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# EFFECTS OF PRESENTATION- AND TEST-TRIAL TRAINING ON MOTOR ACQUISITION AND RETENTION

Joseph D. Hagman

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TRAINING TECHNICAL AREA

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t-trial. For the last group, the first trial was a p-trial and the next five were t-trials. Group acquisition performance was compared at the last trial of each cycle while retention was compared 3 min. and 24 hr. after acquisition.

Absolute error scores indicated that acquisition and short-term retention were best when training emphasized p- and t-trial alternation and p-trial repetition within cycles, whereas long-term retention was best when training stressed t-trial repetition. Results suggest that testing is an effective way to enhance long-term retention of motor skill. This enhancement could be realized by changing the emphasis of training from presentation to testing without added expenditures in training time, money and personnel. If, instead of long-term retention, the goal is rapid acquisition and short-term retention, training methods which emphasize either alternation of presentation and testing or repeated presentation would be most effective.

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**Technical Report 431**

**EFFECTS OF PRESENTATION- AND TEST-TRIAL TRAINING  
ON MOTOR ACQUISITION AND RETENTION**

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Motor Skills Training

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## FOREWORD

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The Training Technical Area of the Army Research Institute for the Behavioral and Social Sciences (ARI) conducts research in support of the systems engineering concept of training. A major objective of this research is to develop the fundamental data and technology necessary to field integrated systems for improving individual job performance. Such systems include Skill Qualification Testing (SQT), job performance aids, and training courses both in schools and in the field.

This report is one of a series on specific topics in the area of skill acquisition and retention. In response to requirements by the Deputy Chief of Staff for Training of the Army Training and Doctrine Command (TRADOC), the long-term research goal is to develop methods for predicting proficiency loss for all types of skills and for determining effective training procedures for reducing this loss. The present work represents a basic research effort completed by ARI personnel under Army Project 2T161101A91B.

  
JOSEPH ZEIDNER  
Technical Director

EFFECTS OF PRESENTATION- AND TEST-TRIAL TRAINING ON MOTOR ACQUISITION  
AND RETENTION

BRIEF

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Requirement:

To evaluate the relative effectiveness of three motor task training methods which differ in their emphasis on presentation and test trials.

Procedure:

Three groups of 15 participants received 18 training trials on a simple motor task. The 18 training trials were divided into three cycles of six trials, containing both presentation and test trials. During presentation trials, participants studied the criterion movement to be learned by moving a sliding mechanism along a linear track for a distance of 250 mm before contacting a mechanical stop. During test trials, they tried to recall the criterion movement by moving the slide for the same distance without the aid of the mechanical stop.

In the acquisition part of the experiment, the sequence of presentation and test trials performed within cycles differed for each training group. For the STANDARD group, a cycle consisted of three presentation and three test trials administered in alternation. For the PRESENTATION group, the first five trials of each cycle were presentation trials and the sixth was a test trial. For the TEST group, the first trial was a presentation trial and the next five were test trials. In the retention part of the experiment, all participants performed a single test trial at both 3 minutes and 24 hours after the last training trial.

Findings:

The three training methods had different effects on acquisition and retention. Absolute (unsigned) error scores indicated that acquisition and short-term (3 minute) retention were best for the STANDARD and PRESENTATION groups, while long-term (24 hour) retention was best for the TEST group.

Utilization of Findings:

Testing is an effective way to enhance long-term-retention of motor skills. This enhancement can be achieved by changing the emphasis in training from presentation to testing, without the need for additional training time, money or personnel. If instead of long-term retention, the goal is rapid acquisition and short-term retention, training which

emphasizes either alternation of presentation and testing or repeated presentation would be most effective. Additional research is needed to determine how well these laboratory results will generalize to actual military motor skills.

EFFECTS OF PRESENTATION- AND TEST-TRIAL TRAINING ON MOTOR ACQUISITION  
AND RETENTION

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# EFFECTS OF PRESENTATION- AND TEST-TRIAL TRAINING ON MOTOR ACQUISITION AND RETENTION

## INTRODUCTION

A long-term goal of the Army is the development of effective methods for training all types of Army-related skills. Of constant interest is the question of which specific training methods promote the highest levels of skill acquisition and retention. Much of the theoretical and empirical information relating to this question has been derived from the conduct of basic research experiments in the areas of verbal and motor learning. In these experiments, training has involved the execution of both presentation (p) and test (t) trials. During p-trials, subjects study information to be learned and during t-trials they attempt to recall it from memory. The number and sequential arrangement of p- and t-trials performed during training has depended on the particular method adopted. The standard training has involved the alternation of p- and t-trials (e.g., Tulving, 1967; Wrisberg & Schmidt, 1975) but other methods which emphasize either p- or t-trial repetition also have been used (Adams & Dijkstra, 1966; Bilodeau & Bilodeau, 1958; Hogan & Kintsch, 1971).

