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SPECIFICITY OF LEARNING, VARIABILITY OF PRACTICE, AND THE TRANSFER OF MOTOR SKILLS TRAINING

Craig A. Wrisberg and Edward McLean

University of Tennessee, Knoxville

BASIC RESEARCH

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The present study represented an attempt to determine the extent to which transfer performance on a motor timing task is influenced by variability of practice during training and by the similarity of performance conditions between training and transfer phases of performance. All subjects were given trials on a task which involved a linear arm movement, the distance of which was defined by a start button and a hinged target which was knocked over by the subject at the end of the response. During training subjects attempted to produce their movements in a time of 550 msec and were given (Continued)

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knowledge of results regarding timing error after each trial. During transfer trials a 300 msec movement time was attempted and no knowledge of results was given. Half of the subjects trained with one movement distance while the other half trained with three distances. Following training half of the subjects in each group transferred to one new movement distance and the other half to three new distances. The absolute timing error of subjects performing a single distance during transfer trials was significantly lower for those who trained with three distances than for those who trained with one distance. However, there was no difference in the timing error of subjects who transferred to the three-distance arrangement from a one-distance situation and from a three-distance condition. The results suggest that similarity of performance conditions between training and transfer is not a crucial determinant of transfer accuracy on a timing task. Rather it appears that a variety of movement distance experiences during training (e.g., throwing hand grenades different distances, performing bayonet lunges which vary in length, executing finger jab movements at targets located in different places) offers the best circumstances for accurate transfer to an unpracticed movement distance - movement time combination (e.g., a shorter, faster bayonet lunge).

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Personnel Performance and Training

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FOREWORD

The Basic Research Program within the Army Research Institute is intended to fill in gaps in behavioral and social science methodology in order to create a cumulative behavioral science knowledge base on which to build new technologies for improving the effectiveness of Army personnel. The Office of Basic Research identifies the concepts and explores new technologies which offer the greatest potential for transition to applied research on the problems facing the Army. Basic research is underway in areas where the payoff to the Army appears highest. One area of special interest is motor skill training. This report presents the results of research on the transfer of motor skill training and the effects of variability of practice and performance conditions. It examines the similarity of performance conditions between training tasks and the corresponding effect on transfer accuracy. These and other previous findings from research efforts within the Training Research Lab are being combined to form the technology base for improving training and training management effectiveness within the Army.

EDGAR M JOHNSON
Technical Director

SPECIFICITY OF LEARNING, VARIABILITY OF PRACTICE, AND THE TRANSFER OF MOTOR SKILLS TRAINING

EXECUTIVE SUMMARY

Requirement:

To determine the extent to which the accuracy of transfer performance on a novel timing task is influenced by variability of practice during training and by the similarity of performance conditions (i.e., similar instructions, task requirements, etc.) between training and transfer phases of performance; to suggest potential application of the findings in the training of military personnel in order to promote more effective transfer of motor skills essential for combat readiness.

Procedure:

Two hundred male righthanded subjects were randomly assigned to one of two training conditions and received 150 trials on a motor timing task. The task involved the execution of a ballistic horizontal arm movement from a start switch to a hinged and padded target. On each trial during the training phase subjects in the constant practice condition attempted to move a distance of 73 cm in a time of 550 msec. Subjects assigned to the varied practice condition were given an equal number of trials with each of three movement distances (73, 88, 103 cm). For these subjects a single movement distance was repeated throughout a 10-trial block with the order of presentation of the blocks randomly determined except for the last block which involved the 73 cm distance. Knowledge of results in terms of the deviation (msec) from the 550 msec criterion movement time was given following each training trial. Half of the subjects in each condition were then transferred to a task arrangement similar to that experienced during training (i.e., one distance to one distance or three distances to three distances) and half were transferred to the opposite arrangement (i.e., one distance to three distances or three distances to one distance). All subjects attempted to produce a movement time of 300 msec on each of 30 transfer trials and no knowledge of results was given. Subjects transferring to one distance moved a distance of 58 cm on each trial while those transferring to three distances (28, 43, 58 cm) performed a 10-trial block with each distance.

Findings:

The absolute timing error of subjects performing a single distance during transfer trials was significantly lower for those who trained with three distances than for those who trained with one

distance. However, there was no difference in the timing error of subjects who transferred to the three-distance arrangement from a one-distance situation and from a three-distance condition.

