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

> ***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, 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, 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 fluency 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 greatest 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, automaticity, 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 latencies 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, & Ol-shan, 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	מ	BAF	2
GIM	ך	GIM	3
DAL	ש	DAL	4
HES	ה	HES	5
LAL	ל	LAL	6
ZAY	ב	ZAY	7
KAP	ק	KAP	8
TET	ט	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.

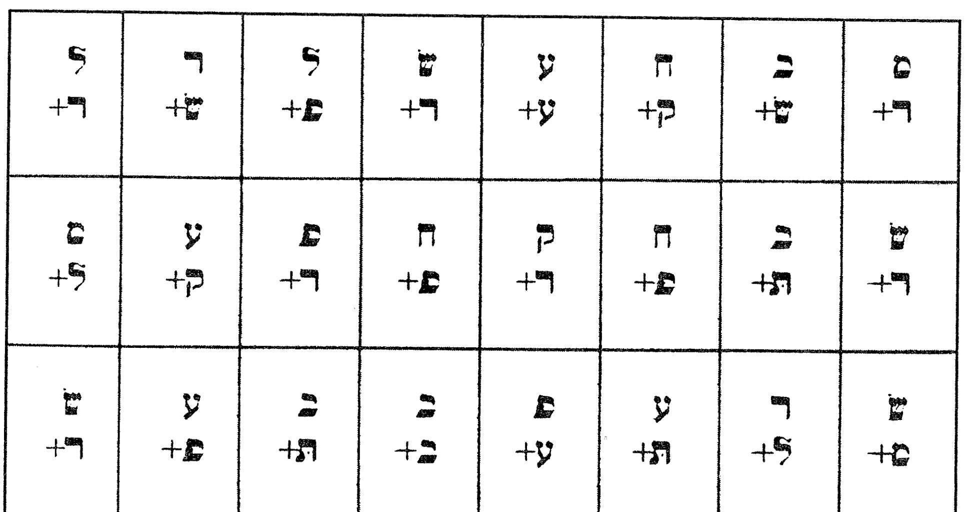

Figure 2. Composite Skill Arithmetic Task

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

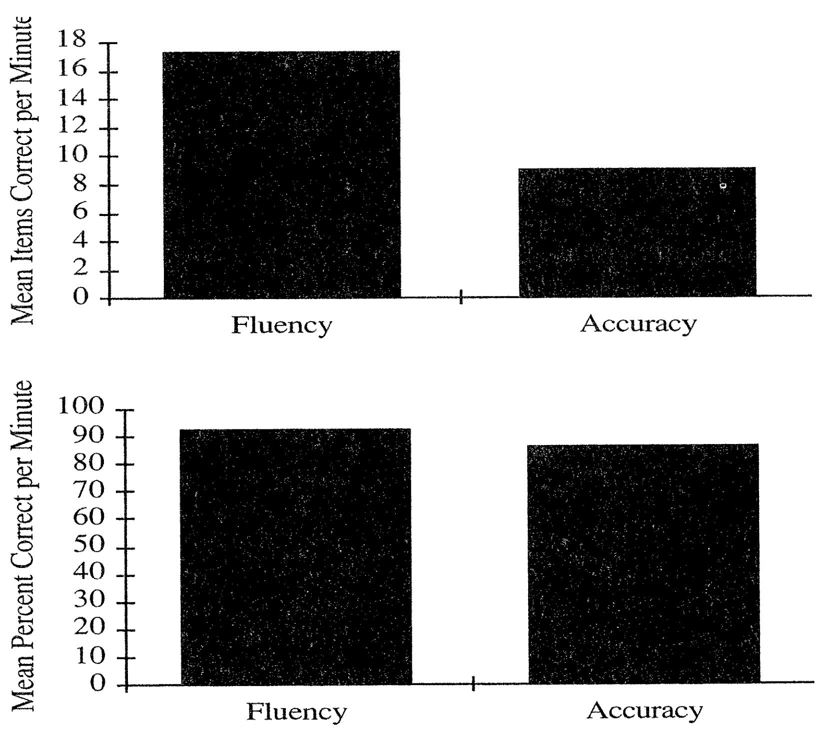

Figure 3. Composite Skill Fluency and Accuracy for Fluency and Accuracy Trainees

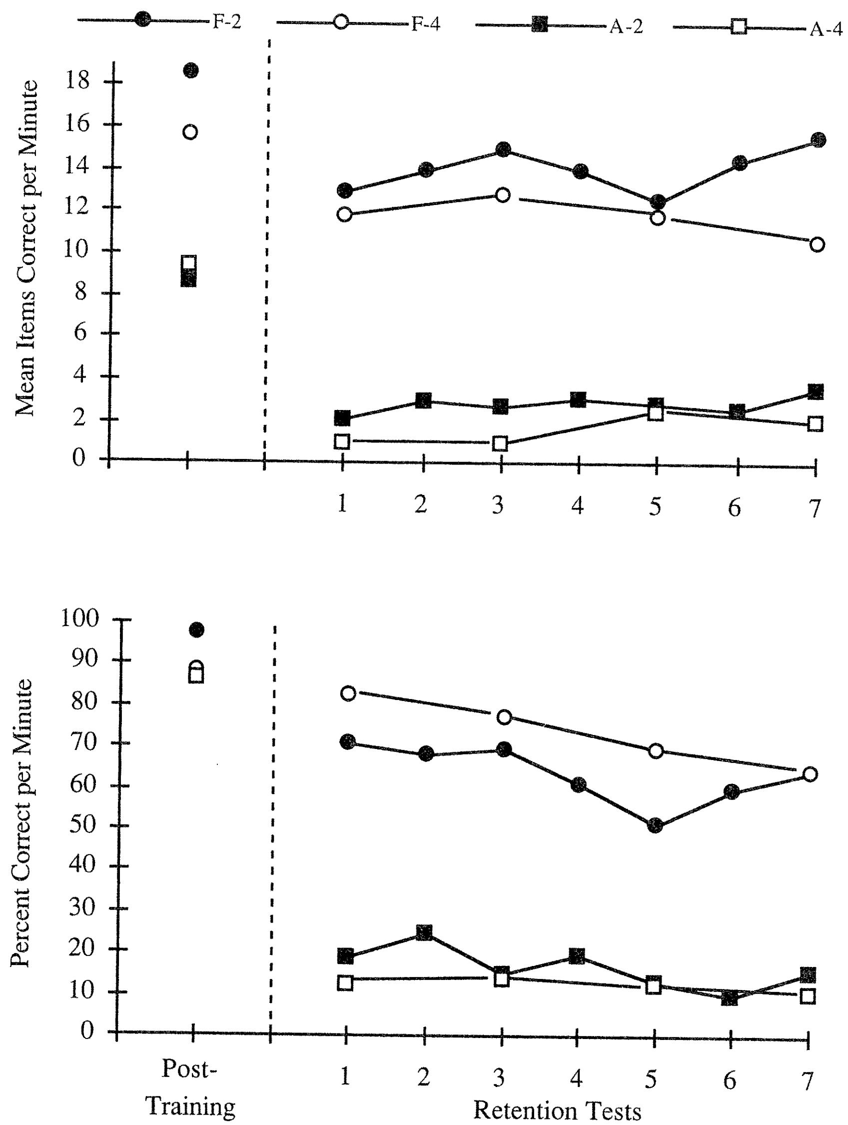

Figure 4. Retention of Composite Skill Fluency and Accuracy for Fluency and Accuracy Trainees with the 2-Week and 4-Week

