A Comparison of the Effects of Fluency Training and Accuracy Training on Application and Retention

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ABSTRACT

The effects of fluency training on the acquisition and retention of a composite skill were compared with those of training to accuracy only Participants were 30 college students, and the task was a stimulus equivalence task, similar to the one used by Binder (1995) in earlier assessments Participants learned associations between Hebrew symbols and nonsense syllables and between nonsense syllables and Arabic numerals Immediately after training and every 2 or 4 weeks for 16 weeks, they were tested on a composite task that required both associations Retention of the original component associations was also assessed after 4 months With respect to the composite skill, fluency training resulted in a) higher response rates immediately after training and across the 16 weeks, b) better accuracy 4 and 16 weeks after training, and c) less deterioration of accuracy after 16 weeks Effects on the component skills were similar The results document that for skilled adult learners, fluency training can aid the acquisition of a higher level skill and increase the retention of accuracy for both the component and composite skills

Beginning in the late 1960s, individuals have asserted that fluent performance leads to, among other benefits, longer retention, increased endurance, resistance to distraction, greater ability to apply skills, and faster acquisition of higher-level skills (Binder, 1993, 1996a, Johnson & Layng, 1992) Fluency is defined as the rate of accurate performance and is typically measured as the number of correct and incorrect responses per minute Fluency training is contrasted with training to accuracy only, that is, insuring performance is accurate but neglecting speed (Binder, 1996a, Binder & Watkins, 1990) Although fluency training has typically been conducted with children in educational settings, it has recently been applied in corporate training programs as well (Binder, 1993, 1996a) Precision Learning Systems, Inc, for example, has developed a number of fluency-based occupational training programs They market their software as a way of ensuring that employees

know what to do and are able to do it without hesitation when confronted with a situation (Precision Learning Systems, n d , a, b, c, d)

The proposed benefits of fluency are primarily based on reports from applied programs, rather than results from experimentally controlled field or laboratory studies If the benefits of fluency training can be documented experimentally, arguments for its adoption would be more persuasive, perhaps leading to greater use by educators and trainers

Precision Teaching

Fluency training is a component of a teaching technology called precision teaching, which was developed in the 1960s by Ogden Lindsley (Lindsley, 1990, 1992, Potts, Eshleman, & Cooper, 1993, West, Young, & Spooner, 1990, White, 1986) Lindsley designed this technology using principles and procedures from the experimental analysis of behavior He emphasized that instructional materials should be evaluated using behavioral measures of learning, stating that "the student knows best " In other words, the student "tells" the teacher that the instructional program is effective when a desired behavior occurs more frequently following instruction When such objective measures of learning are used, if the instruc-

tional program does not produce the desired outcome, it becomes more likely that the program will be revised or discarded (West & Young, 1992)

Precision teaching, with fluency as one of its elements, has improved learner skills in many settings One of the first large evaluation studies was conducted during the early 1970s in the Sacajawea Elementary School, Great Falls, Montana (Binder & Watkins, 1990, Potts et al , 1993, Snyder, 1992, White, 1986) A precision teaching program was implemented with a curriculum that was similar to the curriculum used by other schools in the district Children with skill deficits as well as children in regular classrooms were part of the project After four years, precision-taught students averaged 19-40 percentile points higher in math and reading, as measured on standardized tests, than comparable students attending other schools in the district

At the Morningside Academy in Seattle, Washington, a comprehensive precision teaching system referred to as The Morningside Model of Generative Instruction has produced impressive results with both children and adults (Johnson & Layng, 1992, Snyder, 1992) "Children diagnosed as learning disabled,

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who have never gained more than a half a year in any one academic year, typically gain between two and three years in each academic skill per year" (Johnson & Layng, 1992, p 1482) Morningside's two adult literacy programs have been equally successful In the first literacy program, 29 of the 32 participants who entered the program with skills ranging from the second to the eighth grade levels exited with skills at or above the national eighth-grade literacy standard Students gained an average of 1 7 grades per 20 hours of instruction In the second program, 19 of the 20 students who successfully completed the program gained an average of 2 0 grades per 20 hours of instruction As noted by Johnson and Layng (1992, p 1483), "Such progress is in stark contrast to the U S government standard of one grade level per 100 hours of instruction"

The Morningside Model was adopted by the pre-college institute of Malcolm X College with similar results The purpose of this program was to remediate the skill deficits of high school graduates, enabling success in college Students, who entered the program with reading or math skills below the sixth grade level, gained an average of 2 0 grade levels for every 20 hours of instruction (Johnson & Layng, 1992, Snyder, 1992) Moreover, students acquired proficiency within one or two semesters, preventing protracted remedial work and lowering drop-out rates Other such precision teaching successes, based on case studies or quasi-experimental comparisons, have been widely reported (e g , Bates & Bates, 1971, Haughton, Freeman, & Binder, 1992,

Lindsley, 1992, McDade, 1992, Pennypacker, 1982, Spence & Hively, 1993, White, 1986)

In a rare controlled field study, Olander, Collins, McArthur, Watts, and McDade (1986) examined whether precision-taught college nursing students would learn and retain more than those taught by traditional methods There were nine students in each class, and the same instructor taught both classes using the same text material Traditionally-taught students attended 2 1/2 hours of lecture per week and were examined after every two chapters and, comprehensively, at the end of the course The precision teaching course was self-paced, with oral tests based on ten flash cards, after every two chapters There were no lectures To proceed to the next unit, students were required to answer 8 of the 10 questions correctly per minute Students charted their daily performance on Standard Celeration Charts (Pennypacker, Koenig, & Lindsley, 1972), recording the number of correct and incorrect responses per minute The average grade of precision-taught students was 3 0 out of a possible 3 0, while the average grade of traditionally-taught students was 1 78 An unannounced retention test, conducted eight months later, revealed that the precision-taught subjects were 1 8 times more fluent and 1 8 times more accurate than their traditionally-taught counterparts

Fluency

One commonly used acronym for the benefits of fluency is REAPS (retention, endurance, application, performance standards) (Binder, 1993, 1996a, Johnson & Layng, 1992,

1994) Retention refers to a high rate of accurate performance after a post-training interval during which the skill has not been practiced Endurance is the ability to perform the skill for a long period of time without fatigue and despite distractions Application refers to the transfer of training to a new task, that is, a composite skill that requires several component skills will be more easily and quickly acquired when the component skills are fluent Performance standards are the rate and accuracy "aims" that must be reached in order for the benefits to occur Binder (1995, p 5) stated that practitioners have observed these benefits and reported them at conferences but that, "The field of precision teaching in general and fluency research in particular have suffered from a lack of publication Most of those involved were teachers, and teacher trainers are not driven to publish in journals "

Because the current study focused only on retention and application, the subsequent literature review will be restricted to those topics The following articles are recommended for those wishing information about the effects of fluency on endurance Binder (1993, 1996a), Binder, Houghton, and Van Eyk (1990), and Johnson and Layng (1992, 1994)