Utilization of Findings:

The similarity of performance conditions between training and transfer phases of performance on a closed motor timing task (e.g., throwing a hand grenade at a target, performing bayonet lunges of a particular distance, timing the execution of a finger jab in hand-to-hand combat situations) does not appear to be a crucial determinant of transfer accuracy. Rather, the results suggest that a variety of movement distance experiences during training on a timing task (e.g., throwing grenades different distances, performing lunges which vary in length, executing jabs at targets in different locations) offers the best circumstances for accurate transfer to, at least, a single unpracticed movement distance-movement time combination (e.g., a shorter, faster bayonet lunge).

SPECIFICITY OF LEARNING, VARIABILITY OF PRACTICE, AND THE TRANSFER OF MOTOR SKILLS TRAINING

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Specificity of Learning, Variability of Practice, and the Transfer of Motor Skills Training

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A fundamental purpose of skill learning sessions is to provide the trainee with the capabilities to handle the demands of task situations similar to those experienced during training. If accurate decisions regarding the exact nature of training sessions are made, the efficiency of learning should be increased and the cost of training (and/or retraining) decreased.

In the field of motor skills, two theoretical viewpoints have dominated discussion of the issue of the structure of training sessions. The first viewpoint, formulated by Henry (1968), is known as the specificity of learning hypothesis. According to this hypothesis the best way to teach a person to perform a particular task is to give that person repeated practice under conditions which represent the exact demands of the task. In the way of a military example, a person being taught to throw a hand grenade at a single stationary target should, according to the specificity principle, be given a learning experience involving a) the exact throwing motion (as opposed to motions used in activities like throwing a ball or hurling a discus), b) actual hand grenades (not a weighted object of a different shape), and c) a single stationary target (rather than a variety of target locations or a target which is moving). On the other hand, a person being taught to throw grenades at a variety of fixed targets should, according to the specificity of learning principle, be given a training experience involving a variety of throwing motions needed to rest between Trials 50 and 51 and again betwen Trials 100 and 101.

Following training, half of the subjects in each group were transferred to a single-distance situation and the other half to a multiple-distance situation. All subjects were given 30 transfer trials without knowledge of results in which they attempted to produce a movement time of 300 msec. Subjects who transferred to one new distance moved 58 cm on each trial while subjects transferring to three new distances (28, 43, 58 cm) performed a 10-trial block with each distance. The order in which the blocks were presented was randomized across subjects. A two-minute rest was interpolated between training and transfer phases of the experiment and an intertrial interval of 10 sec was used during transfer trials.

Results

Dependent Measure

The dependent measure of interest was absolute error (AE) which was the absolute difference (in msec) between actual and desired movement times on each trial. In order to assess the effect of training under one-distance and three-distance conditions on transfer performance in one- and three-distance situations, the mean AE for the 30 transfer trials was calculated for each subject.

Statistical Analysis

Separate t-tests of differences between independent group means (Sokal & Rohlf, 1969) were performed for subjects transferring to the single distance situation and the multiple distance situation. In each case, the mean transfer score of subjects who trained under

Figure 5. Subject Contacting the Target at the Completion of the Timing Movement.

