Effects of Rate Building on Fluent Performance: A Review and Commentary

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The use of rate-building procedures to encourage the production of high response rates and to develop fluency has been increasingly justified by research on precision teaching and automaticity. Rate-building procedures often ensure both speed and accuracy, and claims have been made that such procedures result in greater retention, persistence, and generalization of trained skills, as well as preference by students. Given the potential importance of these claims for behavior analysts and educators alike, this review assesses the validity, generality, and implications of research on rate building. The review revealed sparse empirical evidence that retention, persistence, and generalization of skills result from the use of rate-building procedures when the effects of practice and reinforcement rate are controlled. Given the results of this review, the implications are discussed in the context of behavior-analytic research (e.g., behavioral momentum), and further research is recommended.

Key words: rate building, fluency, education, behavior analysis, practice, response strength

The application of behavior-analytic concepts and principles to education is increasing both in number and influence in behavior analysis. At the annual meeting of the Association for Behavior Analysis in San Francisco (May 2003), education was the most highly represented program area, as evidenced by the number of presentations listed in the convention booklet. Within behavioral education, reports on rate building, fluency, and precision teaching account for a large proportion of these presentations. Rate building here refers to the procedures used to in-

crease response rate to some predetermined rate criterion; for example, setting response-rate aims and providing students with repeated 1-min timings to achieve the aims, which is characteristic of precision teaching.

The interest of behavior analysts in rate building specifically reflects attempts to extend precision teaching to new populations (e.g., people with autism) and to empirically validate the claim that practicing a skill "at maximum speed" improves performance (Weiss, 2001, p. 185). There already exists a sizable literature on precision teaching, however, that has not been the subject of an evaluative review. General articles on precision teaching consist of anecdotal evidence from academic programs at schools (e.g., Beck & Clement, 1991) or conceptual analyses of fluency, rate, automaticity, and overlearning (e.g., Dougherty & Johnston, 1996; Johnson & Layng, 1994; Lindsley, 1992) rather than a critique of the empirical investigations. The current article attempts to provide such an evaluative review. Although this review notes throughout that precision teaching is not the only literature that supports using procedures to achieve high response rates, the focus of the

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review is on precision teaching. Precision teaching is the primary example of behavioral education that advocates the use of rate-building procedures for enhanced acquisition and generalization, and precision teachers frequently discuss the relation between rate building and fluent performance (e.g., Johnson & Layng, 1996). Other techniques, however, will be discussed briefly.

The present discussion begins with definitions of critical terms and procedures to clarify the variables that were considered for a review of the experimental literature. From the description of these variables, this review focuses on one set of variables—rate-building procedures—as important for further analysis. The article then turns to the literature on rate building with a description of the methods used to review the literature. The results of the review suggest many avenues of further investigation, particularly with respect to the connection between rate building and other behavior-analytic research areas.

DEFINING AND CLARIFYING TERMS AND METHODS

Whereas precision teaching has been described as a method of measurement rather than instruction (e.g., West, Young, & Spooner, 1995), precision teachers use strategies and tactics that extend beyond simple methods of measurement. Response rate, celeration (i.e., rate of response-rate change), and fluency, for example, all are measures of behavior, whereas setting rate aims, employing 1-min timings, using charting as a goal-setting and feedback process, posting charts publicly, and isolating tool skills are teaching procedures. Similarly, researchers and educators in other fields that incorporate rate-building interventions employ these and related procedures while measuring response rate (e.g., repeated reading procedures, Weinstein & Cooke, 1992; other areas of applied behavior analysis, Van Houten, Morrison, Jarvis, & McDonald, 1974). For clarification, the measurement strategies

and teaching procedures are separated and more fully described below.

Measures of Behavior

Response rate is the primary dependent variable in each of these aforementioned teaching techniques. Skinner (1938) discussed the importance and sensitivity of response rate, or number of responses per unit of time, as a dependent measure.¹ *Fluency* is the proposed outcome of high response rates. Although fluency sometimes is used interchangeably with high rates of behavior, we follow Binder's (1996) definition, using fluency as a result, not a procedure. Binder defined behavioral fluency as "the fluid combination of accuracy plus speed that characterizes competent performance" (p. 164). Haughton (1980), however, was the first to describe fluent behavior in terms of its outcomes, using the acronym REAPs, representing retention, endurance, application, and performance standards.

Although the outcomes that define fluency have been revised and given different names (Binder, 1996; Johnson & Layng, 1996), the names are similar and those examined in the present analysis are given the acronym RE-SAA (e.g., Johnson & Layng, 1996; Weiss, 2001), which represents retention, endurance, stability, application, and adduction. These outcomes have been discussed in detail elsewhere (e.g., Binder, 1996; Johnson & Layng, 1996; Weiss, 2001) and are defined only briefly here. *Retention* refers to the persistence of high response rates after a period of time (e.g., 4 weeks) without practicing the target skill. *Endurance* is the persistence of high response rates over longer durations of time than were used in training (e.g., a 3-min rather than a 1-min timing). *Sta-*

¹ It is important to note that precision teachers use *rate* interchangeably with *frequency*, and often use the term *frequency* more often (Johnson & Layng, 1996; Lindsley, 1972). *Rate* is used in this article to remain consistent with Skinner's (1938) original terminology.

bility is the persistence of high response rates in the face of distraction (e.g., a noisy classroom). *Application* is synonymous with generalization, or the occurrence of a skill in novel stimulus conditions (e.g., new teacher, new classroom, new program materials). Finally, *adduction* is the emergence of a composite skill without specific training of that skill when its component skills have been trained to mastery (e.g., reading words after letters and phonics have been taught).

Teaching Procedures

Rate-building techniques are employed in both educational (e.g., Cooper, 2000; Miller, Hall, & Heward, 1995; Van Houten et al., 1974; Weinstein & Cooke, 1992) and professional (e.g., Olander, Collins, McArthur, Watts, & McDade, 1986) settings. They also are used among populations of children (e.g., Miller et al.; Shirley & Pennypacker, 1994), adults (e.g., Bucklin, Dickinson, & Brethower, 2000; Kim, Carr, & Templeton, 2001), individuals who are typically developed (e.g., Chiesa & Robertson, 2000), those who are learning disabled or diagnosed with attention deficit disorder (e.g., Binder, Haughton, & VanEyck, 1995), and those who are developmentally disabled (e.g., Young, West, Howard, & Whitney, 1986). Finally, rate building is used in several different teaching techniques across a variety of skills. It has been stated, moreover, that fluency is the result of procedures that build high rates of responding (Binder, 1988).