The Army's question of which training method most effectively promotes acquisition and retention is difficult to answer because relevant theories make conflicting predictions regarding the role of p- and t-trials. For example, from a traditional learning theory viewpoint, where p-trials are seen as having an effect similar to reinforcement, training methods which repeat p-trials should be more effective than those which repeat t-trials. Repetition of t-trials reduces the number of reinforcement opportunities, and therefore, should retard both acquisition and retention. From a contemporary cognitive viewpoint, however, information processing activities such as recall and internal generation of to-be-learned items are considered important aspects of acquisition and retention (Bjork, 1975; Doshier & Russo, 1976). Because t-trials provide an opportunity to perform these activities on the information studied during p-trials, training methods which repeat t-trials should be more effective than those which repeat p-trials.

A look at empirical evidence related to the issue of which training methods are most effective also reveals inconsistencies. Most of this evidence has come from research in verbal task learning. Here, the relative effects of p- and t-trial repetition during training have been of interest for a long time (Gates, 1917; Hellyer, 1962; Raffel, 1934) but have only recently received systematic investigation. In general, investigators have found that training methods which emphasize p-trial repetition produce superior acquisition (Hogan & Kintsch, 1971; Thompson, Wenger & Bartling, 1978, Exp III) whereas those which emphasize t-trial repetition produce superior retention (Allen, Mahler & Estes, 1969; Hogan & Kintsch, 1971; Rosner, 1970; Thompson, et al., 1978, Exp III)

In contrast, the pattern of results for motor task learning has been somewhat different. Generally, emphasis on p-trial repetition during training has enhanced both acquisition (Holding & Macrae, 1964) and retention (Adams & Dijkstra, 1966), but emphasis on t-trial repetition has not. Although both subjective recall consistency and error detection ability have developed as a function of repeated t-trials (Newell, 1974; Seashore & Bevelas, 1941) movement accuracy has not been found to improve (Holding & Macrae, 1964; Newell, 1976, Exp I; Thorndike, 1927) except after considerable prior t-trial repetition (Newell, 1976, Exp I and III). In fact, accuracy typically has decreased during both acquisition and retention when t-trials have been repeated during training (Bilodeau & Bilodeau, 1958; Duffy, Montague & Laabs, 1975).

Thus, training methods stressing p-trial repetition have had relatively consistent beneficial effects on both motor and verbal task performance, especially at acquisition. In contrast, methods stressing t-trials have positively affected verbal task retention but have negatively affected both motor task retention and acquisition. Specific reasons for this differential effect of t-trial repetition on verbal and motor task performance are difficult to pinpoint because of the many differences that exist between the two areas of research. One suggested reason, however, centers around the difference in information processing activity required of subjects at p- and t-trials during motor and verbal task training. In verbal task training, p- and t-trials are procedurally distinct and require dissimilar information processing activities. During p-trials, items to be learned are shown to subjects for study. During t-trials, these items are removed and subjects are required to recall them from memory. In motor task training, however, p- and t-trials are procedurally similar and require very similar information processing activities. At p-trials, subjects attempt to recall a criterion movement from memory. This recall attempt is followed by knowledge of results regarding recall accuracy, typically in visual or verbal form. At t-trials, subjects are also required to recall the criterion movement but knowledge of results is not provided. Thus, motor task training requires recall at the execution of both p- and t-trials whereas verbal task training requires study at p-trials and recall at t-trials. To the extent that study and recall processes have been found to differentially affect verbal acquisition and retention (e.g., Hogan & Kintsch, 1971), it is necessary to create a common procedural environment in motor task training such that process effects on motor acquisition and retention can also be examined.

Another suggested reason for the different effects of t-trial repetition on verbal and motor task performance stems from the difference in retention interval lengths used to investigate the retention of each type of task. For example, the effects of repeated t-trial training on verbal task retention have been examined primarily using long-term retention intervals (e.g., Allen, et al., 1969) whereas short-term

retention intervals typically have been used in examining t-trial effects on motor task retention (Duffy, et al., 1975; Stelmach & Bassin, 1971). Because the effect of repeated t-trials on motor retention may vary with the length of the interval as it does for verbal retention (Hogan & Kintsch, 1971; Thompson, et al., 1978, Exp III), meaningful comparisons between t-trial repetition effects on verbal and motor retention have been difficult to make.

The present experiment was designed to examine the relative effectiveness of different motor training methods under acquisition and retention conditions similar to those used in verbal training studies. The general approach was to allow either repetition or alternation of p- and t-trials prior to a given t-trial during training and to compare the effects of such manipulation on both the acquisition and retention of a linear positioning movement.

In order to create acquisition and retention conditions similar to those used in verbal task training, the present experiment differed from other motor task training experiments in three ways. First, training procedures were designed so that subjects were required to study the criterion movement to be learned during p-trials and to recall it from memory during t-trials. This was accomplished by using a constrained movement procedure at p-trial execution and a preselected movement procedure at t-trial execution. Constrained p-trial movements were performed with the aid of a mechanical stop. Use of the stop ensured that subjects would study the criterion movement. Preselected t-trial movements, on the other hand, were performed without the aid of the mechanical stop. Removal of the stop ensured that subjects would have to recall the to-be-learned movement from memory. Second, p- and t-trial training effects were measured over both short- and long-term retention intervals. This allowed for the examination of the potential interaction between training method and retention interval length and permitted a more meaningful comparison of repeated t-trial training effects on verbal and motor retention. Third, training was restricted to the kinesthetic cue of distance. Although multiple cues underlie the recall of positioning movements (Hagman & Williams, 1977; Gundry, 1975), training was restricted to the specific cue of distance to prevent the possibility of unsystematic subject selection of individual cues and the possibility that certain cues might react differently to p- and t-trial repetition because of their differential retention characteristics (Laabs, 1973; Posner, 1967).