Retention

As indicated earlier, Olander et al (1986) found that precision-taught college students retained material considerably better than traditionally-taught college subjects While these results are suggestive, the improved retention cannot be incontrovertibly attributed to flu-ency because the teaching procedures differed in many ways, and subjects were not randomly assigned to conditions

Three controlled studies have investigated the effects of fluency on retention with children in educational settings Berquam (1981) investigated the effects of timed (i e , fluency) versus untimed practice on retention, with two classes of third-grade children using a paired associate task Fluency participants performed faster and more accurately on a retention test that was administered ten days later Ivarie (1986) measured retention after training fourth graders to translate Arabic numerals to Roman numerals to two different levels of fluency (35 or 70 correct responses per minute) Students were classified as having above-average, average, or below-average math skills One-half of the students from each classification were assigned to each fluency group Fluency retention tests were conducted monthly for three months Retention rates were significantly higher for the average and below-average students who were trained to the higher fluency level but were comparable for the above-average students When accuracy (percent correct) was examined alone, only below-average students were found to benefit from the higher fluency rate Shirley and Pennypacker (1994) compared the relative effectiveness of three types of training procedures on retention Using a within-subject design, two eighth-grade boys, diagnosed with learning disabilities, were trained to spell words a) without a specified criterion, b) with an accuracy criterion, and c) with a fluency criterion An

equal number of trials was provided across training procedures Fluency training produced better retention than training without a criterion However, when compared to accuracy training, fluency training improved retention for only one of the boys

The results of these studies, although somewhat equivocal, suggest that fluency aids the retention of some children, particularly those with learning difficulties No well-controlled experimental studies have examined whether skilled adult learners benefit from fluency training, and thus additional studies with this population are warranted

Application

Application refers to the rapid acquisition of a composite skill when the component skills have been trained to fluency For example, a student who has learned basic mathematical facts to a fluency criterion (i e , 80-100 correct responses per minute) could learn more quickly and perform a composite skill such as long division or story problems Moreover, the composite skill may occur with little additional instruction (Binder, 1996a, Johnson & Layng, 1992, 1994, 1996) "Adduction" is said to occur when a composite skill emerges with no or only minimal explicit training Johnson and Layng (1996, p 286) defined adduction as "those instances when the occurrence of novel performance meets new instructional criteria as a function of training its parts and prerequisites " They maintained that adduction, similar to application, is more likely to occur when the component skills are fluent Binder (1996a, p 178) stated that, "By far the great-

est amount of evidence exists to support the conclusion that increased performance frequencies improve application or transfer of training "

Binder and Bloom (1989) demonstrated the effectiveness of fluency-based application in a work setting Bankers were trained to fluency on various exercises relating to customer needs and banking solutions Trainees were then able to answer questions and determine customer needs more quickly and accurately than experienced employees who had not received fluency training on the component skills

Adduction was also demonstrated by four of the Malcolm X pre-college institute students (Johnson & Layng, 1992, 1994) On a 14-item pre-test to assess skills in solving word problems with fractions, these students answered only three to seven problems correctly After fluency training on only the component skills (problem solving with whole numbers and fractional computation), post-test scores ranged from 13 to 14 correct No instruction was ever provided on problem solving with fractions Thus, the more complex skill emerged without direct instruction Moreover, Johnson and Layng (1994, p 183) stressed that "Assessing for contingency adduction saved teachers and learners many hours of instruction!"

Automaticity and Overlearning

The concept of fluency is similar to what others refer to as automaticity and overlearning, both of which emphasize continued practice after a skill can be performed accurately Dougherty and Johnston (1996, p 291) maintain that fluency, automa-

ticity, and overlearning may all refer to the same behavioral phenomenon, stating that, "What distinguishes these concepts may be the extent of training and the behavioral measures used to assess the effects of training rather than some fundamental difference in phenomena." Because of this and the fact that fluency advocates often cite these literatures to support their claims, relevant studies from these two areas will be reviewed

Automaticity

Automaticity refers to performance that is automatic, fast, and involuntary in the sense that it does not require the performer's conscious attention (Cohen, Dunbar, & McClelland, 1990, Logan, 1985, Thurman, 1993) Although automaticity has been defined and measured in terms of response latency, and fluency has been defined and measured in terms of the rate of responding, their proposed benefits are the same Both are said to increase retention and endurance and ease the acquisition of more complex skills (Dougherty & Johnston, 1996) In addition, just as fluent composite skills result from fluent component skills (Johnson & Layng, 1992, 1994), automatic high level skills are said to result from automatic subskills (Hasselbring, Goin, & Bransford, 1988, LaBerge & Samuels, 1974, Logan, 1985)

Research has not, however, strongly supported the relation between automaticity and retention Healy, Fendrich, and Proctor (1990) investigated the effects of automaticity by varying the amount of training on an error detection task Groups of twelve subjects received no training,

limited training (2 days), or extensive training (4 days) Although automaticity was greater for those in the extensive-training group immediately following training, response latencies and accuracy were comparable for all groups on a retention test administered three to five weeks later Fisk, Hodge, Lee, and Rogers (1990) examined the effects of three levels of automaticity training on the retention of a verbal learning skill Twelve college students were exposed to 4320, 2160, or 720 training trials At the end of training, reaction time was positively related to the number of training trials, and all groups performed accurately (94%-97% correct) Retention tests administered 30, 90, and 180 days after training revealed that neither the percent correct nor reaction time differed as a function of the amount of training There was, however, a notable difference in the total amount of information retained the greater the number of training trials, the higher the retention Naslund (1987) examined a psychomotor skill as opposed to a verbal learning skill and provided support for the beneficial effects of automaticity Participants were trained either to mastery (accuracy) or automaticity (accuracy plus speed), with equal amounts of practice After one week with no practice, individuals in the automaticity group performed significantly better

Studies of whether automatic subskills lead to better performance of more complex skills, investigations that are similar to fluency studies of application, have not resulted in convincing data either Spring, Blunden, and Gatheral (1981) examined whether decreasing the laten-

cies to read a specific list of words would increase reading comprehension of passages containing the words from those lists Forty-eight third grade students served as participants Half of them received the latency-reduction training, and half served as a control group that did not receive training No significant difference was found on the reading comprehension test Fleisher, Jenkins, and Pany (1979) also failed to find significant results after training automaticity for words and phrases and later testing for reading comprehension However, Spring et al (1981) maintain that the results do not refute the importance of subskill automaticity Rather, automaticity of other component skills in addition to word recognition may be necessary for improved reading comprehension Similar to the studies of retention, a series of studies in the perceptual-motor literature did find that increased training on component motor tasks led to more accurate, automatic composite task performance (Bilodeau & Bilodeau, 1954, Gange, Baker, & Foster, 1950, Gange & Foster, 1949)

