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ABSTRACT

The purpose of this study was to determine an optimal schedule for the frequency and spacing of drill and practice in the learning of verbal information. Subjects for the first phase were 62 fourth, fifth, and sixth graders in a public elementary school. Using a computer-based drill involving the naming of the capitals of the 50 states of the United States, the students each determined their own practice schedules over a period of two weeks. A pretest and posttest were used to measure the level of success of each student in learning the assigned items. Results suggest that two times through the optimized drill, one near the time of original learning and the other near the retention measure, are sufficient for maximal learning of the drill material. This conclusion will be tested in the second phase of the study. (27 references) (Author/GL)

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Frequency and Spacing of Drill and Practice in the Learning of Verbal Information Using a Computer-Based Drill

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Abstract

The purpose of this study is to determine an optimal schedule for the frequency and spacing of drill and practice in the learning of verbal information. Subjects for phase 1 were sixty-two 4th, 5th and 6th graders in a public elementary school. Using a computer-based drill which incorporated in its structure the findings of past research, the students each determined their own practice schedule over a period of two weeks. A pretest and posttest were used to measure the level of success of each student in learning the assigned items. Results suggest that two times through the optimized drill, one near the time of original learning and the other near the retention measure, are sufficient for maximal learning of the drill material. This conclusion will be tested in phase 2 of the study.

Frequency and Spacing of Drill and Practice in the Learning of Verbal Information Using a Computer-Based Drill

The purpose of this study is to determine an optimal schedule for the frequency and spacing of drill and practice in the learning of verbal information. In order to provide an optimal practice tool, the study is using a computer-based drill which incorporates in its structure the findings of past research.

Since computers entered the educational realm, drill and practice programs have been widely used (Gerlach, 1984; Siegel & Misselt, 1984; Davidson & Traylor, 1987). Some have considered drill and practice a poor use of the computer because it does not use many of the capabilities of the machine (Yates, 1983; Fuson & Brinko, 1985; Salisbury, 1985). Research has been conducted to compare computer drill and practice programs with more traditional methods. Results often implied that the computer and traditional drills yielded the same results (Fuson & Brinko; Jamison, Suppes & Wells, 1974; Campbell, Peck, Horn & Leigh, 1987). In these studies, the traditional drill was often made as alike to the computer drill as possible. This suggests that the medium itself does not make a significant difference in the effectiveness of drill and practice.

At the same time, performance gains and reduced amount of time were found in several studies (Kearsley, Hunter & Seidel, 1983; Kulik, Bangert & Williams, 1983; Suydam, 1984; Carrier, Post & Heck, 1985). Some studies also observed improved attitudes (Kulik et al; Chambers & Sprecher, 1984). The most consistent positive results of improvement in achievement were found for the learning disabled (Edwards, Norton, Taylor, Weiss & Dusseldorp, 1975; Jamison et al; Chambers & Sprecher; Suydam; Balajthy, 1984; Chadwick & Watson, 1986).

Over-all, computer based instruction has spurred research throughout the field of instruction (Kearsley et al, 1983). Characteristics of learners and how these affect the learning process are being studied. The computer's ability to respond to individual differences and to help to analyze them is being more fully realized. For drill and practice programs, aspects of individualization are accomplished through processes such as feedback, correction of errors, varying levels of difficulty, and maintenance of individual student records. For example, by keeping track of errors, the computer can strategically reintroduce missed items in order to maximize the probability of retention. Some of these features would be difficult to implement with more conventional means such as worksheets or teacher presentation. The computer-based research of today, then, is built upon results of earlier studies involving instructional methods administered with more traditional means. With the computer, however, more complex strategies can be used than in the past.

Some research has been conducted to study various features of drill and practice in order to determine what methods/ qualities are most effective. Among the topics researched are spacing and length of practice sessions, review of missed items, and type of feedback.

Spacing and Length of Practice Sessions

Reynolds and Glaser (1964) conducted research on the effects of repetition and spaced review in the learning of a complex task. The study demonstrated the relative ineffectiveness of massed practice following initial learning. There has been much evidence to suggest that short, spaced practice periods yield better results than long concentrated practice periods (Anderson, 1980). At the occasion of each practice period, the learning context is somewhat different (e.g. student's pre-knowledge of the material, time of day, surrounding conditions, etc.), causing the information to be encoded somewhat differently each time (Salisbury, 1984).