Different techniques have been used to obtain high response rates and, eventually, fluency. Often trainers set specific rate criteria (sometimes called aims) and give feedback in the form of graphically depicted results (e.g., Mercer, Mercer, & Evans, 1982; Weinstein & Cooke, 1992; White, 1984). The incorporation of these rate criteria, then, necessitates the use of rate building in some way. Reinforcement often depends on meeting the criterion, or on

successive approximations of that rate aim. Typically within precision teaching, response rate is increased in 1-min timings. A learner is instructed to complete a series of responses "as quickly as [you] can in one minute" (Johnson & Layng, 1992, p. 1485). Therefore, timings (and sprints, i.e., shorter timings) involve responding more and more rapidly until aims are met. Fluency aims usually are determined from the rates of other learners on the target skill (e.g., Young, West, & Crawford, 1985), similar fluent skills of the subject (e.g., Shirley & Pennypacker, 1994), or expert performers (e.g., Kim et al., 2001).

Throughout the course of procedures that incorporate rate building, many instructors also include an accuracy criterion, or ratio of correct to incorrect behavior, as part of the reinforcement contingency. Coaching and error correction often occur, either by stopping timings or immediately after timings (e.g., Johnson & Layng, 1992), although the primary focus of training usually remains on achieving high response rates. In fact, Lindsley (1997) suggested that an emphasis on accuracy actually interferes with achieving fluency in some cases. Thus, rate building is not dependent on accuracy.

Each of the aforementioned teaching procedures contains procedural components that might be separated and analyzed to determine their relative efficacy. Because of the claim that building high response rates results in fluent performance, the emphasis of this review is on the setting of rate aims and rate building as procedures and their relation to the achievement of worthwhile educational outcomes (i.e., fluency). It is critical that these outcomes be examined experimentally for at least two reasons: to determine whether there is evidence that building rates beyond typical accuracy or mastery criteria results in fluency, and to clarify the behavioral mechanisms that might support the contention that high response rates will produce fluency.

This review, then, focuses on ex-

amining whether rate building per se leads to the outcomes defined as fluency (i.e., RESAA) as well as the evidence that learners prefer rate-building training to more traditional teaching. The concern, therefore, is *not* to examine the success of existing programs and schools that employ these educational methods (e.g., precision teaching, repeated readings). Schools such as Morningside Academy have reported extraordinary success in the acquisition and maintenance of academic behavior by their students (Lindsley, 1997). These successes, however, are the result of an entire package of behaviorally based teaching procedures. Analyses of the specific components in the package, particularly the role of rate-building procedures, have not been documented in these reports. Furthermore, it is unclear from reports on these programs whether the fluency outcomes have been evaluated systematically. Finally, such reports do not allow for the analysis of potential confounding variables; for example, rate-building procedures may be confounded with number of exposures (i.e., practice) or reinforcement rate. The following review takes a more analytic and less synthetic approach to examining the literature to identify variables that might improve education and training.

METHOD

Procedure

The research included in the analysis was obtained from a variety of sources. These were, first, a comprehensive key-word search of the PSYCIInfo psychological research and the ERIC EBSCO Host educational databases; second, personal communication with precision teachers, other educators, and reviewers; and third, articles from reference lists of those articles previously obtained (if cited repeatedly or directly relevant to the experimental questions posed herein). Excluded from the analysis were ongoing unpublished research projects at universities, schools,

and academic programs, research presented at conferences, and information disseminated via data (chart) sharing or newsletters. Instead, only peer-reviewed journals and periodicals including research on rate-building techniques (e.g., *Journal of Precision Teaching*) were analyzed (see discussion of this requirement below).

The key words used in each search engine were fluency and endurance, fluency and adduction, fluency and retention, fluency and practice and education, behavioral fluency, rate building, precision teaching, repeated readings, timings and education, and fluency training. (Searches that failed to produce results included the combinations of fluency and endurance and fluency and adduction.) From the articles collected from this search, we looked for relevant articles (based on the abstracts) that employed rate building for acquisition in learning and education.

Personal communication involved feedback from members of audiences at previous conference presentations, answers to questions submitted via electronic mail to precision teachers concerning supporting literature, and commentary from reviewers. Furthermore, we examined a bibliography of precision-teaching references developed by Lindsley in 2001.

Formal analysis focused on the precision-teaching literature and representative other literatures that employed rate building, including other applied behavior-analytic articles that used rate building and related procedures. The reasons for the primary focus on precision teaching, however, were as follows: (a) Precision teachers are vocal proponents of acquiring high-rate behavior leading to fluency outcomes; (b) precision teaching generally is considered to be a behavioral technique, one that uses methods and terminology accepted by other behavior-analytic researchers; (c) much of the information found on, and potential critiques of, precision teaching are applicable to other techniques employing rate building; and (d) precision teaching, unlike

some other teaching methods (e.g., repeated readings), is used across a variety of skills and is not limited to one type of performance (e.g., reading). Other literature obtained in areas of psychology and education that might be relevant to the issues at hand included automaticity (e.g., LaBerge & Samuels, 1974) and overlearning (e.g., Gilbert, 1957; Krueger, 1929). Such literatures were examined because they involve increased training beyond standard percentage correct mastery and may involve similar phenomena (e.g., Dougherty & Johnston, 1996). Differences in conceptualization, procedure, and measurement, however, precluded direct comparison to precision teaching without addressing behavioral preferences for experimental methods and translating the terminology in ways that would detract from the intended message. In addition, none of these literatures has focused on the components of rate building and as such do not involve the kinds of controls discussed (e.g., practice and rate of reinforcement). The main procedure used in these other literatures is overtraining through practice.

Operational Definitions and Interscorer Agreement

The first author developed operational definitions for the components of teaching techniques, procedures, and purported outcomes that were analyzed. Each article was recorded and rated on a dichotomous scale for each component as to whether or not the article was representative of, or specifically tested for, each component (as defined below). The first and third authors then familiarized themselves with the operational definitions of each factor, and interrater reliability was scored for 35% of the articles examined. Interscorer agreement was calculated by dividing the number of agreements by the number of agreements plus disagreements for each component defined.

Articles first were classified as either

empirical or *conceptual*. Empirical articles were those articles that reported original and previously unpublished data, either experimental or correlational, and outlined specific procedures. Conceptual articles were defined as descriptions of proposed methods or reviews of previously implemented methods. Conceptual articles were referenced only to define and clarify certain aspects of rate building.