The preceding studies do not support the contention that automaticity improves the retention or application of verbal learning skills, and hence the results cannot be used to bolster claims that fluency improves retention Neither can they be used to refute such claims, however As indicated earlier, automaticity is measured by latency, fluency by rate of response While the rate of responding is certainly affected by response latency, it is also affected by other response variables, such as the speed of executing the response The end-of-training response rates for

automaticity participants are unknown This is important because while practice may increase rate of responding, it does not necessarily do so, as can be seen in Berquam (1981) and Shirley and Pennypacker (1994) Furthermore, fluency training experts distinguish between response frequency and fluency, maintaining that performance cannot be considered "fluent" unless retention, endurance and application improve (Binder, 1996a, Johnson & Layng, 1996) While this statement is troublesome because of its tautology, fluency advocates would argue that the performance of the automaticity participants may not have been fluent enough for retention to have been affected

Overlearning

Overlearning is based on cognitive theories of memory and is defined as the "deliberate overtraining of a task past a set criterion" (Driskell, Willis, & Cooper, 1992, p 615) To date, neither application nor endurance have been examined in the overlearning literature (Dougherty & Johnston, 1996) However, retention is said to be one of the major benefits of overlearning, and unlike automaticity, studies support this claim (Craig, Sternthal, & Olshan, 1972, Krueger, 1930, Melnick, 1971, Postman, 1962) Kratochwill, Demuth, and Conzemius (1977), in an illustrative study, examined the effects of overlearning on the retention of word recognition Sixty-four preschool children were randomly assigned to one of three groups a control group (accuracy only), 10 overlearning trials, or 20 overlearning trials Retention tests were administered 10 hours after training

Students in the control group and the 10-trial group performed similarly, however, students in the 20-trial group recognized significantly more words than those in the control group

Based on a meta-analysis, Driskell et al (1992) concluded that overlearning generally does produce an increase in retention for both cognitive and motor tasks, although the effect is more pronounced for motor tasks They also found that the greater the overlearning, the greater the retention Cognitive skills appear to be more fragile than physical ones, however For example, longer retention intervals diminished the performance of cognitive tasks but not motor tasks

The overlearning literature can be used to support claims that fluency may lead to the increased retention of both verbal learning and motor skills Although automaticity has been shown to benefit only motor skills, the discrepancy may be due to a variety of factors, including the fragility of the verbal tasks studied in the automaticity studies or, once again, to the measures used to assess retention In overlearning studies, the total amount retained, measured by the percent correct and number of errors, is used as the measure of retention The results of Fisk et al (1990) illustrate the difference between the amount retained and latency as measures In that study, automaticity did not affect subsequent latencies, but it did increase the total amount of information retained

Even though the overlearning studies provide compelling support for a positive relationship between fluency and retention, they do not negate the need for studies of fluency As with studies of automaticity, neither end-of-training response rates nor retention response rates, the elemental data for the concept of fluency, were measured Thus we cannot know from these studies whether increasing the speed of responding assists retention Because of the increasing use of fluency in adult training programs and the paucity of research demonstrating its effectiveness apart from the other components of precision teaching, particularly with adult learners, the purpose of the current study was to investigate the effects of fluency on retention and application with skilled adult learners Moreover, in contrast to previous studies of fluency (Berquam, 1981,

> *Stimulus equivalence tasks lend themselves well to studies of application because two unrelated component tasks are trained, and then individuals are asked to complete a third task that requires the component tasks but is not directly trained.*

Ivarie, 1986, Shirley & Pennypacker, 1994), the study examined whether component-skill fluency training would improve the performance and retention of an untrained composite skill

Method

Participants

Ten male and 20 female undergraduate students, recruited from junior and senior level classes at a midwestern university, served as participants They ranged in age from 20-38 years (mean = 22 3) One was dismissed for failing to attend retention testing sessions, thus, a total of 29 participants completed the study They were paid $5 00 an hour for the training sessions and $3 50 for each retention testing session

Potential participants were excluded if they were mathematics majors or minors or knew the names of Hebrew letters so that performance on the experimental task would not be biased Individuals were also excluded if, after practice, they were unable to print 160 letters correctly per minute, copy 160 numbers correctly per minute, or answer 80 addition problems correctly per minute Failure to meet these criteria would adversely affect performance of the experimental task The fluency criteria were recommended by precision teaching experts (W Boettcher, personal communication, April, 1997, K Johnson, personal communication, April, 1997)

Training and Application Tasks

A stimulus equivalence task (Sidman & Tailby, 1982) was used for training and application Stimulus equivalence tasks lend themselves well to studies of application because

two unrelated component tasks are trained, and then individuals are asked to complete a third task that requires the component tasks but is not directly trained (Binder, 1996b) The particular task was selected because it was similar to one used in earlier, unpublished but often cited, experimental assessments of fluency (Binder, 1996b, Binder et al , 1990, Johnson & Layng, 1992)

The component skills consisted of learning 10 arbitrary associations a) between Hebrew symbols and nonsense syllables and b) between the same nonsense syllables and Arabic numerals Application was assessed by presenting Hebrew symbols written as arithmetic problems and asking participants to write the answers in Arabic numerals The associations between the Hebrew symbols and the Arabic numerals were not directly trained

Dependent Variables

Application (composite skill performance) was assessed by measuring the rate and accuracy of written answers on a Hebrew symbol addition problem worksheet The worksheet contained 36 single-digit arithmetic problems written in Hebrew symbols Participants wrote answers, using Arabic numerals, below each problem There were seven versions of this worksheet Rate was measured as the number of correct answers per minute and accuracy by the percent correct Participants completed this worksheet immediately after training and during the retention tests

Retention of the two component skills was assessed by measuring the rate and accuracy of written answers on two worksheets the "See Hebrew

Symbols-Write Nonsense Syllables" worksheet and the "See Nonsense Syllables-Write Arabic Numerals" worksheet The former worksheet contained 64 Hebrew symbols, randomly ordered, and participants wrote the corresponding nonsense syllable under each Hebrew symbol The latter worksheet contained 88 nonsense syllables, randomly ordered, and participants wrote the corresponding Arabic numeral under each syllable There were seven versions of each worksheet Retention of the component skills was assessed during the last retention test session, approximately 16 weeks after training Retention of these skills was not tested during the earlier retention tests because completion of the worksheets may have constituted a fluency training trial and thus confounded performance on the composite skill worksheet

All of the worksheets were developed through collaboration with precision teaching experts and represent standard fluency worksheets (W Boettcher, personal communication, April, 1997, K Johnson, personal communication, April, 1997)

Independent Variables and Experimental Design

The primary independent variable was the type of training on the component skills accuracy-only or fluency The secondary independent variable was the retention test interval, which was either two or four weeks A between-group design was used The 30 participants were randomly assigned to the accuracy or fluency groups Eight in each group

Flash Card Set 1		Flash Card Set 2	
Side 1	Side 2	Side 1	Side 2
ZUL	ע	ZUL	1
BAF	ם	BAF	2
GIM	ר	GIM	3
DAL	ש	DAL	4
HES	ה	HES	5
LAL	ל	LAL	6
ZAY	ב	ZAY	7
KAP	ק	KAP	8
TET	פ	TET	9
YOD	ת	YOD	0