## METHOD

### Subjects

Forty-five government employees (27 men and 18 women) volunteered to serve as subjects in the experiment. Forty-three were members of the professional and clerical staff of the Army Research Institute and two were professionals affiliated with other agencies.

## Apparatus

Movements were made from left to right using a metal slide which slid along two stainless steel rods 35 in. (88.90 cm) in length. Two Thompson Ball Bushings supported the slide on the rods which were mounted in parallel on a metal frame 4.25 in. (11.00 cm) apart and located 11 in. (27.94 cm) above the base of the frame. The base rested on a standard table top 31 in. (78.74 cm) from the floor. A second slide was used to stop p-trial movements. This slide could be securely positioned by the experimenter along the entire length of the steel rods. Displacement of each slide rotated a separate 10-turn variable voltage precision potentiometer which was mounted on one side of the frame. The position of each slide corresponded to a specific voltage level at the potentiometer and was displayed by a digital voltmeter. The displayed voltage corresponded to millimeters and was accurate to within  $\pm 1$  mm. Additional apparatus included a chin rest to control head movements and body position; earphones through which subjects heard tape-recorded procedural instructions; and a blindfold to prevent subjects from using visual cues during the experiment.

## Design

The experiment contained an acquisition and a retention segment as shown in Figure 1. The acquisition segment consisted of 18 training trials divided into three cycles of six trials each. Each cycle contained p- and t-trials. P-trials were constrained movements during which subjects contacted a mechanical stop after moving the to-be-learned distance of 250 mm. T-trials were preselected movements during which subjects attempted to recall the studied distance without the presence of the mechanical stop. The sequence of p- and t-trials within cycles differed for each of three training groups. For Group STANDARD, a cycle consisted of three p- and three t-trials administered in an alternating sequence. For Group PRESENTATION, the first five trials in each cycle were p-trials and the sixth was a t-trial. For Group TEST, the first trial was a p-trial and the next five were t-trials. Training was such that a t-trial occurred every sixth trial for all three groups. As a result, a 3x3 mixed factorial design was used to examine acquisition performance with the between-subjects variable being Groups (STANDARD, PRESENTATION, TEST) and the within-subjects variable being Trials (6, 12, 18).

The retention segment of the experiment consisted of a single t-trial performed at both 3 min and 24 hr after Trial 18 of acquisition. Performance at Trial 18 was used to evaluate immediate recall accuracy and incorporated into a 3x3 mixed factorial design used to analyze retention. In this design, the between-subjects variable was Groups (STANDARD, PRESENTATION, TEST) and the within-subjects variable was Time

of Recall (Immediate, 3 min, 24 hr). Fifteen subjects were assigned randomly to each of the three groups with the constraint that each group contain the same number of men and women.

A total of 20 movements were performed during the experiment. Each began from a different starting position which varied between 0 and 380 mm from the left end of the apparatus in increments of 20 mm. Variation of movement starting position prevented the use of stopping location as an aid to learning distance. Three random starting position sequences were developed. Five subjects in each group were trained under one of the three sequences.

### Procedure

At the beginning of the experiment, all subjects were instructed to learn and remember distance. They were shown a written copy of the entire p- and t-trial command sequence appropriate to their training group and told the meaning of each command that they would be hearing. The p-trial command was "Movement" and the t-trial command was "Recall Movement." Each of these commands was preceded by "Ready" and followed by "Rest." At "Ready" the experimenter grasped the subject's right hand and placed it on the handle of the slide. Five seconds later, subjects heard either "Movement" or "Recall Movement" depending on their training group. At the "Movement" command, they moved the slide across the linear track at a moderate pace until contacting the mechanical stop. At the "Recall Movement" command, they moved the slide until they felt that they had recalled the correct distance. Five seconds were allowed for execution of p- and t-trial movements. During this interval, white noise was delivered over the earphones to eliminate auditory cues resulting from displacement of the slide. "Rest" marked the start of a 10 sec time interval during which subjects removed their hands from the slide and placed it in a predetermined resting place on the table. It was during rest periods that the experimenter recorded recall accuracy to the nearest mm and repositioned either the slide alone or both it and the mechanical stop in preparation for the next trial. After "Rest" subjects heard "Ready" and the sequence of commands for the next trial began. During the retention segment of the experiment, intervals of 3 min and 24 hr were inserted between "Rest" and "Ready." Subjects were asked not to count while moving the slide and were shown the approximate movement speed (125 mm/sec) desired by the experimenter. Prior to making the first movement subjects donned their blindfold and earphones and were then given an opportunity to move the slide and get a feel for its basic movement characteristics.