According to McGeoch (1932), forgetting is as much a function of the amount of time between use of the material as of the experiences which occur during the intervening period. Thus the optimal spacing of practice sessions would depend on many factors. Research has shown that spaced repetition does increase meaningful retention (Peterson, Wampler, Kirkpatrick & Saltzman, 1963; Ausubel & Youssef, 1965).

Gay (1973) studied the effect of the temporal position of reviews on the retention of mathematical rules. She experimented with placing a review either 1 day, 1 week, or 2 weeks after original learning. A test administered 3 weeks after original learning showed that temporal position was not a significant factor, though the retention of all review groups was significantly more than a no-review group. A second experiment compared two reviews, placing them 1 and 2, 1 and 7, or 6 and 7 days after original learning. Again, all groups retained more than a no-review group. She concluded that additional reviews are highly effective in terms of delayed retention, and are very efficient in terms of numbers of examples as well as amount of time spent on those examples. Peterson, Ellis, Toohill, and Kloess (1935) had shown that a second review is more effective than the first, and Gay's study found that one early and one late are better than two early and two late reviews; i.e. the reviews of 1 and 7 days after original learning resulted in significantly better retention than the reviews of 1 and 2 days after learning.

Merrill and Salisbury (1984) summarize research as indicating that several short spaced reviews are more effective than a few massed reviews. Goldeberg (1987) suggests studying this question of spaced practice, added to his optimized review schedule (explained in the next section), taking into account individual learner differences.

Review of Missed Items

When drilling verbal information, the learner can make errors. It is then necessary to review those items until they are learned correctly. Research has examined the question of how often and how soon to reintroduce a missed item.

Siegel and Misselt (1984) conducted a study involving a drill program on English-Japanese (transliterated) word pairs in which an increasing ratio review was used. Their results suggest that increasing ratio review techniques (e.g. after 1,3,5 intervening items) are more effective than traditional techniques (e.g. 1 later) or no review at all. They also concluded that a 1-later review is no more effective than no review, suggesting that a 2-3-5 or 2-4-6 review schedule may be more effective than a 1-3-5 review schedule.

Goldenberg (1987) studied the optimum number of intervening items that should be inserted after an incorrect response before a drop-off in memory occurs. He used the same subject material as Siegel and Misselt (1984). He concluded that the optimum position was after two intervening items, with the second recommended position being after three intervening items. Salisbury (1985) suggests that missed items reappear according to a spaced review schedule of up to three review positions.

Feedback

The study of Siegel and Misselt (1984), discussed in the last section, also used adaptive feedback techniques with discrimination training. This significantly reduced the number of discrimination errors on the post-test. In their feedback paradigm, the types of mistakes were divided into two types - an "out-of-list" error, when the learner's response is not an answer to another item in the drill list, and a "discrimination" error, when the learner types a response that is an answer to another item in the drill list. When the first type of error is made, the correct answer is provided. In the latter types, discrimination feedback is provided; i.e. the learner is informed of the correct response as well as what stimulus was responded to. For example, in a drill on the states and capitals, if the student types **St. Paul** (the answer to the stimulus **Minnesota**) instead of **Jefferson** (the answer for the stimulus **Missouri**), the feedback provided is "the capital of Missouri is Jefferson; St. Paul is the capital of Minnesota."

Salisbury (1985), in describing what he considers "good" drill and practice strategies, includes discrimination training as one of the features of the strategy.

Observation

The many student differences which can affect success in various learning strategies can make it difficult to come to clear-cut conclusions regarding aspects of computer-based instruction. Tobias (1981), in a discussion of adapting instruction to individual difference among students, suggests that research might be begun by observation of what students of varying individual difference characteristics actually do, and what instructional options they select. From this observation, the researcher can then generate a prediction as to what strategy might be best for them.

Observation is the method used in phase 1 of this study. In order to first obtain additional data from which to propose and test a review schedule, the study is being carried out in two phases. The data obtained through observation in phase 1 (already completed) is being used to determine a schedule which will then be tested in phase 2. This report includes the results from phase 1.