Figure 1 Component Skill Flash Cards

were then randomly assigned to the 2-week retention test condition and seven to the 4-week retention test condition However, the first retention test was administered four weeks after training for all participants

Training Procedures

All participants were first trained, individually, on the component skills using two sets of ten 3" x 5" flash cards In one set, each card had a Hebrew symbol on one side and a three-letter nonsense syllable on the other In the second set, each card had a nonsense syllable on one side and an Arabic numeral on the other Figure 1 displays the associations as presented on the flash cards The Hebrew symbol-nonsense syllable association was taught first Participants studied the cards for 5 minutes The researcher then showed the participant a card with the Hebrew symbol, and he/she wrote the corresponding nonsense syllable on a sheet of paper The researcher said "right" for a correct response, "wrong" for an incorrect response, and showed the subject the side of the card with the correct response The researcher also put a check mark beside incorrect and omitted responses The 10 cards were presented in a random order This part of training ended when the trainee completed this task with 100% accuracy for four consecutive trials Trainees were then taught to write the corresponding Arabic numeral when shown one of the nonsense syllables The training procedures for this set of cards mimicked the earlier training

ק +ר	ר +ש	ק +פ	ש +ר	ע +ע	ח +ק	ב +ש	ם +ר
ם +ק	ע +ק	פ +ר	ח +פ	ק +ר	ח +פ	ב +ת	ש +ר
ש +ר	ע +פ	ב +ת	ב +ב	פ +ע	ע +ת	ר +ק	ש +ם

Figure 2 Composite Skill Arithmetic Task

The accuracy-only group was not given any further training Thus, the terminal training criterion for this group for each of the component skills was 100% correct, with no time requirements However, to ensure that fluency had not developed, these trainees were asked to complete the See Hebrew Symbol-Write Nonsense Syllable and the See Nonsense Syllable-Write Arabic Numeral worksheets A one-minute timing was conducted for each worksheet Participants were instructed to complete accurately as many items as

they could The fluency criteria consisted of 40 or more correct responses per minute on the See Hebrew Symbol-Write Nonsense Syllable worksheet and 70 or more correct responses per minute on the See Nonsense Syllable-Write Arabic Numeral worksheet None of the trainees was fluent according to these criteria

After fluency trainees reached the accuracy criteria for the two component skills, fluency training was provided using the See Hebrew Symbol-Write Nonsense Syllable and the See
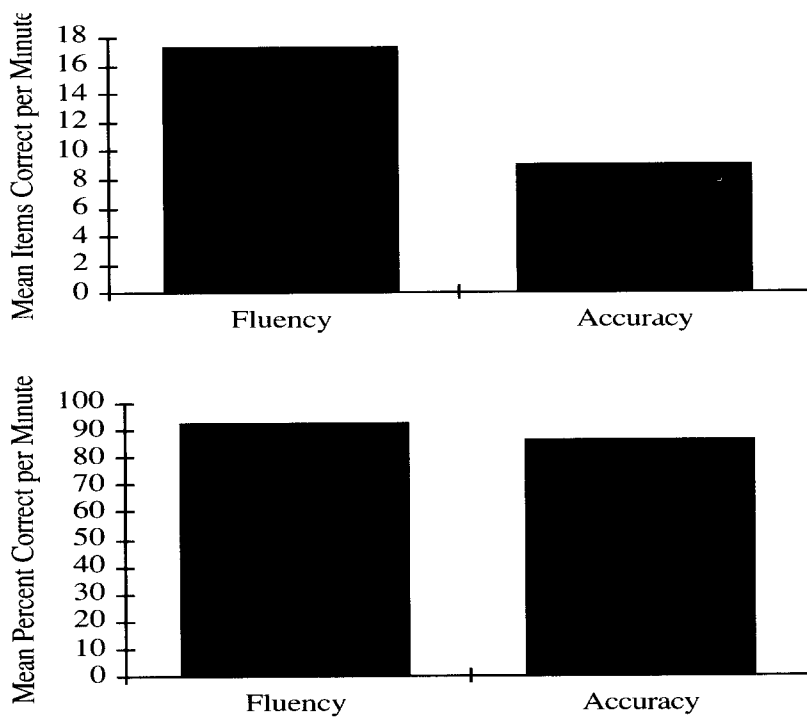

Figure 3 Composite Skill Fluency and Accuracy for Fluency and Accuracy Trainees
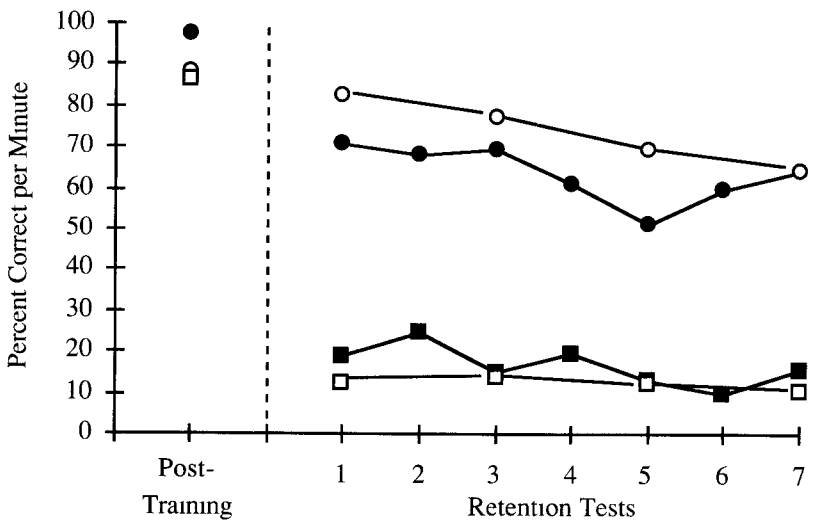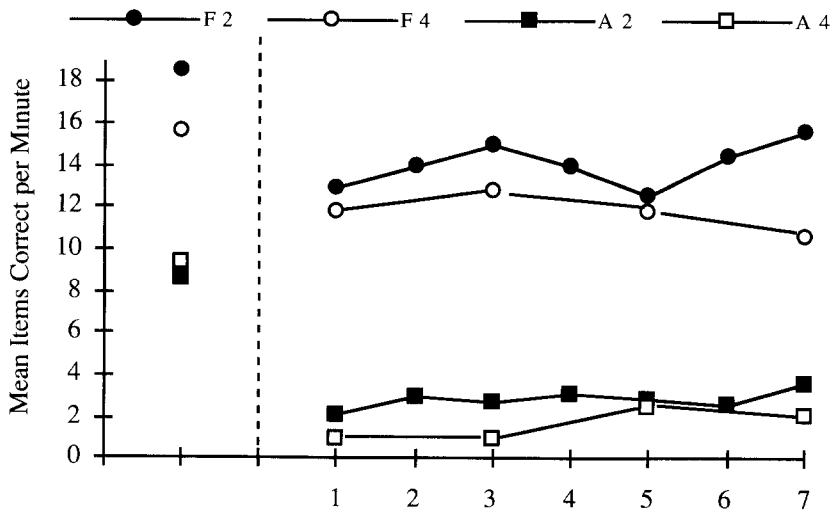
Figure 4 Retention of Composite Skill Fluency and Accuracy for Fluency and Accuracy Trainees with the 2-Week and 4-Week