### RESULTS

Algebraic (signed) and absolute (unsigned) error scores were recorded for each t-trial performed during the acquisition and retention segments of the experiment. The scores for each segment were analyzed separately.

		ACQUISITION																		RETENTION	
		TRIALS																			
		CYCLE 1						CYCLE 2						CYCLE 3							
		1	2	3	4	5	6/	7	8	9	10	11	12/	13	14	15	16	17	18	3 min	24 hr
STANDARD	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	T
T	P	T	T	T	T	T	P	T	T	T	T	T	P	T	T	T	T	T	T	T	T
P	P	P	P	P	T	P	P	P	P	P	T	P	P	P	P	P	P	P	T	T	T

Figure 1. Trial sequence for each training group (P = Presentation; T = Test)

## Acquisition

Mean algebraic and absolute error scores for acquisition t-trials are shown on the left in Figures 2 and 3. Although each figure depicts the mean scores of all t-trials performed during acquisition, initial statistical analyses were restricted to the scores on those t-trials which coincided temporally for all three training groups, i.e., trials 6, 12, and 18. These scores were analyzed using a Groups (STANDARD, PRESENTATION, TEST) by Trials (6, 12, 18) mixed factorial analysis of variance.

Analysis of algebraic error revealed only a significant main effect of Groups,  $F(2,42) = 3.62$ ,  $p < .05$ . Based on this significant F-value, individual comparisons were made using the least squared difference (LSD) method (Carmer & Swanson, 1973). All comparisons had a rejection region of .05. They revealed that TEST group performance was different from that of the STANDARD,  $LSD(42) = 20.98$ , and PRESENTATION groups,  $LSD(42) = 19.80$ , but that the performance of these latter two groups did not differ. The STANDARD and PRESENTATION groups displayed a significant overshooting bias with  $LSD(42) = 17.58$  and  $16.40$ , respectively, whereas the apparent undershooting tendency of the TEST group was not significant. Visual inspection of Figure 2 reveals that algebraic error differences were already present between groups on the first t-trial of the first cycle and remained essentially unchanged throughout acquisition. Consequently, it could be argued that the obtained differences were probably a function of preexisting response bias differences present among the subjects in each training group rather than the result of differential training. Apart from this apparent response bias difference among groups, no other significant algebraic error effects were found.

Analysis of absolute error revealed a significant main effect of Trials,  $F(2,84) = 4.08$ ,  $p < .05$  and Groups,  $F(2,42) = 4.48$ ,  $p < .05$ . Individual comparisons indicated that the Trials effect was caused primarily by a decrease in absolute error between trials 6 and 12,  $LSD(84) = 8.11$ , as the error decrease between trials 12 and 18 was not significant. The Groups effect was the result of the TEST group having greater error than either the STANDARD,  $LSD(42) = 13.17$  or PRESENTATION groups,  $LSD(42) = 14.29$ . The error for these latter two groups, however, did not differ. Thus, the groups which experienced either p-trial repetition or p- and t-trial alternation during training performed better than the group which experienced t-trial repetition during training. Visual inspection of Figure 3 reveals that the curves of the STANDARD and PRESENTATION groups were similar to one another, while the curve of the TEST group was slightly above the other two and had a serrated appearance. This serrated curve of the TEST group reveals that absolute error tended to increase as t-trials were repeated within each acquisition trial cycle but that this increase was compensated for by a large decrease in error between cycles. To determine the reliability of the within-