Empirical articles were evaluated as to whether they controlled for practice (i.e., number of exposures to stimuli) and reinforcement rate across conditions. The articles then were examined to determine which of the measures of fluency were included and tested. These outcomes (i.e., RESAA) were operationally defined as described above. Three of the outcomes of fluency (i.e., stability, application, and adduction) were recorded as a single category of outcomes labeled *extension*² (Skinner, 1957) due to the few articles published in each category and the overlap of terms across different fields. Examples of extension might be teaching component skills and testing on a composite task or implementing procedures in different settings or with different therapists. Finally, because one of the purported benefits of rate building is students' preference for these techniques (compared to other educational techniques), articles were analyzed for an objective measure of preference (e.g., Lockhart, 1979). However, because the authors respect the convenience of using self-reports of preference and recognize that there

² There were three reasons for combining stability, application, and adduction as *extension*. First, each was examined relatively infrequently in the literature. Second, each tested for similar concepts, that is, some type of generality. Third, the definitions and use of these three were inconsistent in the literature. The term *extension* in this review was defined consistently with Skinner's (1957) usage as an instance in which the exact stimulus-response relation being tested was not directly reinforced during training. In the case of stability and application, the stimuli change; in the case of adduction, both the stimuli and the behavior change.

are ways in which to improve social validity measures (e.g., Schwartz & Baer, 1991), the inclusion of reports of preference and satisfaction will be addressed. Nevertheless, they will not be a significant focus nor the subject of detailed analysis because of the problems often found with self-report measures (e.g., Critchfield & Perone, 1990).

RESULTS

The publications resulting from the above selection criteria were published mainly in the following peer-reviewed journals: *Journal of Applied Behavior Analysis*, *Journal of Precision Teaching (and Celeration)*, and *Performance Improvement Quarterly*. For a comprehensive list of articles reviewed ($N = 48$), see Table 1.

Interrater reliability was 100% on the classification of empirical versus conceptual articles, with 60% of the articles reviewed being empirical. Only empirical articles were considered for the remaining analyses, because only experimental investigations can test for the outcomes or equate practice effects and reinforcement rate. Empirical articles were rated as to whether or not they tested for retention and endurance as separate categories. Of the empirical articles, 34% investigated retention and 14% assessed endurance, with interrater reliability of 94% and 100%, respectively. Thirty-four percent were determined to test some aspect of extension; however, that estimate was not reliable because interrater agreement for extension was only 71%. Reliability likely was low in this component because the definitions of stability, application, and adduction were different than those used in the articles and because these terms are used inconsistently in the literature.

Of the empirical articles, 79% failed to control for practice. Of these, 22% specifically reported that, because practice effects were not controlled, it was likely that results were due to greater practice. Fifty percent of the ar-

ticles that did control for practice equated duration of time spent practicing rather than number of exposures. These studies are indicated by the label *time* in the practice column of Table 1. Interrater agreement for whether practice was controlled was 100%. Approximately 22% of the articles reported methods of controlling for reinforcement rate. Agreement on control for rate of reinforcement was 94%.

Finally, although some articles obtained subjective measures of preference or satisfaction (e.g., verbal reports, satisfaction surveys), no articles were found to use objective preference assessments; interrater reliability was 100%. Despite several empirical articles reporting that students seem to enjoy rate-building procedures (e.g., Chiesa & Robertson, 2000), of studies in which students were exposed to rate-building and more traditional teaching methods, only two (i.e., Carroll, McCormick, & Cooper, 1991; Miller et al., 1995) used verbal reports of preference or satisfaction surveys.

Representative Articles: Some Findings

This section presents an overview of the findings of the review. It does not exhaustively discuss each article reviewed; to do so would result in a very long article, indeed. Instead, some noteworthy results are presented in a summary of some articles. Other statements of findings span across articles, and the percentages above (see Results), as well as Table 1, are provided to give a more comprehensive view of the literature.

Retention. As mentioned above, many of the articles that investigated the fluency outcomes examined retention (e.g., Ashbaugh & McLaughlin, 1997; Bucklin et al., 2000; Bullara, Kimball, & Cooper, 1993; Ivarie, 1986; Shirley & Pennypacker, 1994). To illustrate, Olander et al. (1986) taught college students the concepts of pathophysiology through either traditional or rate-building methods, which also

TABLE 1
Articles reviewed

Author	Year	Type	“Tested for” (empirical) or “discussed” (conceptual)			“Controlled for” (empirical) or “addressed” (conceptual)	
			Reten- tion?	Endur- ance?	Exten- sion?	Prac- tice?	Rein- force- ment?
Ashbaugh & McLaughlin	1997	E	Y	N	Y	N	N
Ayllon et al.	1976	E	N	Y	N	N	N
Beck & Clement	1991	C	N	N	N	N	N
Berquam	1985	C	N	N	N	N	N
Binder et al.	1995	C	N	Y	N	N	N
Binder & Watkins	1990	C	N	Y	N	N	N
Brunner et al.	1993	E	N	N	N	N	N
Bucklin et al.	2000	E	Y	N	Y	time	N
Bullara et al.	1993	E	Y	N	N	N	N
Carroll et al.	1991	E	N	N	Y	N	N
Carver & Hoffman	1981	E	N	N	Y	N	N
Chiesa & Robertson	2000	E	N	N	N	time	N
Cooper	2000	C	N	N	Y	N	N
Downs & Morin	1990	C	N	N	N	N	N
Evans & Evans	1985	E	N	N	N	Y	Y
Evans et al.	1983	E	N	N	N	Y	Y
Haughton	1980	C	Y	Y	Y	N	N
Heward	1997	C	N	N	N	N	N
Howell & Lorson-Howell	1995	C	N	N	N	N	N
Ivarie	1986	E	Y	N	N	N	N
Johnson & Layng	1992	C	N	N	N	N	N
Johnson & Layng	1994	C	Y	Y	Y	N	N
Johnson & Layng	1996	C	Y	Y	Y	Y	N
Jones et al.	1987	E	N	N	N	time	N
Kessissoglou & Farrell	1995	E	Y	N	Y	N	N
Kim et al.	2001	E	N	Y	Y	N	N
Lindsley	1992	C	N	N	N	N	N
Lovitt & Fantasia	2000	E	N	N	N	N	N
McDade et al.	1983	E	N	N	N	N	N
McDowell & Keenan	2001	E	Y	N	N	N	N
Mercer et al.	1982	C	N	N	N	N	N
Miller et al.	1995	E	N	Y	N	N	N
Miller & Heward	1992	C	N	Y	N	N	N
Olander et al.	1986	E	Y	N	N	N	N
Polson	1996	C	N	N	N	N	N
Raggio & Bitgood	1982	E	N	N	N	N	N
Shimamune & Jitsumori	1999	E	N	N	N	N	N
Shirley & Pennypacker	1994	E	Y	N	N	Y	Y
Teigen et al.	2001	E	Y	N	N	N	N
Van Houten et al.	1974	E	N	N	Y	N	N
Van Houten & Thompson	1976	E	N	N	N	N	N
Weinstein & Cooke	1992	E	N	N	Y	N	N
Weiss	2001	C	Y	Y	Y	Y	N
West et al.	1995	C	N	N	N	N	N
Whalen et al.	1993	E	N	Y	N	N	N
White	1984	C	Y	Y	Y	N	N
Young et al.	1985	E	Y	N	N	N	N
Young et al.	1986	E	N	N	Y	N	N

Note. E = empirical; C = conceptual.

included charting. The group taught with rate building and charting had greater accuracy and speed of fact and concept naming after an 8-month retention period; however, a number of methodological issues prevent firm conclusions. Single-subject methods in a study by Young et al. (1985) also tested for retention; however, results were less favorable. Specifically, across two skill types that were taught to students with multiple disabilities, only one was retained over time at high rates, and many more errors occurred at retention follow-up than had been observed previously. Neither study equated exposures or reinforcement rate. Finally, in the study by Olander et al., although the group means were significantly different, individual data for students were not reported. As such, it is unclear how many students performed better when learning through precision teaching and how many did not.