Nonsense Syllable-Write Arabic Numeral worksheets During each training session, five one-minute timings were conducted for each type of worksheet, with a 10-minute break in-between The presentation order of the two types of worksheets was randomized across trainees and training sessions Trainees were considered fluent when they reached a fluency criterion with 100% accuracy for five consecutive timings The fluency criterion for the Hebrew Symbol-Nonsense Syllable association was 50 correct responses per minute, it was 100 correct responses per minute for the Nonsense Syllable-Arabic Numeral association

Application and Retention Test Procedures

After trainees (accuracy-only or fluency) had met their respective training criteria, application was tested using the Hebrew symbol arithmetic worksheets Figure 2 displays part of the worksheet that was used Trainees were instructed to work as quickly and as accurately as possible Two one-minute timings were conducted with different versions of the worksheet No feedback was provided to trainees The number of correct responses and the percent correct were averaged across the two timings

During retention test sessions, participants again completed versions of the Hebrew symbol arithmetic worksheet for two one-minute timings, without feedback As above, the number of correct responses and the percent correct were averaged across the timings

To assess retention of the component skills, during the last retention test (approximately 16 weeks after training), trainees completed versions of the See Hebrew Symbol-Write Nonsense Syllable worksheet and the See Nonsense Syllable-Write Arabic Numeral worksheet Two one-minute timings were conducted, and the number of items correctly completed and the percent correct were averaged No feedback was provided to trainees

Results

End-of Training Composite Skill Performance

Application was measured immediately after training for both training groups using the Hebrew arithmetic worksheet Figure 3 displays the mean number of correct responses and percent correct for the accuracy and fluency training groups

Fluency trainees averaged 17 27 (SD = 4 68) correct responses per minute, while accuracy trainees averaged 8 97 (SD = 3 70) This difference is practically significant as well as statistically significant (t = 5 39, df = 28, p < 00001) With respect to the percent correct, fluency trainees averaged 92 52% (SD = 7 77), and accuracy trainees averaged 86 20% (SD = 12 00) This difference was not statistically significant (t = 1 71, df = 28, p = 098) Thus, fluency trainees completed many more items correctly per minute than accuracy trainees with similar accuracy These data support the claim that fluent component skills lead to more fluent composite skills They also suggest that fluent component skills ease the acquisition of higher level skills

Composite Skill Retention

The first retention test was administered to all participants four weeks after training, using the Hebrew arithmetic problem worksheet Thereafter, retention tests were administered to approximately half of the trainees in each group every two weeks and to the other half every four weeks Figure 4 displays the mean number of items completed correctly per minute and the percent correct for the end-of-training test and the retention tests

Loss of fluency (rate of response) and accuracy (percent correct) were assessed by subtracting a trainee's fluency and accuracy scores on the 4-week and 16-week retention tests from her/his end-of-training scores These data were averaged for trainees in each group, and then the group averages were compared statistically This comparison was considered to be more valid than a comparison of the absolute levels of performance because it controlled for end-of-training differences Fluency trainees were trained to higher levels of fluency, and thus one would expect them to have higher levels of performance on the retention tests

Fluency trainees averaged a loss of 4 80 ($SD = 6$ 40) correct items per minute from the end-of-training test to the first retention test Accuracy trainees averaged a loss of 7 71 ($SD = 3$ 47) Although the mean decrease was less for fluency trainees, the difference was not statistically significant, obtained $t = 1$ 51, critical $t = 2$ 05, $df = 27$, $p = 0$ 14 Because the first retention test was four weeks after training for all participants, differences between test retention interval conditions (2 and 4 week groups) were not analyzed

Fluency trainees in the 2-week and 4-week retention test groups averaged a decrease of 2 94 ($SD = 9$ 31) and 5 00 ($SD = 5$ 99) correct items per minute, respectively, from the end-of-training test to the last retention test Accuracy trainees in the 2-week and 4-week retention test groups averaged a decrease of 5 57 ($SD = 3$ 79) and 7 72 ($SD = 4$ 22) There were no statistically significant differences between the difference scores, $F_{obt} = 60$, $F(3, 25) = 3$ 00, $p = 624$

Even though mean decreases in rate were less for fluency trainees than for accuracy trainees, the differences were not statistically significant However, it should be noted that the performance of accuracy trainees decreased to very low levels on the first retention test, and could not decrease much further This floor effect may well have precluded statistically significant differences

For percent correct, the mean losses between the end-of-training test and the first retention test for the fluency and accuracy groups were 16 20 ($SD = 24$ 60) and 72 10 ($SD = 20$ 5), respectively This difference was both practically and statistically significant (obtained $t = 6$ 62, critical $t = 2$ 05, $df = 27$, $p < 00001$)

Between the end-of-training and the last retention tests, the mean decreases in percent correct for fluency trainees in the 2-week and 4-week retention test groups were 24 13 ($SD = 26$ 77) and 33 04 ($SD = 27$ 24), respectively For accuracy trainees in the 2-week and 4-week retention test groups, they were 73 89 ($SD = 15$ 18) and 75 69 ($SD = 17$ 13), respectively The differences were statistically significant, $F_{obt} = 10$ 55, $F(3, 25) = 3$ 00, $p < 00001$ Tukey multiple comparison tests

confirmed that the significant differences occurred between the accuracy and fluency groups and not between the 2-week and 4-week retention interval conditions within those groups

The differences in the loss of accuracy between the fluency and accuracy groups are striking In spite of the fact that both groups were trained to 100% accuracy, the fluency trainees retained a high level of accuracy across the 16-week retention test period, while the accuracy trainees lost considerable accuracy after only four weeks

Component Skill Retention

Participants completed the See Hebrew Symbol-Write Nonsense Syllable and the See Nonsense Syllable-Write Arabic Numeral worksheets during their last retention test, which occurred approximately 16 weeks after training Figures 5 and 6 display the average number of items completed correctly per minute and the percent correct for each group by worksheet