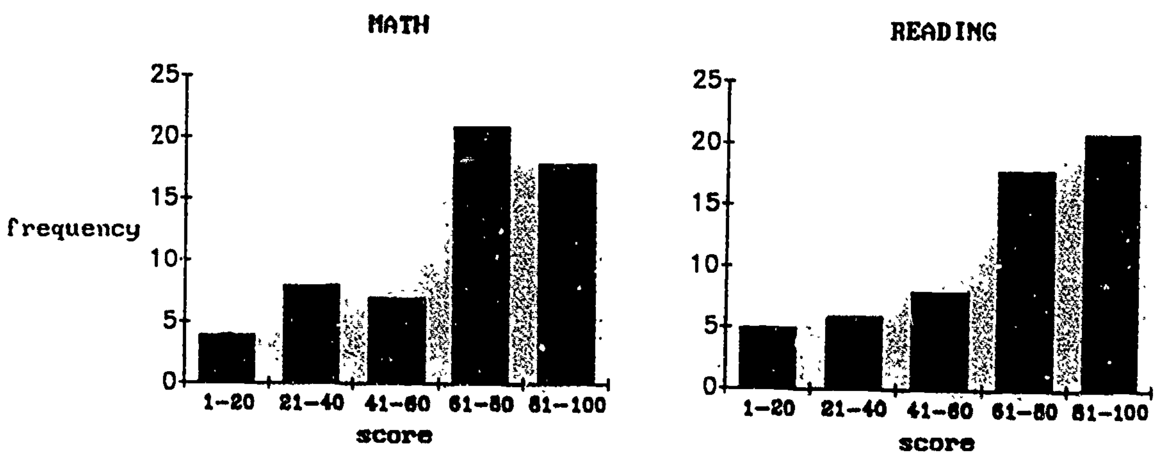
Methods

Sample

Students involved in phase 1 of this study were the sixty-two 4th, 5th and 6th graders in an urban Minneapolis public elementary school. Absenteeism was the major reason for a student's not being able to participate fully in the study. 55 students (89%) took the pretest, 58 (94%) used the computer drill, and 61 (98%) took the posttest. 51 students (82%) participated in all three parts of the study.

Data was obtained from the school files on CAT exams taken in the fall of 1988 by 58 (94%) of these students. Math concepts and math computation results were averaged to obtain a math score. The group mean for math is 66.1 with a standard deviation of 25.8. The mean for reading is 67.6 with a standard deviation of 26.8. These math and reading scores were obtained as a measure of ability in order to observe whether better choices (leading to better success) would be made by students of higher ability. Figure 1 shows the frequency distribution of the math and reading scores.

Figure 1: Frequency Distribution of Math and Reading CAT Scores



Materials

The teachers of these students were consulted to determine which verbal information would be used for the study. This was done so that the drill might enhance regular classroom procedures rather than interfere with them, and so that the material used would be a part of the students' program of study. The resulting drill involves the naming of the capitals of the 50 states of the United States.

A computer-based drill program was developed for use with this verbal information. The findings of research, as described above, were utilized in the designing of the drill in the following ways:

1) Feedback includes discrimination feedback; i.e. when a student answers incorrectly with another response from the list, both the correct answer and the stimulus for which their response should be given is indicated. If the response is not in the list, only the correct answer is given. After correct answers, a counter is incremented and the next item appears.
2) Once an item is missed, it is reviewed three times with the following schedule: after 2 intervening items, after 3 more intervening items, and then after 5 more intervening items. If it is missed again, this pattern is begun over. If two items are cued to the same position, the item most recently incorrect is placed first.
3) If an item is answered correctly the first time, or if it has passed through a review schedule with no further errors, it is moved to the review pool. In this way the size of the working pool is controlled.
4) The drill session can be ended at any time. This allows the student to decide the amount that he/she studies at one time. This is a second way of controlling the size of the working pool.
5) Records are kept of each practice session. Therefore, if a student stops before completing the entire list of items, at the next session the program continues where it left off.

The drill was reviewed by four persons (one professor, two adults, and a teacher of the sample group) who suggested editorial changes which were incorporated into the program before it was used by the students.