Endurance. The duration of fluency timings (i.e., endurance) rarely was examined in empirical studies, although it has been discussed in several conceptual articles (e.g., Binder, 1996; Miller & Heward, 1992). Whalen, Willis, and Sweeney (1993) measured endurance across 1-, 2-, 3-, and 4-min timings in a correlational study. Rates were measured across the different durations of timings, and it was determined that 1-min timings resulted in the highest rates. When rates increased during the 1-min timings, it was found that rates also increased during 4-min timings. Because rate was measured as a product of the precision-teaching program, however, and was not manipulated as an independent variable, the effect of rate building on endurance could not be assessed. Such an evaluation was not uncommon in assessing endurance (e.g., Ayllon, Garber, & Pisor, 1976).

Extension. Articles describing tests of extension (i.e., application, adduction, and stability) as potential outcomes of fluent response rates (e.g., Bucklin et al., 2000; Carroll et al.,

1991; Kessissoglou & Farrell, 1995; Young et al., 1986) also were found. Young et al., for example, examined application through the training of self-dressing skills in 2 preschoolers with mental retardation. Baseline performance on both percentage correct and rate of correct performance showed poor skill performance in the training setting and application across new trainers and settings. Acquisition training then was provided, consisting of training dressing skills with fading of prompts on each skill until each skill was independent. Acquisition training was implemented in a multiple baseline across skills design. Accuracy and rate of performance gradually increased across time for each skill in the training setting, but measures of application to new trainers and settings were mixed. Only one skill was applied successfully at percentages and rates equal to or better than those in the training setting. Rate building then was introduced in multiple baseline fashion across the four skills not showing application. Rate-building training led to maintenance of the percentage of correct performance across skills and individuals as well as improvements in application for the four skills taught. Rate of correct performance both in the training setting and the new settings also increased for all skills with both subjects. Although the multiple baseline design allowed for control of the number of days of training under acquisition and rate-building conditions, no information was given on the rate of reinforcement or amount of practice within sessions during the rate-building and acquisition sessions. In addition, the methods used to build rates suggested that rate criteria actually were not used; instead, a criterion of 10 consecutive practice trials was used for component skills.

Bucklin et al. (2000) also investigated performance they characterized as application. College students learned relations between Hebrew symbols and nonsense syllables and Arabic numerals and nonsense syllables. These re-

lations were the component (tool) skills taught to either an accuracy-only criterion or a combination of accuracy and rate criteria. It was ensured that subjects in the accuracy-only condition had not satisfied the rate criteria. The test for application was a composite-skill task involving adding Hebrew symbols. Subjects in the rate-building condition not only had higher response rates with equal accuracy after training but they also demonstrated relatively more retention after 4- and 16-week follow-up sessions. Mean differences between groups were significant for correct responses per minute immediately after training and the percentage correct losses (i.e., percentage of skills that were "forgotten" over time) at the retention test for some tasks, favoring the rate-building group. Although the authors discussed the possible confounding effect of practice, practice was not equated between the two groups. Based on the report, it seems likely that the rate-building group received more practice. Feedback occurred after every response; thus, reinforcement rate also was confounded with rate building.

Kim et al. (2001) tested for endurance and performance stability with a distraction. Subjects learned to say the name for Hindi characters on flashcards in 1-min timings, with rate aims set from the rates obtained by native Hindi speakers. Twenty-minute timings used in the test conditions allowed the assessment of both endurance without distraction and performance stability under distraction conditions. Maintenance of response rates occurred in the 20-min timings without distraction (demonstrating endurance), but the effects of rate building and distraction were inconclusive, because there was a decrease in responding for four of the nine distraction assessments. Because practice was not controlled, it was hypothesized by the authors that the effects might be related directly to increased practice provided by the rate-building procedures. Reinforcement rate also was not controlled.

Controlling for the effects of practice and reinforcement rate. Although the studies reported above and others demonstrated effects from rate-building procedures on some measures of fluency, these higher response rates may have been a result of increased practice or reinforcement rate (e.g., Bucklin et al., 2000; Raggio & Bitgood, 1982; Whalen et al., 1993). In fact, some authors stated explicitly that their effects may have been due to the practice that occurred via the rate-building exercises (e.g., Bucklin et al.; Kim et al., 2001). Some studies controlled for time spent practicing (e.g., duration; Chiesa & Robertson, 2000; Jones, Torgesen, & Sexton, 1987), but these attempts to control for practice did not control for number of exposures. Thus, the rate-building conditions are still likely to have more trials of practice despite equating the duration of practice. Although from a practical standpoint this may (or may not) always be the case, practice and rate *can* be separated (described below) such that the mechanism that underlies potentially superior performance under rate-building conditions can be determined.

Only three studies yoked the number of practice trials between rate-building conditions and accuracy-only conditions and controlled for rate of reinforcement (Evans & Evans, 1985; Evans, Mercer, & Evans, 1983; Shirley & Pennypacker, 1994), and these studies demonstrated contradictory or inconclusive results. Evans et al. trained responding on a consonant-vowel-consonant trigram recognition task to criteria of 40, 60, or 80 responses per minute. To separate the possible effects of practice, all subjects practiced trigrams the same number of times in training. This practice criterion was established by the number of trials required for the 1st subject to reach the aim criterion of 80 responses per minute. If any other subject reached the terminal-rate criterion earlier, he or she repeated the task until the practice criterion was satisfied. Praise was deliv-

ered after each timing, so reinforcement rate also was held constant across subjects. The group with the highest percentage correct performance on a posttest was trained to 80 responses per minute. The group with the lowest score on one posttest, however, was trained to 60 responses per minute rather than 40 responses per minute.

Evans et al. (1983) suggested that their inconclusive results were due to the rates not being high enough. Evans and Evans (1985) repeated the previous experiment with the same task and procedure, but with terminal-rate criteria of 60, 90, or 120 responses per minute. Both practice effects and rate of reinforcement again were controlled. The group with the highest percentage of correct responses on the posttest was the group trained to 90 responses per minute, and the lowest scores were achieved by the group who performed at a rate of 120 responses per minute. Thus, no conclusions were drawn about the relation between response rate and retention, independent of practice, in either of these two studies.