Loss of fluency and accuracy was again assessed by subtracting scores obtained on the last retention test from terminal training scores, obtaining the average for the trainees in each group and comparing the
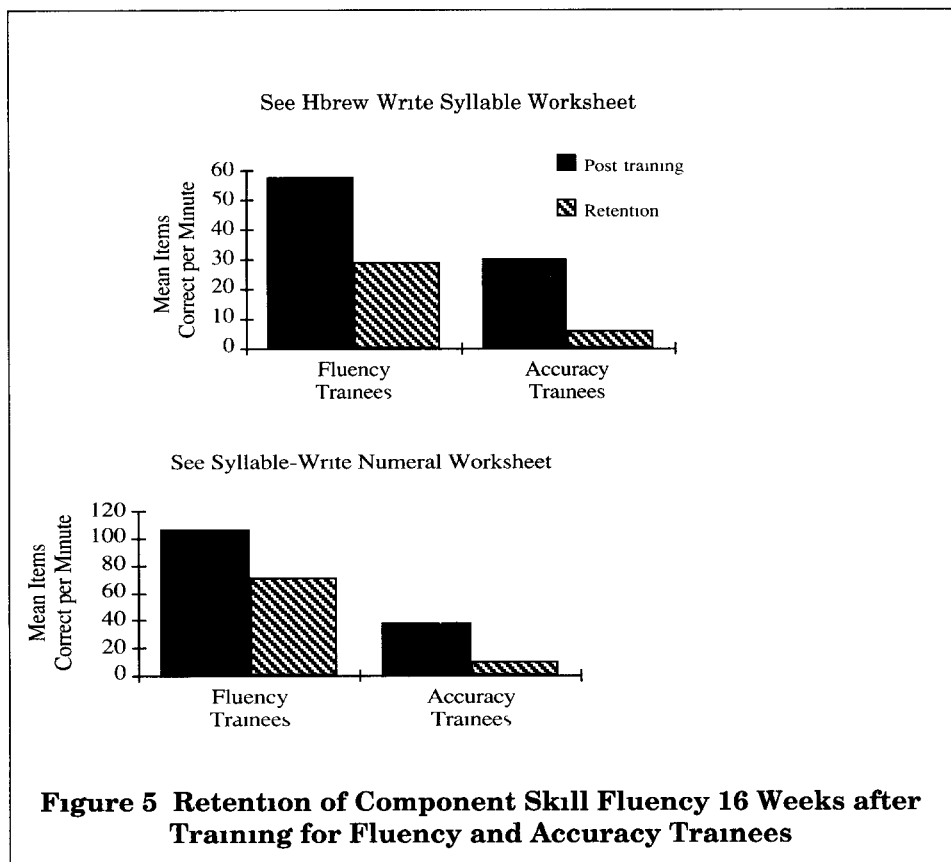

Figure 5 Retention of Component Skill Fluency 16 Weeks after Training for Fluency and Accuracy Trainees

group averages statistically For the number of items completed correctly on the See Hebrew Symbol-Write Nonsense Syllable worksheet, the mean loss scores for the fluency and accuracy and trainees were 25 0 (*SD* = 10 70) and 24 0 (*SD* = 10 10), respectively The difference was not statistically significant, obtained t = 0 16, critical t = 2 05, df = 27, p = 0 88 For the See Nonsense Syllable-Write Arabic Numeral worksheet, the mean decreases for the fluency and accuracy groups were 35 3 (*SD* = 24 3) and 28 6 (*SD* = 11 3), respectively Once again, the difference was
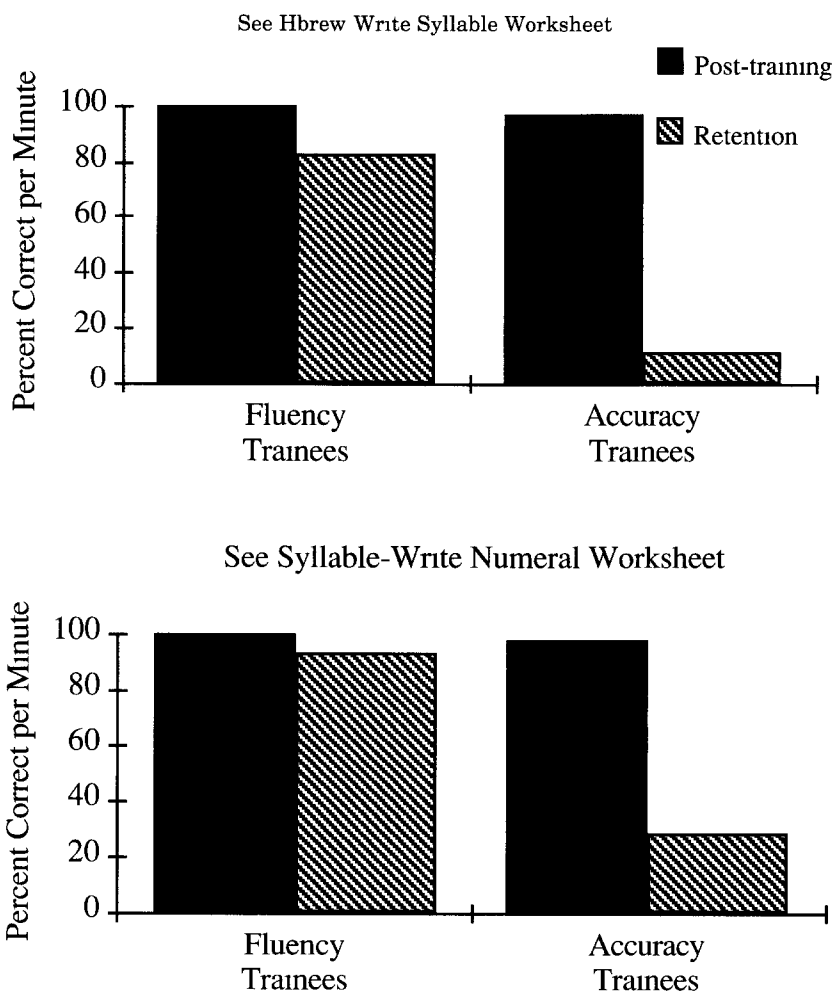

Figure 6 Retention of Component Skill Accuracy 16 Weeks after Training for Fluency and Accuracy Trainees

not statistically significant, obtained $t = 95$, critical $t = 2\ 05$, $df = 27$, $p = 0\ 35$ These data may be somewhat misleading As with the composite skill performance, the component skill performance of the accuracy trainees was very low and could not decrease much lower, perhaps artificially constraining differences between the groups

On the See Hebrew Symbol-Write Nonsense Syllable worksheet, the average decrease in percent correct for fluency trainees was 17 30 ($SD = 17\ 90$) For accuracy trainees, it was 86 20 ($SD = 10\ 20$) This difference was large and statistically significant, obtained $t = 12\ 57$, critical $t = 2\ 05$, $df = 27$, $p < 00001$ Similarly, for the See Nonsense Syllable-Write Arabic Numeral worksheet, the average loss scores for the fluency and accuracy groups were 6 70 ($SD = 11\ 60$) and 69 50 ($SD = 17\ 50$), respectively Again, this difference was large and statistically significant, obtained $t = 11\ 48$, critical $t = 2\ 05$, $df = 27$, $p < 00001$ As with the composite task, for both component tasks, fluency training resulted in significantly less loss of accuracy 16 weeks after training than did accuracy training

Discussion

The primary purpose of this study was to determine whether the fluent performance of two component skills would improve the performance and retention of a composite skill by skilled adult learners The study extended the research on the effects of fluency because prior studies examined the effects of fluency training on retention using only children as participants and directly-trained component skills A second purpose of the current study was to assess whether fluency would increase retention of the component skills themselves