Pretest and Posttest

The pretest and posttest consisted of a random listing of the 50 states for which the students were asked to give the capital. Both tests were paper and pencil tests, as a sufficient number of computers were not available for administration to a large group.

Procedure

At the beginning of the first week, the material was assigned and the written pretest was given. The computer-based drill was demonstrated to the students and the other details involved in using it (location, procedure, etc.) were explained. The students were given two weeks for the learning of the material, at the end of which the written posttest was administered. The choice of when and how often to practice was left completely to the student. The computer recorded each practice session and its results. Each student had a folder on file containing a diskette with the drill program, and a paper which served as a backup to the information recorded by the computer. On the paper, the student recorded the results (number tried, number correct, number remaining) on blanks arranged according to the date of the practice.

Results

Data Collected

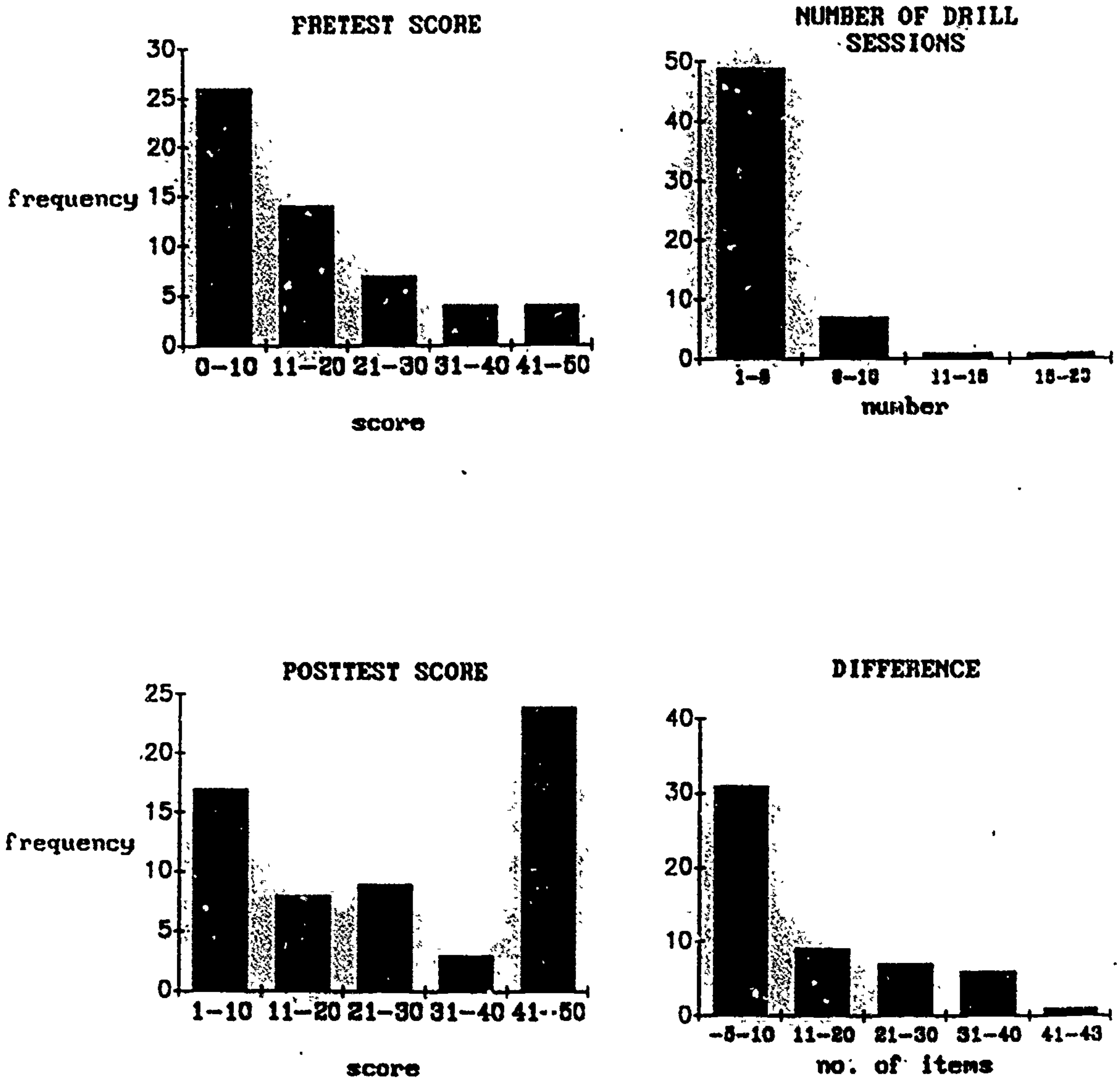
Pretest scores ranged from 0 to 43 (N= 55, M=14.47, SD=12.8) out of a maximum of 50. For an item to be considered correct, it had to be spelled correctly. This was consistent with the computer drill, in which an answer was not considered correct with improper spelling.