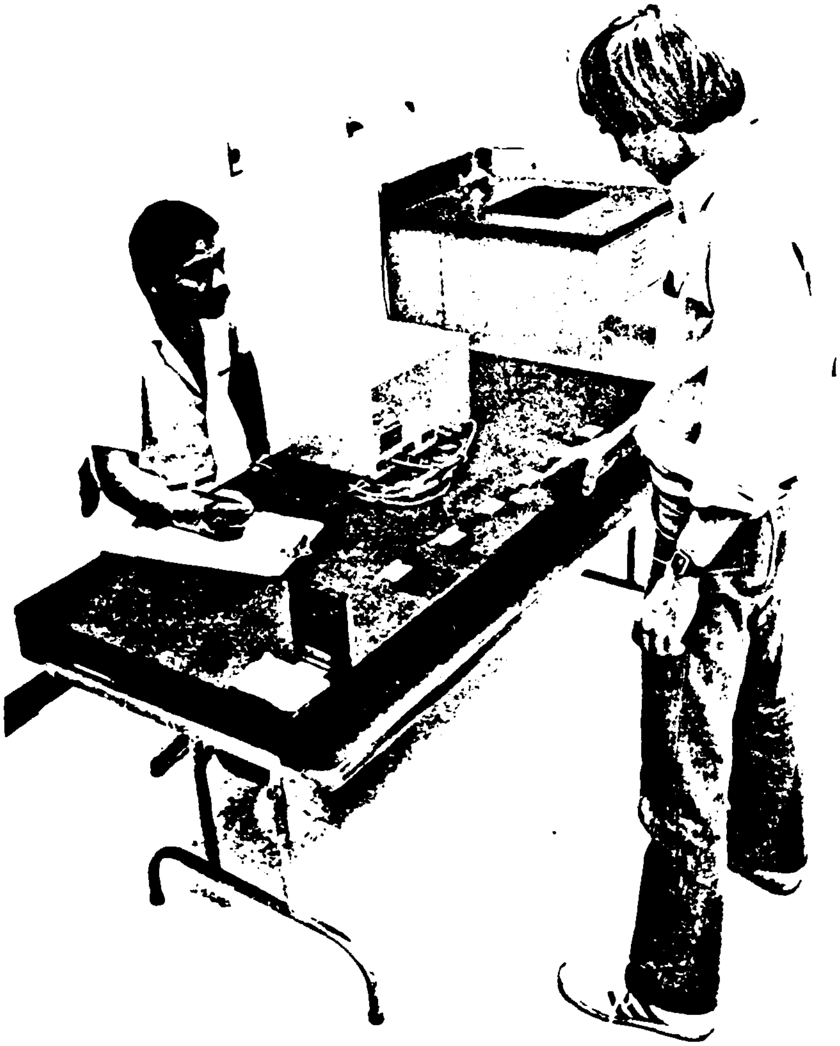

Figure 4. Subject Standing at the Apparatus in the "Ready" Position.

Table 1. Experimental Design

Training Phase		Transfer Phase	
Distance (cm)	Time (msec)	Distance (cm)	Time (msec)
73	550	58	300
73	550	28,43,58	300
73,88,103	550	58	300
73,88,103	550	28,43,58	300

Procedure. The experiment was comprised of two phases, a training phase and a transfer phase (Table 1). On all trials subjects were instructed to produce a particular movement time over a designated movement distance. The subject stood facing the response platform with the target situated to his left. During training all subjects attempted to execute their movements in a time of 550 msec. Trials were initiated with the experimenter verbally designating a particular start switch (this defined the movement distance for the trial) which the subject subsequently depressed with the index finger of his right hand (Figure 4). When ready, the subject then made a ballistic right to left arm movement from the start switch, knocking down the hinged target in as close to a time of 550 msec as possible (Figure 5).

Following each training trial the experimenter verbally reported the subject's actual movement time (in msec) and then indicated whether it was shorter or longer than the desired criterion time. All subjects received 150 training trials with knowledge of results. Subjects receiving constant practice (i.e., one movement distance) during the training phase performed all of their trials with a distance of 73 cm while subjects receiving varied practice performed a quasi-random arrangement of 10-trial blocks in which a single movement distance (73, 88, or 103 cm) was repeated throughout the block. All varied-practice subjects received an equal number of training blocks with each distance. In addition, no distance was repeated on consecutive blocks and all varied-practice subjects received the 73 cm distance on their last block of training trials. An intertrial interval of 10 sec was used throughout the training phase with a two-minute