Fluency training on two component skills led to much higher levels of performance on the composite task immediately after training and across the 16-week retention period than did training to accuracy only After training, fluency trainees completed an average of 8 3 more items correctly per minute than accuracy trainees, almost twice the rate of accuracy trainees After 16 weeks, the gap had widened Fluency also led to less deterioration in the rate of composite skill performance 4 and 16 weeks after training, although these differences were not statistically significant Failure to find significance may have resulted from the fact that the performance of accuracy trainees decreased to very low levels on the first retention test and could not decrease much further, restricting the differences between the groups Anecdotal reports from the accuracy trainees suggest that their correct responding on the retention tests was due primarily to guessing Future research should further explore differences in the loss of fluency over time

Differences in the loss of accuracy on the composite task were striking, both 4 and 16 weeks after training Even though both groups were trained to 100% accuracy on the component skills, fluency subjects averaged 76 3% items correct per minute after 4 weeks on the composite task, while accuracy subjects averaged only 15 8% This represents average decreases of 16 2 versus 72 10, respectively, from end-of-training accuracy After 16 weeks, fluency trainees still performed quite accurately,

averaging 64 2% items correct This was not the case for accuracy trainees, who averaged only 13% items correct

Data for the two component skills were similar After 16 weeks, fluency trainees completed considerably more items correctly per minute than accuracy trainees, although, once again, changes in performance over time were comparable As with the composite skill, absolute differences in accuracy and differences in the loss of accuracy across the 16-week retention period were dramatic

With respect to the composite skill, thus, fluency training resulted in a) higher rates of performance immediately after training, b) higher rates of performance across the 16-week retention period, c) significantly better accuracy 4 and 16 weeks after training, and d) strikingly less loss of accuracy after 4 and 16 weeks Similarly, for the two component skills, fluency training resulted in a) higher response rates immediately following training, b) high-er accuracy after 16 weeks, and c) significantly less deterioration in accuracy after 16 weeks

This study is important primarily because it demonstrated that for skilled adult learners, fluency training on component skills a) aided the acquisition of a composite skill and b) improved the retention of accuracy for both the composite and component skills The results, thus, support the claims of fluency advocates (e g , Binder, 1996a, Dougherty & Johnson, 1996, Johnson & Layng, 1992, 1994) They are also consistent with those of earlier studies (Berquam, 1981, Iva-rie, 1986, Shirley & Pennypacker, 1994) Berquam (1981), Ivarie (1986), and Shir-ley and Penny-packer (1994) all found that fluency training led to higher response rates and better accuracy on retention tests As indicated earlier, the current study extended the documented benefits of fluency training to a new population, skilled adult learners, and to a composite rather than a component task It also introduced a new analysis that can be used to compare the effects of fluency training with other training procedures—the extent to which response rate and accuracy deteriorated over time Previous studies of fluency analyzed differences between training procedures in terms of the absolute levels of performance While differences in the absolute performance levels are certainly important data, it is not surprising, as indicated earlier, that individuals who are trained to higher

> *The primary purpose of this study was to determine whether the fluent performance of two component skills would improve the performance and retention of a composite skill by skilled, adult learners.*

levels of performance exhibit higher levels of performance on retention tests The current loss measure appears to be a less biased measure because it controls for differences in terminal training rates Moreover, comparative information regarding how quickly performance is lost over time would be of considerable value for both educators and trainers who could use it when deciding what training procedure to adopt

In the current study, the loss measure answered the question "How rapidly is material lost after training?" For the accuracy training, the answer is "within two weeks " For the accuracy plus fluency training, the answer is, "There is a gradual decline over four months " This answer is important in practical terms because it shows that though fluency training takes longer, it lasts longer In many situations, accuracy training that lasts less than two weeks would be the practical equivalent of no training at all

It should be noted that replication of this study is necessary prior to drawing conclusions regarding generalization to different populations, settings, and most importantly, training materials This study should be considered only a first step in that direction Nonetheless, given that these results generalize to other

subjects, settings, and training materials, they certainly indicate that fluency training should be incorporated into both educational and occupational training programs Others have discussed the many benefits of fluent performance and longer retention (e g , Binder, 1993, Binder & Bloom, 1989, Johnson & Layng, 1992, 1994, Precision Learning Systems, n d , b), as a result, only a few will be mentioned here The current results suggest that fluency training on component tasks would not only aid their retention, but permit quicker and easier acquisition of higher level skills, saving time and expense Both educators and trainers should carefully analyze the desired terminal performance, train component skills to fluency, and constantly probe for the emergence the higher level skills, which would eliminate unnecessary training Moreover, by doing so, the component skills that are essential for the emergence of the higher level skill could be identified, which may again decrease training time

The current results are particularly pertinent for tasks that are not performed frequently yet require a high level of accuracy For example, in many cases, responding to emergencies requires unhesitant, highly accurate performance in order to

> *The current results suggest that fluency training on component tasks would not only aid their retention, but permit quicker and easier acquisition of higher level skills, saving time and expense.*

avoid dire consequences Although such skills should be rehearsed or retrained at consistent intervals, they usually are not The results of this study suggest that fluency training could dramatically increase the retention of the accurate performance of such critical tasks

It should be noted that practice effects were not controlled in this study That is, fluency trainees practiced the component skills more than accuracy trainees Thus, the results cannot be attributed solely to the response rate requirement inherent in fluency training Nonetheless, the differences between the fluency and accuracy-only training procedures in this study do reflect typical training differences Therefore, the study documents the effectiveness of fluency training as it is typically implemented, benefits that had not been decisively documented for skilled learners in prior studies Additional research is needed to isolate the components of fluency training that contribute to its benefits and to replicate the results with different participants and tasks

References

Bates, S , & Bates, D (1971, Spring) And a child shall lead them Stephanie's chart story *Teaching Exceptional Children,* 111 113

Berquam, E (1981) *The relation be tween frequency of response and re tention on a paired associates task* Unpublished doctoral dissertation, University of Florida, Gainesville, FL

Bilodeau, E , & Bilodeau, I (1954) The contribution of two component activities to the total psychomotor task *Journal of Experimental Psychology, 47,* 37 46

Binder, C (1993) Behavioral fluency A new paradigm *Educational Technol ogy, 33,* 8 14

Binder, C (1995, May) *Fluency re search Questions, parameters, and designs* Paper presented at the annual meeting of the Association for Behavior Analysis, Washington, DC

Binder, C (1996a) Behavioral fluency Evolution of a new paradigm *The Behavior Analyst, 19,* 163-197

Binder, C (1996b, May) *Fluency re search* Workshop at the annual meeting of the Association for Behavior Analysis, San Francisco, CA

Binder, C , & Bloom, C (1989, February) Fluent product knowledge Application in the financial services indus try *Performance and Instruction,* 17 21