During the two-week period, the length and number of practices were affected by computer availability, absenteeism and classroom schedule. Student use of the drill thus ranged from 0 to 17 sessions, with a median of 2 sessions (N= 62, M=3.13, SD=2.9). Length of practices also varied widely, from an individual student average of 5.5 items per session to an individual student average of 148 items per session (Mdn=33.5).

At the end of the practice period, posttest scores ranged from 1 to 50 (N=61, M=27.54, SD=18.15). The resulting difference scores (posttest minus pretest) ranged from -5 to 43 with a mean of 12.4 and a standard deviation of 12.28.

Figure 2 shows the frequency graphs of the above variables.

Figure 2: Frequency Distribution of Descriptive Variables



Fifty-one of the students (82%) took both the pretest and posttest and used the drill during the 2-week period. All of the remaining statistics refer to this group.

New Variables Computed

Because the length of practices varied widely, a variable was created to indicated number of items tried as another way of quantifying amount of practice. This variable, which counts an item each time it is encountered, ranges from 7 to 436 items tried (M=122.43, SD=112.4).

A third variable used to quantify amount of practice was the number of times a student completed the entire drill. It ranges from 0 to 6 with a mean of 1.19 (Mdn=.54) and a standard deviation of 1.45.

To quantify the student's success in learning unknown items, the difference between the posttest and pretest scores was divided by the number each student needed to learn (50 minus the pretest score), creating a percentage of "success" in learning unknown items. It ranged from -.12 to 1.00 (M=.43, SD=.39).

A variable was created to compare practice with success. It was obtained by dividing the number of items tried by the number of items learned. Thus, it indicates the number of items tried per each item learned. It ranges from 0 to 148, with a mean of 13.95 and a standard deviation of 21.9.

A final variable was created indicating when the student practiced. The coding was E (early) for those who practiced only the first week, L (late) for those who practiced only the second week, and B (both) for those who practiced both weeks.

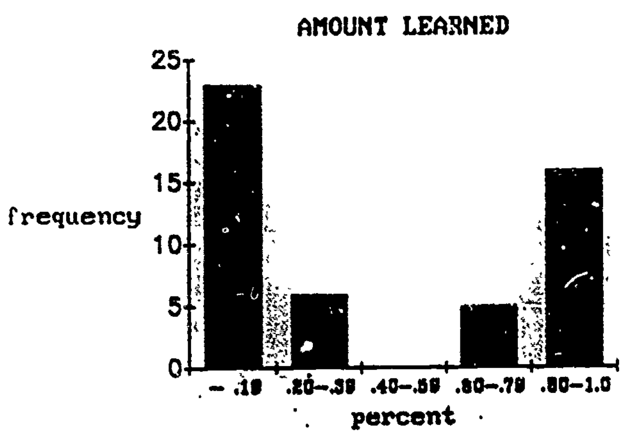
Statistical Procedures Used

The frequency graphs of the math and reading scores indicate that the ability level of the sample group is not normally distributed (see Figure 1). There are various opinions as to which tests should be used with such samples. For this reason, both parametric and non-parametric tests were used for many of the statistical procedures. In all cases, basic conclusions were the same, with differences being found only in the strength of the results. For example, regression analysis on the rank scores resulted in more conservative figures than regression on the raw scores. The non-parametric values are reported in this paper.

Comparison of Two Groups

22 students learned 60% or more of their unknown items, and 29 learned 38% or less. The distribution of AMOUNT LEARNED is shown in Figure 3.