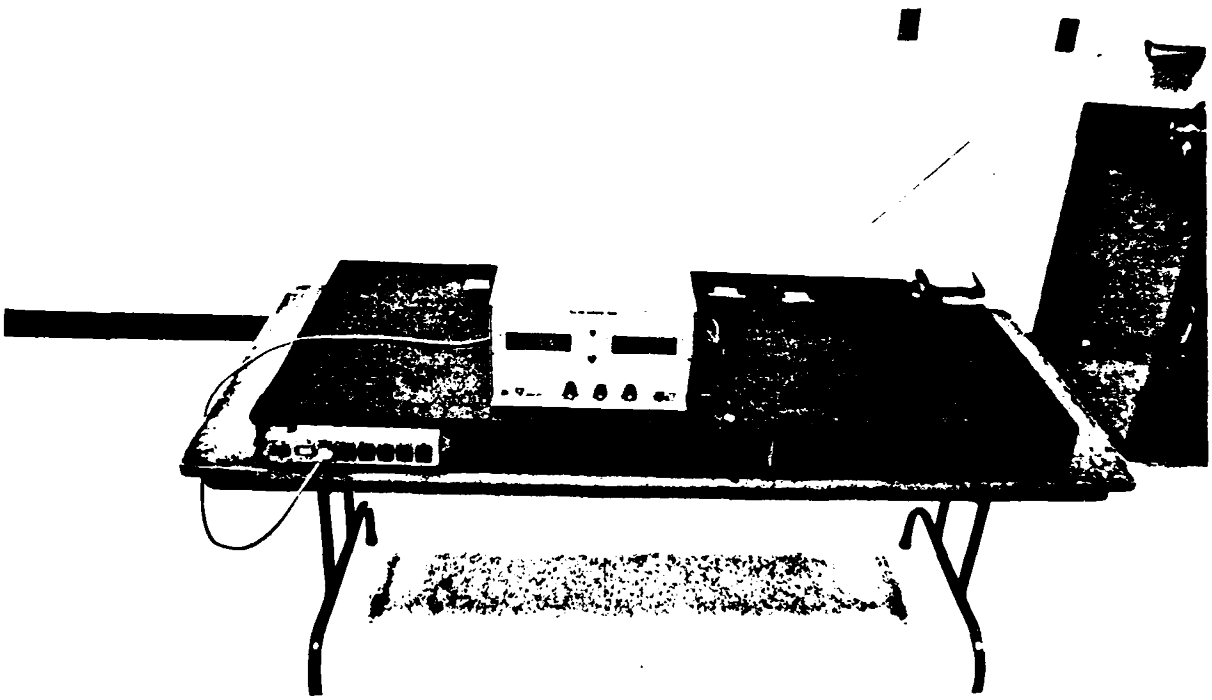

Figure 3. Experimenter's View of the Apparatus with the Hinged Target (Upper Right) Knocked Over.

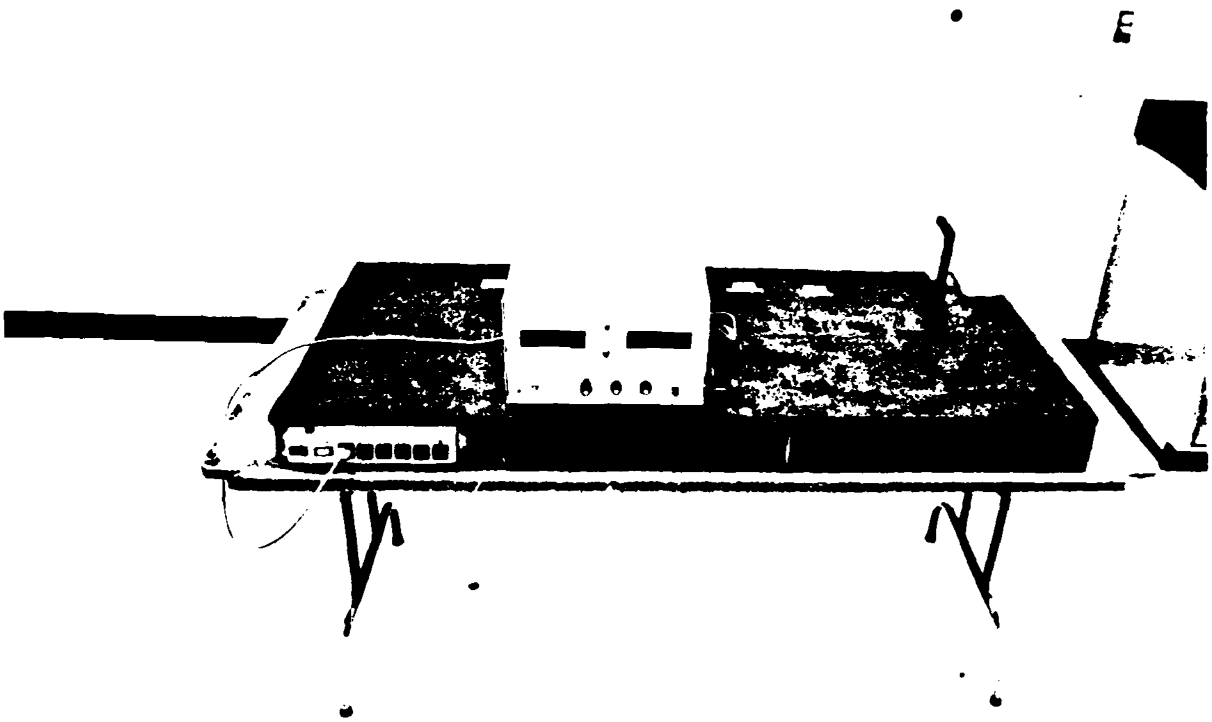

Figure 2. Experimenter's View of the Apparatus with the Hinged Target (Upper Right) in the Vertical Position.

