let us examine each of these features in turn.

Variation. There are differences in organisms from one generation to the next, some resulting in one form meeting environmental requirements for reproduction while others do not. *Variants* that meet the requirements are said to be selected. At times these variants may result in small and gradual changes, sometimes referred to as *adaptations*. At other times these variants may result in hanges that are great and rapid, described in macroevolutionary theories as *punctuated equilibria* (Eldridge & Gould, 1972) and in microevolutionary theories as *exaptations* (Vrba & Gould, 1982). According to Gould (1989), forms that prevail are not predictable or deducible a priori from preceding forms or environments. For both the evolutionary theorist and the behavior analyst, understanding why one variant (phenotypical in the former and behavioral in the latter) prevails over another requires an a posteriori or *retrospective* search for the sequence of both the particular variants and the environmental requirements they faced and met. For the behavior analyst, making one variant more likely than another is a function of a set of *prospective* sequences and environmental requirements (i.e., a program; Goldiamond, 1974).

Selection. Evolutionary theorists are faced with a central question, namely, given the many possible phenotypes, how can we account for the occurrence of one phenotype over any other? How can we account for the number and complexity of life forms encountered on Earth? Who or what does the selecting? According to Gould (1989), an answer is found by examining the contingencies of selection. That is, certain forms meet certain environmental requirements and live to reproduce, whereas other forms do not. Although subtle, there is a distinction between Gould's contention and what has been called survival of the fittest. For Gould, the concept of fitness is not required either in the organism's morphology or in the environment. The forms that prevail are not necessarily better, nor predictable, nor logically deduced from preceding forms or environments. They are not more "fit" as organisms, they simply meet regnant environmental contingencies; that is, they are fitted to their environments (I. Goldiamond, personal communication, 1990). Likewise Skinner (1981) argued that behavior is similarly "selected" by its consequences over the life span of the individual, making it unnecessary to invoke animistic or what Donahoe (1986, 1991) has called *essentialist* notions to account for complex behavior.

Retention. Critical to evolutionary theory is the maintenance of the change that results in this fitted organism. Research in statistical genetics has helped identify patterns of retention in reproducing populations (with gene frequency as a fundamental datum), whereas chromosomal genetics and, later, molecular biology have shed light on the physical basis for these patterns in individual organisms. Together, progress in these areas has provided a plausible outline of how evolutionary change is accomplished and retained. Similarly, the analysis of behavioral frequency is leading to a greater understanding of patterns of behavioral retention.

The same elements of variation, selection, and retention form the basis for the educational program described in this article. Much as animal husbandry might practice artificial selection (which served as the basis for Darwin's metaphor of natural selection), the Morningside Model described here attempts to "breed" certain educationally important behaviors. As described earlier, we begin (as suggested by Skinner, 1968) by identifying the point at which the program must begin, that is, where small changes or variations may be made more likely by the instructional sequence and then may be maintained (or retained in the students' repertoire) with the help of fluency building. The program can then proceed in gradual steps to build on that foundation. But as in evolutionary biology, gradual progression turns out to be only part of the story.

Contingency Adduction: The Selection and Retention of Variations Shaped by Other Contingencies

In recent years, scientists have noted that evolution can sometimes proceed in fits and starts, described by the concept of punctuated equilibrium (Eldridge & Gould, 1972), in which substantial morphological changes occur suddenly, followed by long periods of stasis. In addition, Gould (1980) has argued that modest changes in one small morphological attribute can cause dramatic changes at the level of the organism and that one or more morphological forms, evolving under one set of conditions, may be recruited by a quite different set of conditions into a new function and eventually into a radically new form. This phenomenon has been described as a process of exaptation (Vrba & Gould, 1982).

A similar process has been identified by scientists working in the area of behavioral selection. As in the case of exaptation, repertoires, initially shaped under one set of conditions, may be recruited by a quite different set of conditions into a new function and eventually into a radically new repertoire. This phenomenon of rapid behavioral change, as opposed to the gradual process of contingency shaping, has been elucidated as a process of *contingency adduction* (Andronis, 1983; Andronis et al., 1983; Layng & Andronis, 1984). One example of contingency adduction, which produced a *curriculum leap,* was illustrated by four students enrolled in the Malcolm X College summer program. As a part of a mathematics sequence, the four students were given tests that included word problems involving fractions. The best single performance on these problems was 7 correct out of 14, the worst was 3 correct out of 14. Other tests showed similar shortcomings in lower level whole number word problems and fraction computation skills. Establishing high frequencies of these lower level skills turned out to be sufficient to generate the repertoire needed to solve higher order fraction word problems, without the need for instruction.