Figure 3: Frequency Distribution of Amount Learned



Since the goal for the students was to learn all the states and capitals, the 22 students who learned at least 60% of their goal were considered "successful" (S), and the other 29 were considered "unsuccessful" (U). These groups were then compared in order to observe what may have determined their level of success.

The Wilcoxon rank-sum test was used to identify significant differences in means between the S and U groups. As shown in Table 1, the means of several variables varied significantly between the two groups.

Table 1: Comparison of Means of S and U groups Using the Wilcoxon Rank-Sum Test

	MEAN		p-value
	S	U	
math	82.08	55.80	.0002
reading	76.70	60.54	.0170
pretest score	22.09	9.56	.0001
number of sessions of practice	4.46	1.75	.0001
number of times through the drill	2.28	.32	.0001
number of items tried	207.32	52.59	.0001
posttest score	45.96	14.16	.0001
difference (posttest minus pretest)	23.86	4.53	.0001

These results indicate that the successful group practiced more times, completed the drill more times, and tried more items than the unsuccessful group.

One variable did not differ significantly between groups, and that is the number of items tried per each item learned (p=.7973). The mean of this variable for the combined groups was 13.95. This suggests that it may be possible to quantify the amount of practice needed in order to learn an item.

Agreement with Previous Research

Although no control was made for effects of the pretest results on student choices, data from this study appears to agree with previous research regarding the time of practice, as discussed on page 4. The students who practiced both weeks (both early and late) numbered 23, and learned an average of 65% of unknown items. The students who practiced late (N=14) learned an average of 36%, while those who practiced early (N=12) learned an average of 19%. None of the successful students (S) practiced only during Monday-Wednesday of the first week. Likewise, none of the students with a success rate less than 10% (N=11) practiced both weeks or at the end of the second week.

Predictors of Amount Learned

Spearman rank order correlation coefficients were run on pairs of variables to note any strong relationships between them. These results are reported in Table 2.

Table 2: Spearman Rank Order Correlation Coefficients Between Variables

Variables	No. Times Through Drill	No. of Items Tried	Percent Learned
Math	.36	.33	.44
Reading	.34	.28	.31
Pretest	.47	.34	.53
No. Times Through Drill		.92	.76

Spearman Rank Order Correlation Coefficients of .37 or more have a p-value of .01 or less. Those of .28 or more have a p-value of .05 or less.

The r-values suggest that success correlates more with the number of times through the drill than with number of items tried. The strong relationship between number of times through the drill and number of items tried results from the fact that they both measure amount of practice. The r-values in the first two rows of the table suggest that ability level (as provided through the math/reading CAT scores) was not strongly correlated with the choices made by the students.

Regression analysis was performed with the amount learned (percentage of success) as the dependent variable, and with pretest score and the number of times through drill (or number of items tried) as independent variables. The number of times through the drill contributed 58% of the variance and the pretest added another 4% ($p=.03$). The other combination (pretest, number of items tried), yielded an R^2 of 59% ($p=.001$).

A second analysis was done with the same variables, but first controlling for the effect of the pretest score. The pretest score explains 28% of the amount learned ($p=.0001$). After the effect of the pretest score is removed, the number of items tried explained 38% of the amount learned, while the number of times through the drill explained 36.5% of the amount learned ($p=.0001$ for each).