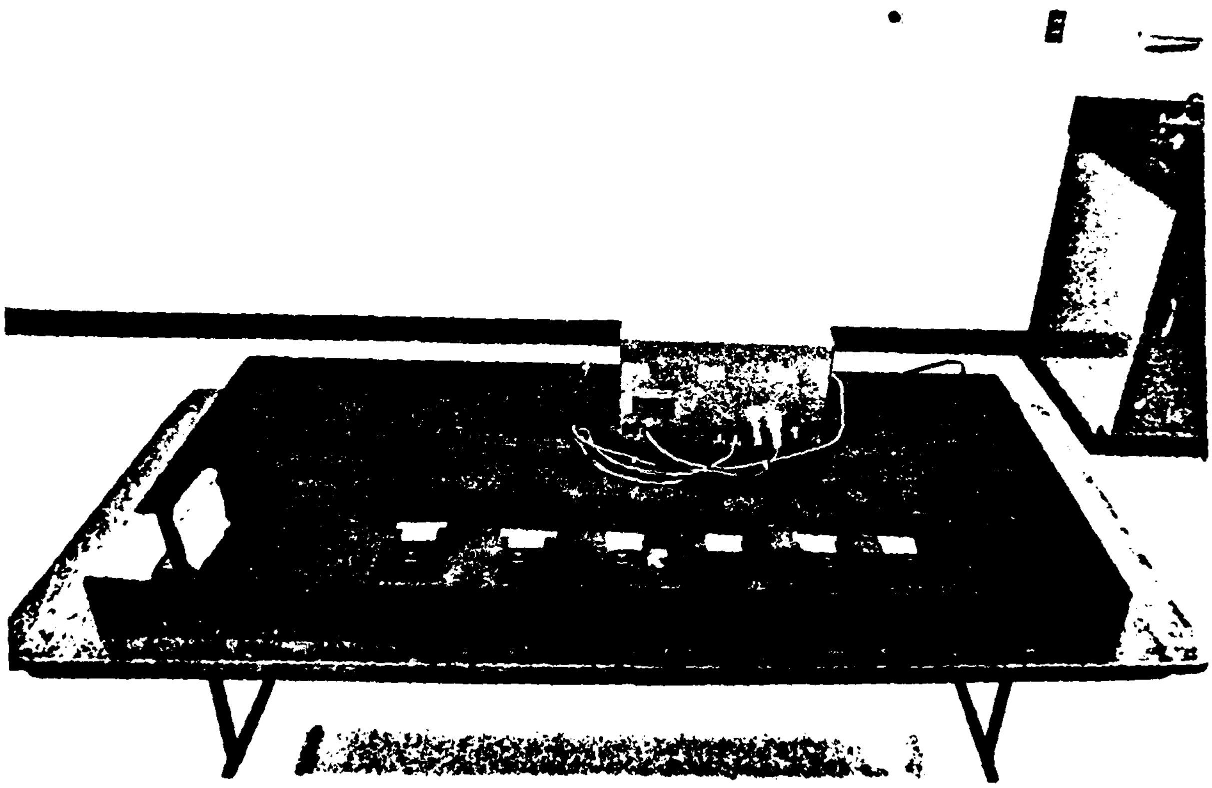

Figure 1. The Experimental Apparatus

practice situation. However, if varied practice (Schmidt, 1975) is the preferred training strategy for all transfer situations, then it would be expected that the timing accuracy of subjects trained under varied-practice conditions would be superior to that of subjects trained under constant-practice conditions for both the single movement and the multiple movement transfer situations.

Method

Subjects. A total of 200 male righthanded subjects participated in the experiment. All of the participants were students at The University of Tennessee - Knoxville, ranging in age from 19 to 28 years. None of the subjects was familiar with the apparatus and all were paid for their participation.