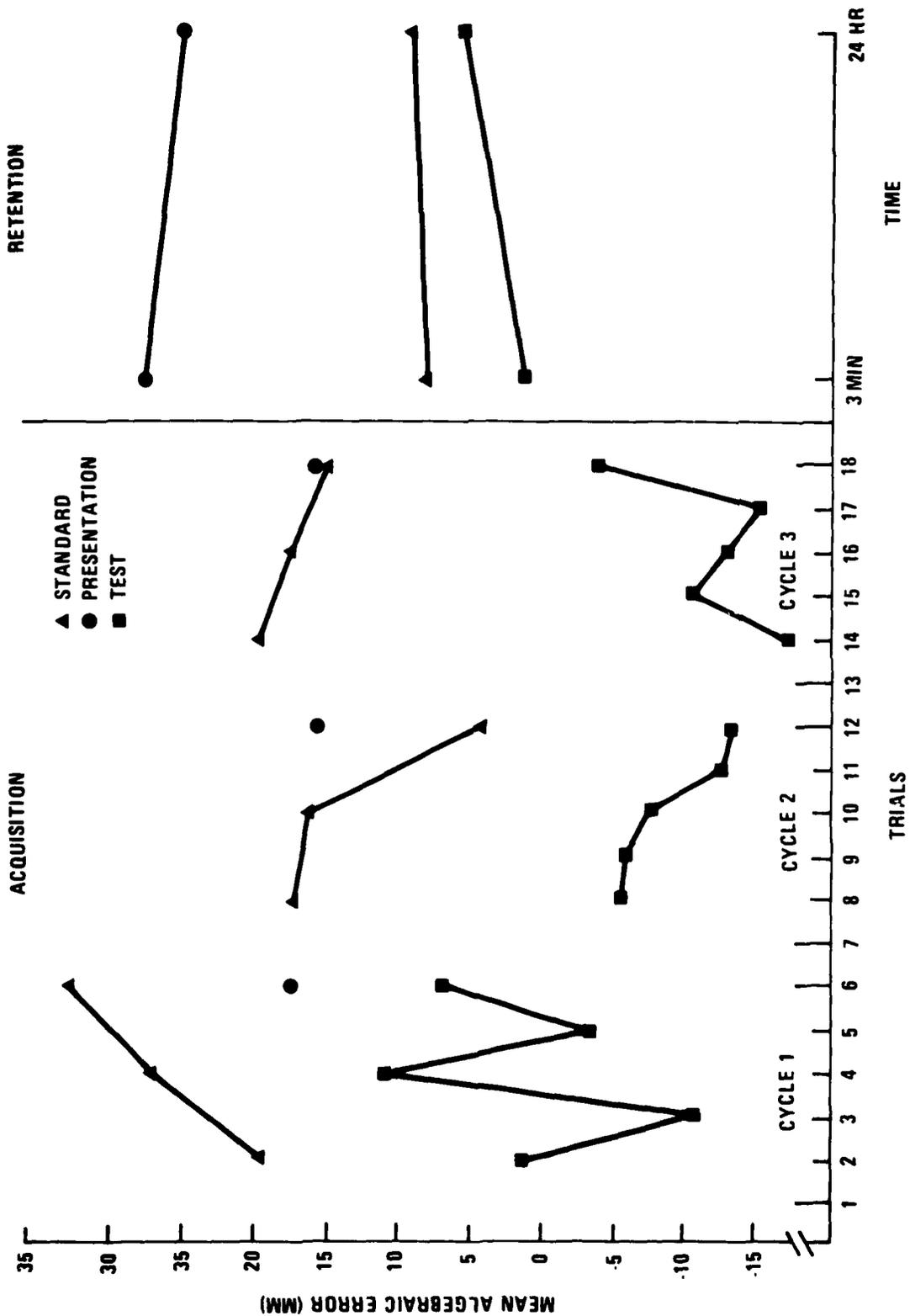


Figure 2. Mean algebraic error resulting from t-trial execution by the STANDARD, PRESENTATION and TEST training groups at acquisition and retention