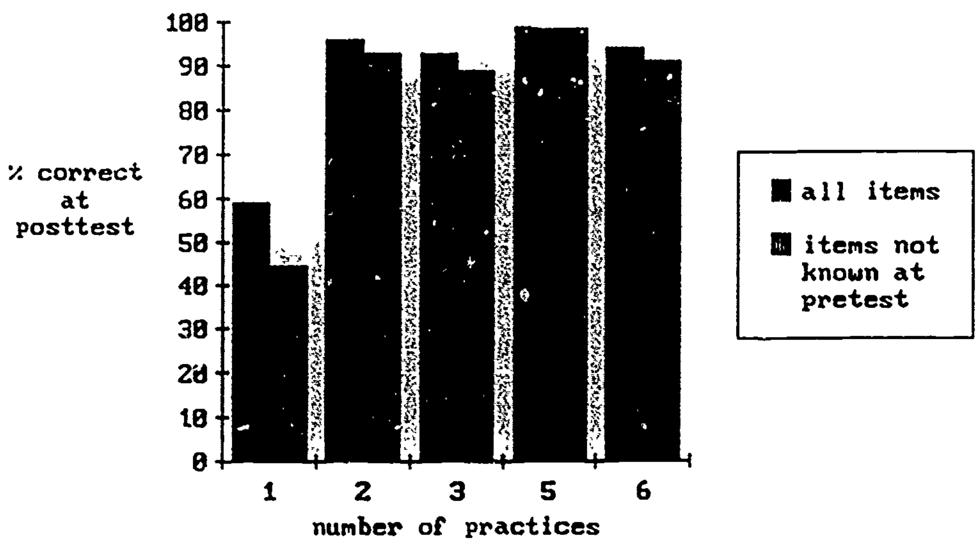
Item Analysis

The computer recorded the status of each item at the end of a practice session. In this context, an item was considered as practiced once either when it was answered correctly and thus encountered once, or when it was missed and therefore repeated 3 times. This information was studied item-by-item in order to observe at what point an item appeared to be learned by the student. Since 30 of the 51 students did not complete the drill even once, many of the items were not practiced at all.

With 51 students potentially practicing 50 different items, there was a total of 2550 items to consider. Forty-two percent (1065 items) were not practiced at all. Of the remaining 1485 items, 58% (861 items) were practiced once, 15% (218 items) were practiced twice, 17% (256 items) were practiced 3 times, 7% (100 items) were practiced 5 times, and 3% (50 items) were practiced 6 times.

The percentage of items correct on the posttest after the various number of times of practice was calculated. Percentages were calculated on all items, as well as on those which were not known at the time of the pretest. These results are shown in Figure 4.

Figure 4: Percent of Items Correct After Practice



From this graph, it is possible to see that once an item was practiced twice, it was about as likely to be answered correctly on the posttest as if it were practiced more than twice (whether it was known at the pretest or not). This suggests that two times through the drill may be sufficient for learning most of the items.

Using average figures from the data on each item practiced, it was possible to approximate the number of items tried per each item learned while completing the drill twice, as follows: The average "student" (out of 50 states and capitals),

had 19 correct on the pretest
knew 29.5 after the first practice (based upon the data on items practiced only once)
had 37 correct on the posttest,

thus learning 18 items.

During the first practice, this "student" would have tried the 19 problems once each, and tried 31 problems 4 times each, for a total of 143 items encountered. At this point, he/she knew 29.5 items. During the second practice, 29.5 items were tried once and 20.5 items were tried four times, for a total of 111.5 items.

After two practices, then, the average "student" had tried 254.5 items. Since he/she learned 18 items between the pretest and posttest, he/she tried 254.5/18 or 14.14 items for each item learned. This figure is comparable to the actual mean of 13.95, as calculated from the student data. This fact suggests that both the item-by-item analysis and the variable "number of items tried per each item learned" are indicating that practicing an item two times with the procedures used was sufficient for learning most of the drill material.

Discussion

The purpose of phase 1 of this study was to obtain data from which to propose an optimal schedule of review for the learning of verbal information. The following are the conclusions drawn.

The ability level of the students, as indicated from their CAT scores, did not seem to strongly affect the choice, and thus effectiveness, of their practice schedule. (The highest r-value was .36 between the math score and number of times through the drill, as seen in Table 2.) The math and reading scores were therefore not used for further analyses.

The number of times through the drill was the strongest factor for predicting the success of the student. This was demonstrated both in the correlation and the regression analyses, as well as in the item-by-item analysis. The item-by-item analysis suggests that two times through the drill is sufficient. Since those who practiced both early and late in the two-week period were more successful, the two practice sessions should be scheduled accordingly.

The conclusion of this phase of the study, then, is that for the learning of verbal information, when an optimized computer drill (with discrimination training and an increased ratio review of 3 positions for missed items) is used with placement of reviews early (near the time of original learning) and late (near the retention measure), then the two practice sessions are sufficient. In phase 2, these conditions will be tested in comparison to practice strategies in which the review of missed items and/or the scheduling of practice sessions are altered.

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