The students were placed in sequences that began with instruction only in the skills required to solve the classes of whole number word problems and fraction computation tasks that they missed on the placement tests. Both the whole number problem solving and calculation with fractions repertoires were gradually shaped to criterion by separate instructional sequences. The objective of the instructional strategy was to guide the student's behavioral variation—to make certain responses more probable than others, thereby making the constituent skills available for selection by an increasingly demanding instructional environment involving fractions problem solving (analogous to the artificial selection by dairy farmers breeding cattle herds that produce more milk).

Now, when the four students were faced with a test of similar word problems involving fractions, and with no instruction in fractions problem solving, the worst single performance was 13 correct with only one error; all others had 14 correct and zero errors. The same test environment in which their previous performance had failed now resulted in a highly successful adduction of a new variant, the behavioral parallel of exaptation. This new repertoire was not a product of gradual shaping but appeared fully established as a function of establishing its constituent parts and placing the student in an environment where the behavior, correctly solving word problems involving fractions, had been absent. With no fraction problem solving instruction necessary, fluency building was prescribed to ensure the retention of this new variant.

From a selectionist perspective these results suggest that fluency building may be necessary, in part, to ensure that a particular performance is more likely to occur on a particular occasion than another performance in the population on that same occasion. In a sense, the variation is allowed to take hold and is readily available for further shaping. Establishing the performance to a high percentage correct criterion but at a low frequency will not ensure that the occasion–behavior relation will continue to occur. To continue with the evolution analogy, the larger the population, the less chance a lower frequency variation in the population has of being maintained. What is more, anything that reduces the frequency may wipe out that variant in the population. The higher the frequency of a variant and the smaller the population, the more rapid the shift in the population. The goal of building performance frequencies, by sprints and endurance timings, is to help ensure that these new variants are well established in the students' response populations. By separately making whole number problem solving and calculating with fractions fluent, the likelihood of their occurrence and recombination in the presence of novel, complex tasks is greater than the likelihood of alternative performances in the student's repertoire.

Laboratory and applied investigation into the constituent elements of the contingency adduction process (Alessi, 1987; Andronis, 1983; Andronis et al., 1983; Birch, 1945; Epstein, 1981; Epstein & Skinner, 1980; Layng & Andronis, 1984; Schiller, 1957) is producing a moment-to-moment account (Epstein, 1985, 1990, 1991) of the evolution of unshaped, radically new complex behavior patterns that are adduced by certain consequential contingency arrangements. The generative aspects of the Morningside Model are a result of prospective instructional sequences carefully designed to take advantage of past instructional sequences and repertoires in order to promote contingency adduction whenever possible.

In keeping with the legacy of B. F. Skinner, careful attention to arranging educational selection contingencies, along with careful monitoring of response frequencies, especially by learners themselves, may precisely reveal when each dimension of learning comes into play during the course of learning. Such dynamics will help students finally break through the barriers to achievement placed in their paths by structuralist approaches. Monitoring response frequencies can also reveal when dysfluent tool skills put a ceiling on student achievement. Unfortunately the vast majority of the educational establishment is devoid of such practices. Perhaps this is why of the nearly 10 million secondary school students who make it to high school mathematics each year, fewer than 800 eventually receive doctorates in the mathematical sciences (Mullis, Dossey, Owen, & Phillips, 1991). It may be that as the number of steps in a cumulative subject matter, such as mathematics, increases, dysfluent component skills make progress impossible at worst and tedious at best.

The selectionist approach presented in this article is yielding new methods for teaching skills such as problem solving, creativity, and analytical thinking (Layng, Jackson, & Robbins, 1992), as well as new ways to teach subject matter information itself (Johnson, 1992b). Somewhere in the quantitative patterns of individual progress through the Morningside Model may lie the functional definitions of *retarded, gifted, noncompliant* or *behavior-disordered, learning disabled, attention-deficit disordered, bright,* and good old *average.* Whatever the route, the selectionist approach advocated by B. F. Skinner and used here may yet put everyone on the road to true mastery.

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