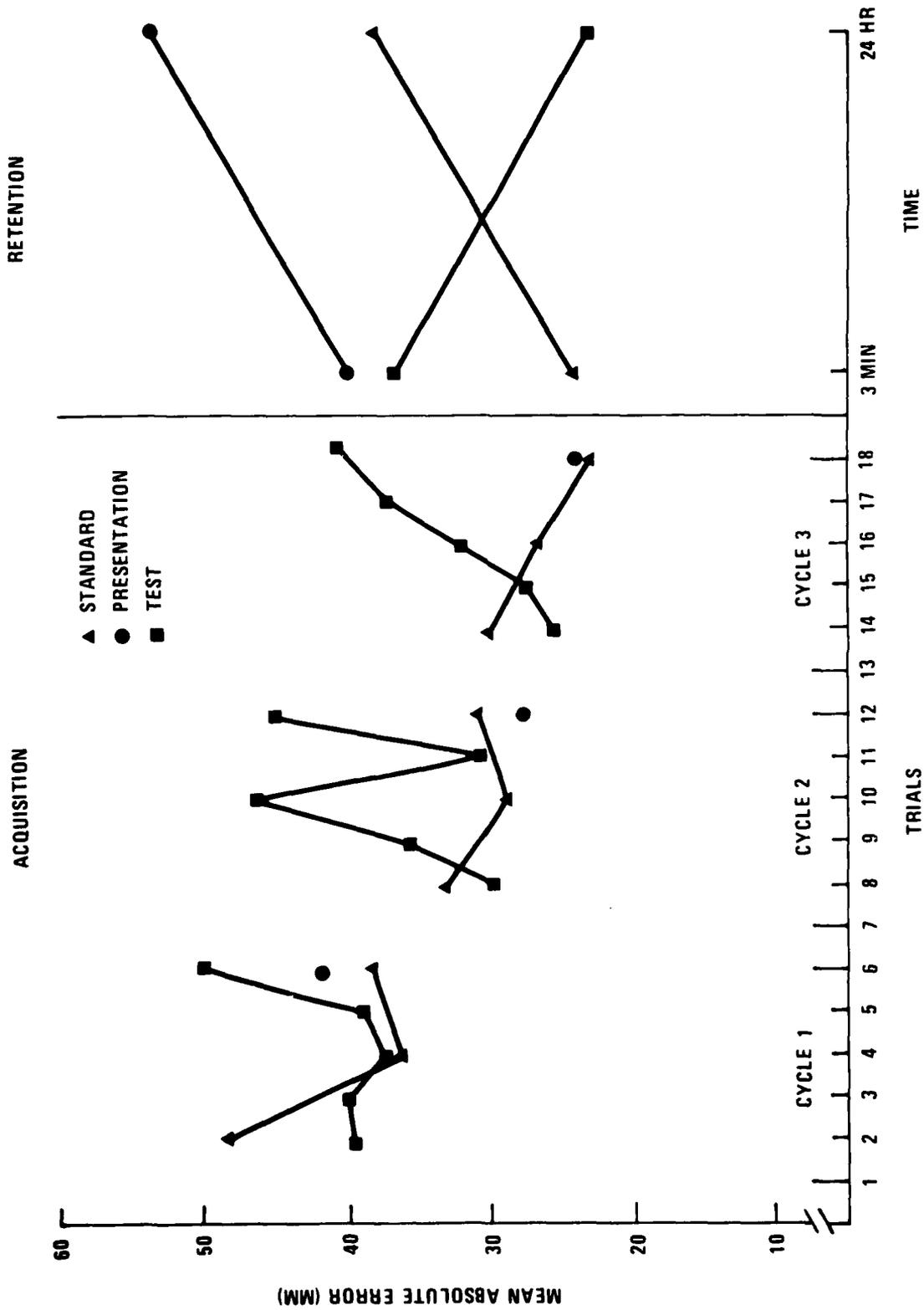


Figure 3. Mean absolute error resulting from t-trial execution by the STANDARD, PRESENTATION and TEST training groups at acquisition and retention

cycle error increase, a Cycle (1-3) by Trials (1-5) analysis of variance was performed on all t-trial scores for the TEST group. As expected, the Trials effect was significant,  $F(4,56) = 4.24$ ,  $p < .05$ . Individual comparisons showed that absolute error increased reliably within cycles and that performance on the last t-trial of each cycle was inferior to that on the first t-trial of each cycle. This within-cycle error increase caused by t-trial repetition is consistent with the results of previous motor (Bilodeau & Bilodeau, 1958; Duffy, et al., 1975) and verbal learning studies (e.g., Bregman & Wiener, 1970) which also have used repeated t-trials during training. To examine the between-cycle decrease in error, group performance was compared before within-cycle error had a chance to materialize for the TEST group. This comparison required the use of an additional Groups by Trials analysis of variance. In this analysis, STANDARD and PRESENTATION group performance at the end of each cycle, i.e., trials 6, 12 and 18, was compared with TEST group performance at the beginning of each cycle, i.e., trials 2, 8 and 14. Although the trials effect was still significant with this analysis,  $F(2,84) = 4.78$ ,  $p < .05$ , the Groups effect was not. The lack of a Groups effect indicated that TEST group error was greater than that of the other two groups only at the end of each cycle after within-cycle error had had a chance to build up. This build up of within-cycle error, however, was somehow compensated for by a decrease in error between cycles. Thus, repeating t-trials during training produced both positive and negative effects on acquisition. The negative effects took the form of increased within-cycle error and the positive effect took the form of decreased between-cycle error. Both of these effects have been reported previously by verbal researchers (e.g., Izawa, 1970; Tulving, 1967).

### Retention

Mean algebraic and absolute error scores obtained during the retention segment of the experiment are shown on the right side of Figures 2 and 3. Retention was examined using a Groups (STANDARD, PRESENTATION, TEST) by Retention Interval (Immediate, 3 min, 24 hr) analysis of variance. Performance at trial 18 was included in the analysis to indicate immediate recall at the end of acquisition trials.

For algebraic error, no significant effects were found although the order of group performance present at the end of acquisition was maintained across retention intervals. For absolute error, a significant Groups by Retention Interval interaction was found,  $F(4,84) = 4.10$ ,  $p < .05$ . As shown in Figure 3, this interaction resulted from an increase in error across retention intervals for the STANDARD and PRESENTATION groups and a decrease in error for the TEST group. Individual comparisons of simple effects revealed that at the end of acquisition (trial 18) the TEST group displayed greater error than either the STANDARD,  $LSD(84) = 19.00$ , or PRESENTATION group,  $LSD(84) = 17.86$ , and that no difference existed between the errors of these latter two groups (i.e.,  $TEST > PRESENTATION = STANDARD$ ). Three minutes after acquisition the only

significant change in group performance was an increase in error for the PRESENTATION group, LSD (84) = 16.07. As a result of this increase, the TEST and PRESENTATION group scores did not differ 3 min after acquisition and their average absolute error was greater than that of the STANDARD group, LSD (84) = 13.83 (i.e., TEST = PRESENTATION > STANDARD). Both the PRESENTATION and the STANDARD group displayed significant error increases between 3 min and 24 hr after acquisition, with LSD (84) = 13.45 and 13.40 for each group, respectively. In contrast, TEST group error decreased significantly over this same time period with LSD (84) = 13.13. As a result, 24 hr after acquisition TEST group performance was superior to that of the STANDARD group, LSD (84) = 13.40 which, in turn, was superior to that of the PRESENTATION group, LSD (84) = 15.80 (i.e., TEST < STANDARD < PRESENTATION). Thus, emphasis on p-trials during training resulted in rapid and extensive retention losses, whereas p- and t-trial alternation enhanced short-term retention while emphasis of t-trial repetition enhanced long-term retention of movement distance.