Shirley and Pennypacker (1994) also controlled for the number of stimulus exposures and reinforcement rate, and they tested directly for retention. Subjects learned two spelling lists: one with rate and accuracy criteria, and one with an accuracy-only criterion. Both lists were practiced an equal number of times, and greater retention was reported after 1 month for the list with the rate criterion. This difference, however, was small, and inconsistencies in responding also were evident. First, whereas participants performed better with a rate criterion in some phases, the results did not replicate across phases. Second, 1 participant performed better in follow-up conditions without an accuracy criterion than with the criterion in place, an apparently unusual finding. One conclusion drawn by the authors is that "daily sessions result in greater learning . . . than weekly sessions" (p. 86). This statement supports the notion that practice

has a critical role in the acquisition and maintenance of new material. Their suggestion that more repetitions are needed to achieve fluency further supports the use of practice. Shirley and Pennypacker also suggest that higher rate criteria may have resulted in "larger, more consistent, effects" (p. 86) and that more research is needed.

The results of these three studies that controlled for practice and rate of reinforcement were unconvincing in that the two studies by Evans and colleagues do not support rate building per se, and the article by Shirley and Pennypacker (1994) shows an effect for only 1 of 2 subjects. Still, these studies do represent the best methods used to date to control for practice and rate of reinforcement and therefore have potential to influence future fluency research.

Preference for rate building. As mentioned above, two articles were found that reported formal satisfaction surveys or social validity data. Carroll et al. (1991) interviewed 3 of 4 students who participated in baseline and intervention (i.e., rate building) conditions, and results suggested that participants reportedly "enjoyed" rate building and indicated that they "under[stood] the story better" under rate-building conditions, although it was unclear if they preferred it over baseline conditions (p. 20). In the study by Miller et al. (1995), approximately three quarters of all participants reported a preference for rate building. Most of these students, however, preferred rate building when combined with other behavioral techniques typically employed in precision-teaching programs over simple rate-building procedures. Other articles (e.g., Van Houten et al., 1974) reported more positive and fewer negative comments surrounding rate-building conditions; however, no formal data analysis was conducted. Furthermore, it is noteworthy that neither of the studies that did specifically measure verbal report of preference equated reinforcement rate or practice effects across conditions;

thus, students may have been indicating a preference for higher reinforcement rate or the opportunity to practice.

Related Literature: Similarities and Differences

As mentioned previously, precision teaching has been a focus of this review. Many of the reasons for this focus have been detailed above. Precision teaching, however, is not the only area of research concerned with the relation between rate and subsequent performance. Much of the previous commentary is relevant to other methods of acquisition, such as repeated reading (e.g., Carver & Hoffman, 1981; Weinstein & Cooke, 1992). Repeated reading is an intervention that has evolved from the automaticity literature, and focuses on improving the fluency of readers who have high accuracy but read “in a slow, halting manner” (Weinstein & Cooke, p. 21). Students read a passage or passages until they reach rate and accuracy criteria (either one or the other of these dependent variables generally is emphasized more; e.g., accuracy in Carver & Hoffman, and rate in Weinstein & Cooke). Then, generalization to unpracticed passages (similar to application) or answering comprehension questions (similar to adduction) is used as a test of improvement in reading. Increases in both accuracy and speed and on the tests of generalization are a common finding; however, these interventions (i.e., rereading a passage repeatedly) have not controlled for practice or reinforcement. In addition, the National Research Council (1998) has indicated that generalization occurs “only if the overlap of occurrence of specific words is high between the texts” (p. 214). However, it was also noted that repeated readings is “promising,” although this promise is arguably the result of efficient and effective repeated practice as well as high rates of consequences from teachers or computers on student reading performance.

DISCUSSION

Three conclusions follow from the preceding review. First, the evaluated teaching packages generally provide effective methods of instruction (e.g., Bucklin et al., 2000; Olander et al., 1986). Second, despite the claim that children prefer rate-building techniques to traditional teaching methods (e.g., “Fluent performance is more fun,” Lindsley, 1992, p. 55), a study conducting a preference analysis was not found, although the technology is available (e.g., Hanley, Piazza, Fisher, Contrucci, & Maglieri, 1997; Lockhart, 1979). Third, both practice and reinforcement rate have often been confounded with rate-building techniques, and thus the effects on the outcomes are compromised. Conceptually, it makes sense for educators to try to achieve the outcomes of fluency (i.e., RESAA). So few studies have measured these outcomes, however, and none have tested for stability, application, or adduction while controlling for practice and rate of reinforcement, that it is premature to conclude that fluency is the result of precision teaching or any of its component procedures—rate building, for example. If the results of research have not been demonstrated conclusively, then the field needs to continue to investigate the independent variables that will produce fluency. Thus, each of these concluding points is further discussed below, with particular attention to future directions.

Effective Teaching Packages and Students' Reported Preferences

Empirical research supports the claims projected in conceptual analyses and among educators that the aforementioned teaching methods (e.g., precision teaching, repeated readings) enhance learning and demonstrate positive educational outcomes. In essence, the answer to the question posed by an article title in 1985: “Precision Teaching—Does It Work?” seems to be “yes” (Berquam, 1985). The combination of increased reinforcement, ef-

ficient practice, feedback, and individualization creates a seemingly positive environment where skills are acquired, maintained, and generalized, as many of the articles in Table 1 demonstrate. Some of these teaching packages include rate building, and thrive either because of it, independent of it, or in spite of it. Furthermore, according to verbal reports of preference, in the majority of cases in which students were asked their preference, they preferred rate building over more traditional teaching methods. More objective measures never were taken. Regardless, learners in many areas have benefited from these methods and would benefit, of course, from continued research, which likely would lead to continued developments and improvements in education.

Controlling for Confounding Variables

One of the most significant outcomes of this analysis is that it is rare for studies to control for practice or reinforcement rate (but see Evans & Evans, 1985; Evans et al., 1983; Shirley & Pennypacker, 1994). Further, the studies that controlled for practice have had inconclusive outcomes. Although these results suggest little empirical support for the use of rate-building procedures beyond the effects of practice and reinforcement, it might be argued that rate building follows directly from interpretation of research in the experimental analysis of behavior. If this were the case, and the complexities of separating response rate from practice and reinforcement rate precluded an experimental analysis of rate building, then interpretation might be sufficient to support the use of rate-building procedures. As discussed below, the idea that higher rates of responding lead to the outcomes of fluency, however, seems contrary to some existing literature on both acquisition (e.g., Evans & Evans; Evans et al.) and response strength (e.g., Nevin, 1979). Another argument in favor of rate

building may be that it is an efficient method of practice. If the old adage is true that "practice makes perfect," then rate building may be an efficient method to achieve practice. Again, though, more research is necessary to demonstrate this efficiency, because it is possible that rate criteria take longer to achieve than practice criteria that produce the same outcomes. Furthermore, rate building is just one procedure for ensuring practice. Other procedures, like choral responding (e.g., Miller et al., 1995), latency or reaction-time requirements (e.g., Samuels, Miller, & Eisenberg, 1979; Weiss, 2001), and frequent and cumulative practice (Mayfield & Chase, 2002), may also produce the same outcomes.