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

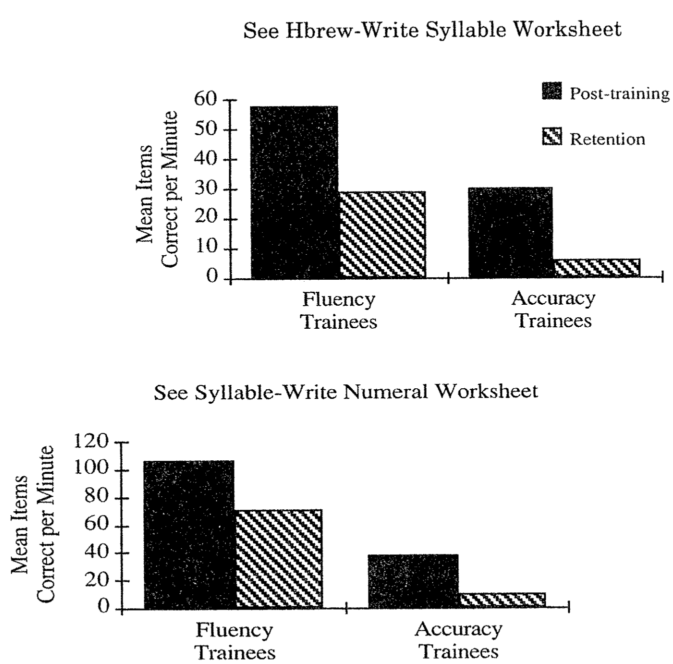

Figure 5. Retention of Component Skill Fluency 16 Weeks after Training for Fluency and Accuracy Trainees

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

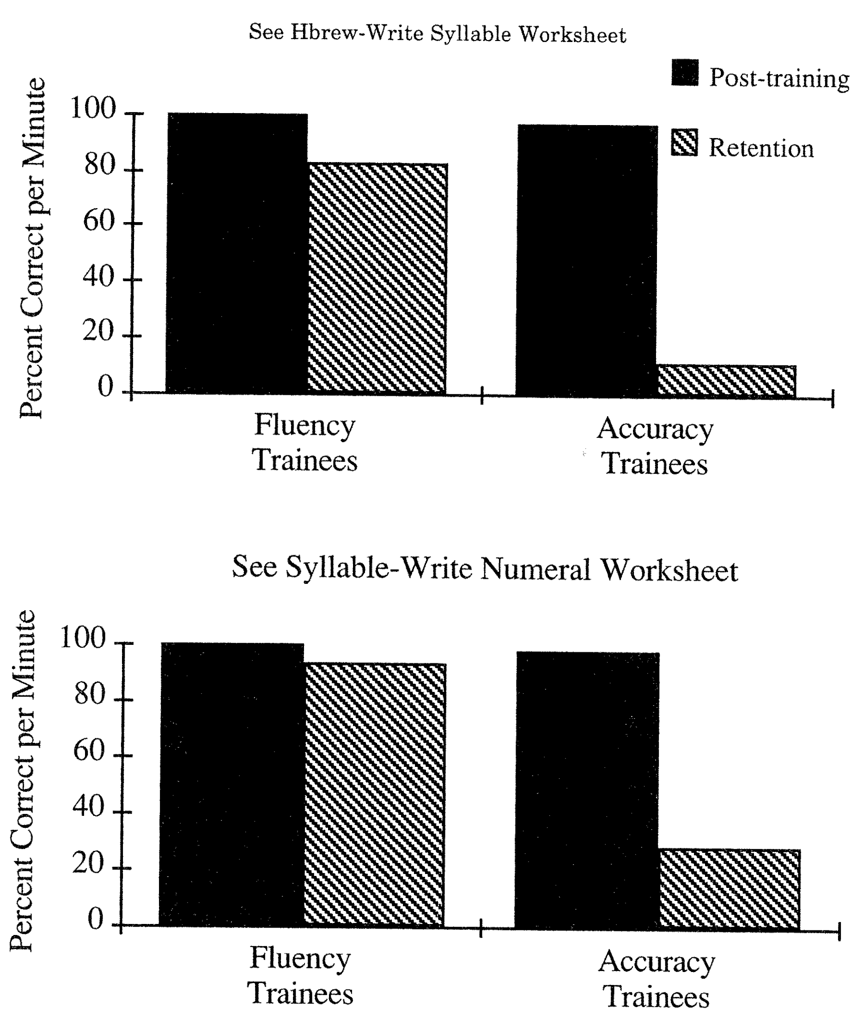

Figure 6. Retention of Component Skill Accuracy 16 Weeks after Training for Fluency and Accuracy Trainees.

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.

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.

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 Pennypacker (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 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 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.

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 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.

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