#### DISCUSSION

The three training methods examined in the present research produced different effects on motor acquisition and retention. During acquisition, performance improved in the usual negatively accelerated fashion when training consisted primarily of p-trial repetition or p- and t-trial alternation. However, when training consisted primarily of t-trial repetition, performance was characterized by increased within-cycle error offset by decreased between-cycle error. Because of the way that performance varied during acquisition when t-trials were repeated, the relative superiority of the three training methods was a function of where their performance was compared during acquisition. When comparisons were made before t-trial repetition had inflated the within-cycle error of the TEST group, no performance differences were found among the three groups. When comparisons were made after the TEST group had completed t-trial repetition, the training methods employing p-trial repetition and p- and t-trial alternation produced superior acquisition performance.

Of particular interest is the question of why t-trial repetition produced both increased within-cycle error and decreased between-cycle error during acquisition. There are at least two reasons for the increased error within cycles. First, subjects may have been attempting to recall an ever-decaying memorial representation of movement distance established at the execution of an earlier p-trial, and as a result, their recall accuracy got progressively worse. This notion is consistent with short-term motor memory research showing that distance information does decay rapidly and cannot be retained over even short retention intervals (e.g., Laabs, 1973). Second, within-cycle error could have increased because t-trial repetition produced interference (Bilodeau & Bilodeau, 1958). Although t-trials are not intended to interfere with retention, they usually are different from the criterion movement, and therefore possess the potential for producing interference (Hagman,

1978). Assuming a positive relationship between the magnitude of absolute error and the number of interfering movements performed, increased within-cycle error could have been a function of the added number of interfering movements afforded by t-trial repetition. Because both decay and interference have adversely affected retention of distance in the past, it is likely that both processes contributed to the within-cycle error increases observed in the present experiment. One way to examine the effect of interference alone would be to perform the same experiment using a movement cue such as stopping location which is affected adversely by interference (Hagman, 1978) but not by decay (Laabs, 1973).

Reasons why t-trial repetition produced such large between-cycle decreases in error are not readily apparent. Researchers in verbal learning have suggested that one function of testing via recall is to enhance a subject's ability to recognize past words recalled (Klee & Gardiner, 1976). Perhaps, the same effect of testing occurs in motor learning. After repeated testing attempts, subjects may know more about their recall performance than those subjects who do not perform repeated testing. Consequently, subjects in the TEST group may have been better able to discriminate their recalled distance from that of the criterion distance and been more capable of making the appropriate adjustments needed for more accurate recall. Although speculative, the notion that increased discrimination ability results from t-trial repetition is consistent with previous motor research (Newell, 1974). In essence, t-trial repetition may serve to potentiate the effect of subsequent p-trials. This type of potentiating effect has been reported to occur in verbal learning (Izawa, 1970) but has only been hinted at in motor learning (Bilodeau & Bilodeau, 1958; Henderson, 1977). Thus, additional research is needed before a firm conclusion can be drawn about the potentiating effects of t-trial repetition in motor learning. One approach might be to vary the number of t-trials repeated prior to p-trial execution. If potentiation does occur, one should find that as the number of repeated t-trials increases performance following a subsequent p-trial should also increase.

To better examine potentiation effects in motor learning, a task more difficult than linear positioning should be chosen. This would reduce the possibility of unwanted ceiling or floor effects influencing the data. In the present experiment, acquisition performance of the STANDARD and PRESENTATION groups tended to flatten out both within and between cycles 2 and 3. Because of this, it was possible that ceiling effects on accuracy prevented future reduction of errors for these two groups. TEST group performance, however, was not near the ceiling at the end of each cycle due to within-cycle error increases, and thus, had ample room for improvement between cycles. By eliminating any possibility of ceiling effects differentially affecting group performance, potentiation could be examined more effectively.

The different influence of p- and t-trial training methods was most evident at retention. Forgetting of distance was rapid and extensive when p-trials were repeated during training. Repetition of t-trials during training, however, retarded long-term forgetting and actually produced improvements in recall accuracy over time. Alternation of p- and t-trials during training prevented short-term retention losses but was not as effective as t-trial repetition in reducing long-term retention losses. Apparently, a greater emphasis on t-trial repetition during training is needed to prevent long-term forgetting of movement distance.

Two questions regarding the retention results need to be discussed. First, why did repeated t-trial training at acquisition cause superior long-term retention of movement distance? And second, why did repeated t-trial training cause improved retention over time? Although it would be premature to suggest any definite answers to these questions before additional research is conducted, some mention of a potential explanatory concept for each question would seem appropriate at this time.