Effects of practice. Separating the effects of practice and rate building is important because a large body of research indicates that practice facilitates the acquisition and maintenance of skills. Furthermore, much of the literature on fluency and automaticity (and thereby precision teaching and repeated readings) emphasized the role of practice and used the word *practice* almost interchangeably with the method (e.g., Carver & Hoffman, 1981). It has been suggested that practice is one of the most critical variables in learning (e.g., Samuels, 2002), and that type of practice, as well as amount, is significant (e.g., Ericsson, Krampe, & Tesch-Römer, 1993). In fact, Ericsson et al. reported that there is no substitute for "deliberate" practice. They demonstrated that deliberate, or highly structured, practice is critical in distinguishing expert performers from those who are not. When teaching includes informative, individualized, and immediate feedback as well as repeated trials, repeated practice increases accuracy and speed of performance (Ericsson et al.). Therefore, in evaluating any claims of the effects of rate building per se, practice effects must be controlled.

Effects of reinforcement rate. Failing to control for reinforcement rate is also a serious limitation because research repeatedly suggests that differences in

reinforcement conditions rather than differences in response rate per se control both resistance to disruption and preference (see Nevin & Grace, 2000, for a review). In general, both relative resistance to disruption and preference often result from higher reinforcement rates. In addition, when reinforcement rate is equated, it has been found that lower response rates are more resistant to disruption (Lattal, 1989; Nevin, Grace, Holland, & McLean, 2001) and are more preferred (Nevin et al.), findings that seemingly oppose the assertion that high response rates may lead to stability and preference.

In the experimental analysis of behavior, response strength often is measured as resistance to disruption (e.g., Nevin, 1979). Subjects, frequently pigeons (but see Mace et al., 1990, for an experiment with humans), are exposed to a multiple schedule in which different schedules are correlated with different reinforcement parameters (e.g., different reinforcement rates). Resistance to disruption has been measured in a number of different conditions, including prefeeding, alternative reinforcement delivered between the multiple-schedule components, extinction, or, with humans, some distracter (like a video playing simultaneously with the task that provides reinforcers). These events are similar to the disrupters suggested for assessing stability in the precision-teaching literature. Moreover, research on response strength suggests that if equal response rates on two tasks are maintained by unequal reinforcement rates, the response maintained by the higher reinforcement rate will be maintained better under disruption conditions. These conclusions from the experimental analysis of behavior should be considered when evaluating precision teaching and the need for rate building. Consistent with this assertion, Nevin (1995) has suggested that any added persistence of rate-building groups may be the result of an increased reinforcement rate.

Future Directions: A Call for More Research

The general lack of published experiments on precision teaching has been noted previously (see Berquam, 1985; Binder, 1996). Binder suggested that the lack of publication results from different goals for researchers and practitioners. Behavioral practitioners use behavioral concepts and principles to solve significant social problems, often by using a package of procedures to obtain desired results. Results then are disseminated via conferences, newsletters, word of mouth, and general reports of the success of the package. The goals of practitioners might be satisfied by these types of communication, at least in the short term, but the goals of scientific understanding may not be achieved if analyses are not subject to detailed peer review. The type of review that occurs before an investigation is published is part of the self-correcting process of science. Such review often leads to alternative reasons for the findings (e.g., rival hypotheses). This process may occur for other forms of dissemination, like conference presentations, but due to time constraints as well as the ephemeral nature of presentations, thorough critique and review typically do not occur at the same level as in peer-reviewed journals. This is presumably one of the reasons that the *Journal of the Experimental Analysis of Behavior*, the *Journal of Applied Behavior Analysis*, and *The Behavior Analyst* discourage the citation of convention presentations.

Although it is appropriate for practitioners to employ the most effective procedures and combinations thereof, the goal of discovering the conditions necessary and sufficient for learning and behavior change is an equally important goal. There are numerous reasons for having comprehensive understanding as a goal, but one practical reason is that comprehensive understanding will aid practitioners in the future. Educational technologies may become more efficient and more effective

if experimental analyses reveal the necessary and sufficient conditions for learning. Even tightly reasoned interpretations based on the concepts and principles derived from experimental analyses do not replace the need for experimental evidence. Given the attention that behavior analysts have devoted to the strategies and techniques of precision teaching and the need to explore the experimental evidence for these procedures, this is an opportune time to conduct such research.

The research that is being proposed is possible (e.g., Evans & Evans, 1985; Evans et al., 1983; Shirley & Penny-packer, 1994). Of greatest interest at the present time is the isolation of the effects of high rates of responding from increased practice (i.e., number of exposures) or a denser schedule of reinforcement. Researchers might consider teaching some skills in a rate-building format while teaching others in a rate-controlled format using a within-subject design. By keeping number of exposures and reinforcement rate constant across conditions, the effects of high-rate responding are isolated. For example, if expressive labels are trained in 1-min timings to a fluency criterion of 100 responses per minute, a learner might require 300 exposures to attain that rate. If similar labels are presented and trained at a fixed (experimenter-controlled) rate, reinforcement is delivered every minute, accuracy criteria (if any) are identical across conditions, and the "rate-controlled" items also are practiced 300 times, the fluency outcomes (i.e., RE-SAA) can be tested. Then, it could be determined more conclusively if rate building alone has any effect on learning. Furthermore, research, including preference for teaching method, could be conducted more objectively. Rather than utilizing verbal reports alone, which are often not related to choice, a concurrent-chains procedure (e.g., Hanley et al., 1997) can more objectively measure preference between interventions (and can do so in students with poor communication skills). This

procedure might indicate whether rate building actually is selected when students are given a choice of receiving different methods of teaching.

Although Berquam (1985) called for more research promoting precision teaching, 10 years later, Lindsley (1995) indicated that Berquam's (1981) unpublished dissertation was "one of the few controlled researches on fluency products" (p. 2). Still 5 years after Lindsley's statement, Bucklin et al. (2000) stated, "If the benefits of fluency training can be documented experimentally, arguments for its adoption would be more persuasive" (p. 141). It remains evident from the present review that research consisting of component analyses and testing for fluency outcomes still has not been conducted satisfactorily. More controlled research may increase the acceptance of precision teaching among behavior-analytic investigators and, regardless of outcome, would benefit education as a whole by yielding more efficient and effective techniques.