Binder, C , Houghton, E , & Van Eyk, D (1990) Increasing endurance by building fluency Precision teaching attention span *Teaching Exceptional Children, 22,* 24-27

Binder, C , & Watkins, C (1990) Precision teaching and direct instruction Measurably superior instructional technology in schools *Performance Improvement Quarterly, 3(4),* 74 97

Cohen, J , Dunbar, K , & McClelland, J (1990) On the control of automatic processes A parallel distributed processing account of the stroop effect *Psychological Review, 97,* 332-361

Craig, C , Sternthal, B , & Olshan, K (1972) The effect of overlearning on retention *Journal of General Psychology, 87,* 86-94

Dougherty, K , & Johnston, J (1996) Overlearning, fluency, and automaticity *The Behavior Analyst, 19,* 289-292

Driskell, J , Willis, R , & Cooper, C (1992) Effect of overlearning on retention *Journal of Applied Psychology, 77,* 615 622

Fisk, A , Hodge, K , Lee, M , & Rogers, W (1990) Experimental Series 4 Toward an understanding of skill decay Retention of automatic component processes *Automatic information processing and high performance skills Acquisition, transfer, and retention* Brooks Air Force Base, TX Air Force Systems Command, Human Resources Laboratory (AFHRL-TR -89-69)

Fleisher, L , Jenkins, J , & Pany, D (1979) Effects on poor readers' comprehension of training in rapid decoding *Reading Research Quarterly, 15,* 30 48

Gange, R , Baker, K , & Foster, H (1950) Transfer of discrimination training to a motor task *Journal of Experimental Psychology, 40,* 314-328

Gange, R , & Foster, H (1949) Transfer of training from practice on components in a motor skill *Journal of Experimental Psychology, 39,* 47-68

Hasselbring, T , Goin, L , & Bransford, J (1988) Developing math automaticity in learning handicapped children The role of computerized drill and practice *Focus on Exceptional Children, 20,* 1-7

Haughton, E , Freeman, G , & Binder, C (1992) Learning with precision teaching A gift we share at the Haughton Learning Center *Journal of Precision Teaching, 9,* 33

Healy, A , Fendrich, D , & Proctor, J (1990) Acquisition and retention of letter-detection skill *Journal of Experimental Psychology Learning, Memory, and Cognition 16,* 270-281

Ivarie, J (1986) Effects of proficiency rates on later performance of a recall and writing behavior *Remedial and Special Education, 7,* 25-30

Johnson, K , & Layng, T (1992) Breaking the structuralist barrier Literacy and numeracy with fluency *American Psychologist, 47,* 1475 1490

Johnson, K , & Layng, T (1994) The Morningside model of generative instruction In R Gardner, D Sainato, J Cooper, T Heron, W Heward, J Eshleman, & T Grossi (Eds), *Behavior analysis in education Focus on measurably superior instruction* (pp 173-197) Belmont, CA Brooks/Cole

Johnson, K , & Layng, T (1996) On terms and procedures Fluency *The Behavior Analyst, 19,* 281-288

Kratochwill, T , Demuth, D , & Conzemius, W (1977) The effects of overlearning on preschool children's retention of sight vocabulary words *Reading Improvement 14,* 223 228

Krueger W (1930) Further studies in overlearning *Journal of Experimental Psychology, 13,* 152-163

LaBerge, D , & Samuels, S (1974) Toward a theory of automatic information processing in reading *Cognitive Psychology, 6,* 293-323

Lindsley, O (1990) Precision teaching By teachers for children *Teaching Exceptional Children, 22,* 10 15

Lindsley, O (1992) Precision teaching Discoveries and effects *Journal of Applied Behavior Analysis, 25,* 51-57

Logan, G (1985) Skill and automaticity Relations, implications, and future directions *Canadian Journal of Psychology, 39,* 367-386

McDade, C (1992) Computer-based precision learning A course builder application *Behavior Research Methods, Instruments, and Computers, 24,* 269-272

Melnick, M (1971) Effects of overlearning on the retention of gross motor skill *Research Quarterly, 42,* 60 69

Naslund, J (1987) *Learning mastery to automaticity Its effect on individual*

variation and retention Unpublished doctoral dissertation, University of Chicago, IL

Olander, C, Collins, D, McArthur, B, Watts, R, & McDade, C (1986) Retention among college students A comparison of traditional versus precision teaching *Journal of Precision Teaching, 6,* 80-82

Pennypacker, H (1982) Higher education (about PT) *Journal of Precision Teaching, 3,* 25-26

Pennypacker, H, Koenig, C, & Lindsley, O (1972) *Handbook of the standard behavior chart* Kansas City Precision Media

Postman, L (1962) Retention as a function of the degree of overlearning *Science, 135,* 666-667

Potts, L, Eshleman, J, & Cooper, J (1993) Ogden Lindsley and the historical development of precision teaching *The Behavior Analyst, 16,* 177 189

Precision Learning Systems, Inc (n d, a) *It is possible to fly without motors, but not without knowledge and skill* [marketing material] (Available from Precision Learning Systems, Inc, 3531 Habersham at Northlake, Tucker, GA)

Precision Learning Systems, Inc (n d, b) *Nobody accelerates safety better than Precision Learning Systems* [marketing material] (Available from Precision Learning Systems, Inc, 3531 Habersham at Northlake, Tucker, GA)

Precision Learning Systems, Inc (n d, c) *The Precision Learning System A measurably superior learning method that is* [marketing material] (Available from Precision Learning Systems, Inc, 3531 Habersham at Northlake, Tucker, GA)

Precision Learning Systems, Inc (n d, d) *The Precision Learning system Creating fluent performance* [marketing material] (Available from Precision Learning Systems, Inc, 3531 Habersham at Northlake, Tucker, GA)

Shirley, M, & Pennypacker, H (1994) The effects of performance criteria on learning and retention of spelling words *Journal of Precision Teaching, 12,* 73-86

Sidman, M, & Tailby, W (1982) Conditional discrimination vs matching to sample An expansion of the testing paradigm *Journal of the Experimental Analysis of Behavior, 37,* 5-22

Snyder, G (1992, Summer) Morningside Academy A learning guarantee *Performance Management Magazine, 10,* 29-35

Spence, I, & Hively, W (1993) What makes Chris practice? *Educational Technology, 33,* 15-20

Spring, C, Blunden, D, & Gatheral, M (1981) Effect on reading comprehension of training to automaticity in word-reading *Perceptual and Motor Skills, 53,* 779-786

Thurman, R (1993) Instructional simulation from a cognitive psychology viewpoint *Educational Training and Design, 41,* 75-89

West, R, & Young, K (1992) Precision Teaching In R West, & L Hamerlynck (Eds), *Design for excellence in education The legacy of B F Skinner* (pp 113 146) Longmont, CO Sopris West

West, R, Young, K, & Spooner, F (1990) Precision teaching An introduction *Teaching Exceptional Children, 22,* 4-9

White, O (1986) Precision teaching–precision learning *Exceptional Children, 52,* 522-534

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