Consider the first question of why did t-trial repetition produce superior long-term retention of distance. A potential answer to this question relies on the distinction between constrained and preselected movement procedures and the types of information available to subjects for processing as a result of executing constrained p-trials and preselected t-trials. Investigators have shown that constrained movements provide subjects with kinesthetic feedback information originating from muscles and joints (Goodwin, McCloskey & Matthews, 1972; Marteniuk & Roy, 1972). Preselected movements, on the other hand, not only provide this kinesthetic feedback but also provide additional information regarding efferent commands given to the muscles (Jones, 1974). Presumably, for accurate efferent-command information subjects must know the movement stopping location in advance (Stelmach, Kelso, & McCullagh, 1976). Hence, in the present experiment accurate efferent information was present only under preselected movement procedures. The presence of efferent information allows subjects to preprogram their recall of distance (Jones & Hulme, 1976) and because of this distance is retained better when performed under a preselected rather than a constrained movement procedure (Kelso, 1977; Stelmach, Kelso & Wallace, 1975). Because of the superior retention characteristics associated with preselected movements, subjects may have relied on retention of their recall performance at t-trials rather than their study performance at p-trials to support later t-trial recall attempts. If long-term retention of t-trial recall performance improves as a function of t-trial repetition as might be expected, then the order of group recall error 24 hr after acquisition would have been as reported (i.e., TEST < STANDARD < PRESENTATION).

One problem with this interpretation is the relatively low error level shown by the TEST group 24 hr after acquisition. If retention of recall performance were a function of prior t-trial repetition, one

might expect a performance error level similar to either the average error level of all prior t-trials or to the error level of the last t-trial of acquisition. Instead, the error level was similar to that of the first t-trial of the last acquisition trial cycle (trial 14). It appears as though TEST group subjects tried to duplicate the recall performance of acquisition trial 14. If so, this would explain their relatively low recall error level. To support this notion, other researchers (Bilodeau, Jones & Levy, 1964) have found that when a series of t-trials follows a p-trial (as in Cycle 3 of acquisition), subjects tend to recall their performance on the first t-trial of the series rather than their performance on either the p-trial or other adjacent t-trials. It is as though t-trial repetition within-cycles produces a form of serial learning task where subjects try to remember their recall performance at each successive trial. Because of the strong primacy effects usually associated with serial motor tasks (Magill & Dowell, 1977), subjects are better able to remember their recall performance on the first t-trial of the series and rely on it for later recall. Additional support for the notion that knowledge of recall performance is better for the initial items of a serial task has been reported for verbal task learning (Klee & Gardiner, 1976; Lockhart, 1975).

A possible answer to the second question of why did TEST group recall performance improve across retention intervals involves the notion of retroactive interference. If the assumption is correct that TEST group subjects did attempt to duplicate their recall performance of acquisition trial 14, then the decrease in absolute error experienced between 3 min and 24 hr after acquisition was caused by the dissipation of retroactive interference. This retroactive interference was generated initially by added acquisition t-trials performed after trial 14 and was of sufficient strength to degrade recall performance both at the end of acquisition and at the 3 min retention interval. However, its strength apparently dissipated thereafter and did not adversely affect retention 24 hr after acquisition. Although dissipation of retroactive interference has primarily been found in verbal retention studies (e.g., Postman, Stack & Fraser, 1968), the general viewpoint that the strength of inter-item interference does change over time has received support in recent motor retention studies (e.g., Wrisberg, 1975).

#### CONCLUSION

In conclusion, the results of the present experiment clarify certain training issues regarding the relative effects of presentation and testing on motor task acquisition and retention. In doing so, they answer the Army's question of which specific training methods most effectively promote the highest levels of skill acquisition and retention.

The results indicate that, first, training methods which either repeat or alternate presentation and testing during acquisition enhance motor acquisition performance. Final acquisition performance is better,

however, when training is conducted using methods which emphasize either repeated presentation or alternation of presentation and testing of the to-be-learned movement rather than its repeated testing.

Second, the primary benefit of repeating testing during training is enhanced long-term retention. Relative to the other two training methods, long-term motor retention is improved substantially by a training method which allows opportunities for repeated testing during acquisition. Thus, the viewpoint that regards testing as merely an opportunity to show what has been learned during presentation is incorrect. Apparently, there are benefits associated with repeated testing which are derived from the additional memorial information generated by the process of active recall. Recall serves to modify memory such that prior recall of memorized motor information facilitates later recall of this same information. This facilitation is greater than that resulting from repeated study of motor information during presentation.

Third, training methods which manipulate presentation and testing opportunities during acquisition have a similar effect on the acquisition and retention of both motor and verbal tasks. This is true, at least, when presentation and test procedures employed during training are similar for both types of tasks.

Fourth, the benefits of repeated testing have been shown for the standard laboratory motor task of linear positioning. Future research should be directed toward answering the question of whether or not these benefits will generalize to other types of motor tasks. Of particular interest should be the examination of procedural motor tasks which require the execution of successive simple motor movements in the correct serial fashion and are characteristic of many motor tasks performed within the Army.

Fifth, and lastly, testing should be viewed as an effective way of enhancing the long-term retention of motor information. This enhanced retention can be achieved by changing the emphasis of training from presentation to testing and would occur without the negative aspects of additional expenditures in training time, money and personnel.

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 1 Medecin Chef, C.E.R.P.A.-Arsenal, Toulon/Naval France  
 1 Prin Scientific Off, Appl Hum Engr Rsch Div, Ministry of Defense, New Delhi  
 1 Pers Rsch Ofc Library, AKA, Israel Defense Forces  
 1 Ministeris van Defensie, DOOP/KL Afd Sociaal Psychologische Zaken, The Hague, Netherlands