REFERENCES

- Ashbaugh, R., & McLaughlin, T. (1997). Precisely teaching street names and locations. *Journal of Precision Teaching and Celeration*, 14, 19-23.
- Ayllon, T., Garber, S., & Pisor, K. (1976). Reducing time limits: A means to increase behavior of retardates. *Journal of Applied Behavior Analysis*, 9, 247-252.
- Beck, R., & Clement, R. (1991). The Great Falls Precision Teaching Project: An historical examination. *Journal of Precision Teaching*, 8, 8-12.
- Berquam, E. (1981). *The relation between frequency of response and retention, on a paired associates task*. Unpublished doctoral dissertation, University of Florida.
- Berquam, S. (1985). Precision teaching: Does it work? *B.C. Journal of Special Education*, 9, 321-327.
- Binder, C. (1988). Precision teaching: Measuring and attaining exemplary academic achievement. *Youth Policy*, 10, 12-15.
- Binder, C. (1996). Behavioral fluency: Evolution of a new paradigm. *The Behavior Analyst*, 19, 163-197.
- Binder, C., Haughton, E., & VanEyck, D. (1995). Increasing endurance by building fluency: Precision teaching attention span. *Journal of Precision Teaching*, 12, 29-34.

- Binder, C., & Watkins, C. L. (1990). Precision teaching and direct instruction: Measurably superior instructional technology in schools. *Performance Improvement Quarterly*, 2, 74–91.
- Brunner, M., McLaughlin, T. F., & Sweeney, W. J. (1993). Employing error drill and feedback to improve the legibility of manuscript and cursive handwriting. *Journal of Precision Teaching*, 11, 32–37.
- Bucklin, B. R., Dickinson, A. M., & Brethower, D. M. (2000). A comparison of the effects of fluency training and accuracy training on application and retention. *Performance Improvement Quarterly*, 13, 140–163.
- Bullara, D. T., Kimball, J. W., & Cooper, J. O. (1993). An assessment of beginning addition skills without instruction or practice. *Journal of Precision Teaching*, 11, 11–16.
- Carroll, C. L., McCormick, S., & Cooper, J. O. (1991). Effects of a modified repeated reading procedure on reading fluency of severely disabled readers. *Journal of Precision Teaching*, 8, 16–25.
- Carver, R. P., & Hoffman, J. V. (1981). The effect of practice through repeated reading on gain in reading ability using a computer-based instructional system. *Reading Research Quarterly*, 16, 374–390.
- Chiesa, M., & Robertson, A. (2000). Precision teaching and fluency training: Making maths easier for pupils and teachers. *Educational Psychology in Practice*, 16, 297–310.
- Cooper, J. O. (2000). Tutoring Joe: Winning with the precision teaching team. In W. L. Heward (Ed.), *Exceptional children: An introduction to exceptional children* (6th ed., pp. 268–270). Upper Saddle River, NJ: Prentice Hall/Merrill.
- Critchfield, T. S., & Perone, M. (1990). Verbal self-reports of delayed matching to sample by humans. *Journal of the Experimental Analysis of Behavior*, 53, 321–344.
- Dougherty, K. M., & Johnston, J. M. (1996). Overlearning, fluency, and automaticity. *The Behavior Analyst*, 19, 289–292.
- Downs, J., & Morin, S. (1990). Improving reading fluency. *Teaching Exceptional Children*, 22, 38–40.
- Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, 100, 363–406.
- Evans, S. S., & Evans, W. H. (1985). Frequencies that ensure skill competency. *Journal of Precision Teaching*, 6, 25–30.
- Evans, S. S., Mercer, C. D., & Evans, W. H. (1983). The relationship of frequency to subsequent skill acquisition. *Journal of Precision Teaching*, 4, 28–34.
- Gilbert, T. H. (1957). Overlearning and the retention of meaningful material. *Journal of General Psychology*, 56, 281–289.
- Hanley, G. P., Piazza, C. C., Fisher, W. W., Contrucci, S. A., & Maglieri, K. A. (1997). Evaluation of client preference for function-based treatment packages. *Journal of Applied Behavior Analysis*, 30, 459–473.
- Haughton, E. C. (1980). Practicing practices: Learning by activity. *Journal of Precision Teaching*, 1, 3–20.
- Heward, W. L. (1997). Four validated instructional strategies. *Behavior and Social Issues*, 7, 43–51.
- Howell, K. W., & Lorson-Howell, K. A. (1995). What's the hurry? Fluency in the classroom. *Journal of Precision Teaching*, 12, 24–28.
- Ivarie, J. J. (1986). Effects of proficiency rates on later performance of a recall and writing behavior. *Remedial and Special Education*, 7, 25–30.
- Johnson, K. R., & Layng, T. V. J. (1992). Breaking the structuralist barrier: Literacy and numeracy with fluency. *American Psychologist*, 47, 1475–1490.
- Johnson, K. R., & Layng, T. V. J. (1994). The Morningside Model of generative instruction. In R. Gardner, III, D. M. Sainato, J. O. Cooper, T. E. Heron, W. L. Heward, J. W. Eshleman, & T. A. Grossi (Eds.), *Behavior analysis in education* (pp. 173–197). Belmont, CA: Wadsworth.
- Johnson, K. R., & Layng, T. V. J. (1996). On terms and procedures: Fluency. *The Behavior Analyst*, 19, 281–288.
- Jones, K. M., Torgesen, J. K., & Sexton, M. A. (1987). Using computer-guided practice to increase decoding fluency in learning disabled children: A study using the Hint and Hunt I program. *Journal of Learning Disabilities*, 20, 122–128.
- Kessissoglou, S., & Farrell, P. (1995). Whatever happened to precision teaching? *British Journal of Special Education*, 22, 60–63.
- Kim, C., Carr, J. E., & Templeton, A. (2001). Effects of fluency building on performance over “long” durations and in the presence of a distracting social stimulus. *Journal of Precision Teaching and Celeration*, 17, 7–26.
- Krueger, W. C. F. (1929). The effect of overlearning on retention. *Journal of Experimental Psychology*, 12, 71–78.
- LaBerge, D., & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. *Cognitive Psychology*, 6, 293–323.
- Lattal, K. A. (1989). Contingencies on response rate and resistance to change. *Learning and Motivation*, 20, 191–203.
- Lindsley, O. R. (1972). From Skinner to precision teaching. In J. B. Jordan & L. S. Robbins (Eds.), *Let's try doing something else kind of thing: Behavior principles and the exceptional child* (pp. 1–11). Arlington, VA: Council for Exceptional Children.
- Lindsley, O. R. (1992). Precision teaching: Discoveries and effects. *Journal of Applied Behavior Analysis*, 25, 51–57.
- Lindsley, O. R. (1995). Ten products of fluency. *Journal of Precision Teaching*, 13, 2–11.
- Lindsley, O. R. (1997). Precise instructional design: Guidelines from precision teaching. In C. R. Dills & A. J. Romiszowski (Eds.), *In-*

- structional development paradigms (pp. 537–554). Englewood Cliffs, NJ: Educational Technology Publications.
- Lockhart, K. A. (1979). Behavioral assessment of human preference. *The Behavior Analyst*, 2, 20–29.
- Lovitt, T. C., & Fantasia, K. (2000). A precision teaching project with learning disabled children. *Journal of Precision Teaching*, 16, 30–38.
- Mace, F. C., Lalli, J. S., Shea, M. C., Lalli, E. P., West, B. J., Roberts, M., et al. (1990). The momentum of behavior in a natural setting. *Journal of the Experimental Analysis of Behavior*, 54, 163–172.
- Mayfield, K. H., & Chase, P. N. (2002). The effects of cumulative practice on mathematics problem solving. *Journal of Applied Behavior Analysis*, 35, 105–123.
- McDade, C. E., Rubenstein, S. B., & Olander, C. P. (1983). Parallel between frequency testing and performance on essay questions in a theories of personality course. *Journal of Precision Teaching*, 4, 1–5.
- McDowell, C., & Keenan, M. (2001). Developing fluency and endurance in a child diagnosed with attention deficit hyperactivity disorder. *Journal of Applied Behavior Analysis*, 34, 345–348.
- Mercer, C. D., Mercer, A. R., & Evans, S. (1982). The use of frequency in establishing instructional aims. *Journal of Precision Teaching*, 3, 57–59.
- Miller, A. D., Hall, S. W., & Heward, W. L. (1995). Effects of sequential 1-minute time trials with and without inter-trial feedback and self-correction on general and special education students' fluency with math facts. *Journal of Behavioral Education*, 5, 319–345.
- Miller, A. D., & Heward, W. L. (1992). Do your students really know their math facts? Using daily time trials to build fluency. *Intervention in School and Clinic*, 28, 98–104.
- National Research Council. (1998). Instructional strategies for kindergarten and the primary grades. In C. E. Show, M. S. Burns, & P. Griffin (Eds.), *Preventing reading difficulties in young children* (pp. 172–225). Washington, DC: National Academy Press.
- Nevin, J. A. (1979). Reinforcement schedules and response strength. In M. D. Zeiler & P. Harzem (Eds.), *Reinforcement and the organization of behaviour* (pp. 117–158). Chichester, England: Wiley.
- Nevin, J. A. (1995). Contingencies of reinforcement and behavioral momentum: Research and applications. *Revista Mexicana de Análisis de la Conducta*, 21, 107–122.
- Nevin, J. A., & Grace, R. C. (2000). Behavioral momentum and the law of effect. *Behavioral and Brain Sciences*, 23, 73–130. (includes commentary)
- Nevin, J. A., Grace, R. C., Holland, S., & McLean, A. P. (2001). Variable-ratio versus variable-interval schedules: Response rate, resistance to change, and preference. *Journal of the Experimental Analysis of Behavior*, 76, 43–74.
- Olander, C. P., Collins, D. L., McArthur, B. L., Watts, R. O., & McDade, C. E. (1986). Retention among college students: A comparison of traditional versus precision teaching. *Journal of Precision Teaching*, 6, 80–82.
- Polson, D. A. D. (1996). Fostering multiple repertoires in undergraduate behavior analysis students. *The Behavior Analyst*, 18, 293–299.
- Raggio, S., & Bitgood, S. C. (1982). The effect of number of math drills per day on math performance. *Journal of Precision Teaching*, 3, 50.
- Samuels, S. J. (2002). Reading fluency: Its development and assessment. In A. E. Farstrup & S. J. Samuels (Eds.), *What research has to say about reading instruction* (pp. 166–183). Newark, DE: International Reading Association.
- Samuels, S. J., Miller, N., & Eisenberg, P. (1979). Practice effects on the unit of word recognition. *Journal of Educational Psychology*, 71, 514–520.
- Schwartz, I. S., & Baer, D. M. (1991). Social validity assessments: Is current practice state of the art? *Journal of Applied Behavior Analysis*, 24, 189–204.
- Shimamura, S., & Jitsumori, M. (1999). The effects of grammar instruction and fluency training on the learning of the and a by native speakers of Japanese. *The Analysis of Verbal Behavior*, 16, 3–16.
- Shirley, M. J., & Pennypacker, H. S. (1994). The effects of performance criteria on learning and retention of spelling words. *Journal of Precision Teaching*, 12, 73–86.
- Skinner, B. F. (1938). *The behavior of organisms*. New York: Appleton-Century-Crofts.
- Skinner, B. F. (1957). *Verbal behavior*. Acton, MA: Copley Publishing Group.
- Teigen, T., Malanga, P. R., & Sweeney, W. J. (2001). Combining repeated readings and error correction to improve reading fluency. *Journal of Precision Teaching and Celeration*, 17, 58–67.
- Van Houten, R., Morrison, E., Jarvis, R., & McDonald, M. (1974). The effects of explicit timing and feedback on compositional response rate in elementary school children. *Journal of Applied Behavior Analysis*, 7, 547–555.
- Van Houten, R., & Thompson, C. (1976). The effects of explicit timing on math performance. *Journal of Applied Behavior Analysis*, 9, 227–230.
- Weinstein, G., & Cooke, N. L. (1992). The effects of two repeated reading interventions on generalization of fluency. *Learning Disability Quarterly*, 15, 21–28.
- Weiss, M. J. (2001). Expanding ABA interventions in intensive programs for children with autism: The inclusion of natural environment training and fluency based instruction. *The Behavior Analyst Today*, 2, 182–185. Retrieved

- January 18, 2004, from <http://www.behavior-analyst-online.org/BAT/BAT23.pdf>
- West, R. P., Young, R., & Spooner, F. (1995). Precision teaching: An introduction. *Journal of Precision Teaching*, 12, 2–8.
- Whalen, K. P., Willis, R. J., & Sweeney, W. J. (1993). Using 1-minute time trials and 4-minute practice sessions to improve a student's performance of fraction problems. *Journal of Precision Teaching*, 11, 2–10.
- White, O. R. (1984). Aim*Star Wars: Setting aims that compete. *Journal of Precision Teaching*, 5, 55–64.
- Young, K. R., West, R. P., & Crawford, A. (1985). The acquisition and maintenance of reading skills by intellectually handicapped deaf students. *Journal of Precision Teaching*, 5, 73–86.
- Young, K. R., West, R. P., Howard, V. F., & Whitney, R. (1986). Acquisition, fluency training, generalization, and maintenance of dressing skills of two developmentally disabled children. *Education and Treatment of Children*, 9, 16–29.