Apparatus. Six microswitches and a hinged and foam-padded plywood target (11 x 13 cm) were attached to a platform which was mounted on top of a large table (Figure 1). The microswitches (2 x 2 cm) were separated by a distance of 15 cm and mounted along a line parallel to and 18 cm from the edge of the table. The distance from the target to the first microswitch was 28 cm and to the second, third, fourth, fifth, and sixth microswitches 43, 58, 73, 88, and 103 cm, respectively. A Reaction-Movement Timer (Lafayette Instruments #62017) was interfaced with the response system and the digital display was turned to face the experimenter. When the target was in the vertical position (Figure 2) it depressed a set of contact points. Time began to accumulate on the timer when the subject released one of the microswitches and stopped when the target was knocked over, opening the contacts (Figure 3).

Conversely, if the production of several novel movements was required during transfer, subjects trained under varied-practice conditions might be expected to construct those new movements with greater accuracy than would subjects who learned under constant-practice conditions. Some suppport for the notion that varied-practice during training would more likely manifest itself in superior transfer performance in a varied, rather than a constant movement situation has been suggested from the results of a study by Shea and Morgan (1979). In this study a task was used which required subjects to minimize movement time in the production of arm movements which followed a variety of spatial patterns. It was found that subjects who trained in a varied-context situation moved significantly faster than constant-context-trained subjects on both a constant-context and a varied-context retention test, with the difference being much more pronounced on the latter test.

The purpose of the present investigation was to determine the extent to which specificity of learning (Henry, 1968) and variability of practice (Schmidt, 1975) facilitate transfer to single response and multiple response situations. If similarity between training and transfer conditions is important (i.e., specificity) then subjects trained in a constant-practice situation would be expected to demonstrate superior transfer to a single novel version of the movement than would subjects trained in a varied-practice situation. Similarly, subjects trained under varied-practice conditions would be predicted to demonstrate superior transfer to a variety of novel movement versions than would subjects who trained in a constant-more clearcut support for the theory might be due to a diminished specificity of task conditions between training and transfer phases of performance for subjects who initially were given varied practice. In other words, the task and/or situational demands during transfer always involved the repetition of a single new version of the movement. In light of earlier discussion of the rationale for the specificity of learning hypothesis (Henry, 1968) it might be contended that a person who would eventually be asked to repeatedly produce a single timing movement would benefit more from a training regimen which involved the repeated production of a similar version of the movement than from one involving the practice of a variety of movement versions. The former type of training was, in fact, what constant-practice subjects were receiving and the latter what varied-practice subjects received in the earlier studies.

Jenkins (1977) has proposed that the learning context is an important determiner of the way memory is constructed, and therefore of what material/strategies are retained for future use. It seems plausible therefore that memory development which involves the repeated rehearsal of a single movement version (i.e., constant practice) would require a strategy which is different than that used to develop memory for a variety of related movements (i.e., varied practice). Moreover, constant-practice subjects and varied-practice subjects might be expected to approach transfer performance in different ways. For example, if a single new movement version was to be performed during transfer, subjects trained under constant-practice conditions might be predicted to adapt to that situation with greater ease than would subjects trained under varied-practice conditions.

(Newell & Shapiro, 1976) or distances (McCracken & Stelmach, 1977; Zelaznik, 1977) during training while constant-practice subjects were given only one time (or distance). All subjects were then transferred to a time (or distance) which neither group had performed during training.

The results of these studies suggest some support for Schmidt's (1975) variability of practice prediction. McCracken and Stelmach (1977) reported significantly more accurate transfer to a novel movement distance for varied-practice than for constant-practice subjects. However, Newell and Shapiro (1976) found that transfer was more accurate for varied-practice subjects only when the novel movement time was a) outside the range of times practiced during training, and b) represented the slowest in a systematic progression of movement times attempted (i.e., transferring to a movement time of 180 msec following consecutive training with 70 and 130 msec movement times, respectively). Neither Zelaznik (1977) nor Wrisberg and Winter (1982) found significantly more accurate transfer for varied-practice subjects. An important methodological consideration in the latter two studies was the use of a transfer movement with task requirements which were very similar to those of the movement practiced by constant-practice subjects during initial learning. Such similarity of training and transfer movements for constant-practice subjects would be expected to diminish the probablility of superior transfer performance by varied-practice subjects.

Closer inspection of the paradigm used in tests of Schmidt's (1975) variability of practice hypothesis suggests that the lack of performance conditions, movement requirements, sensory feedback, and goal achievement), the learner develops rules for moving (i.e., the schema) which go beyond the details of any specific movement to emphasize the general structure of, or interrelationships within, the movement class. From Schmidt's viewpoint, throwing a grenade to a single unpracticed transfer target or to a variety of unpracticed targets should occur with the highest accuracy for the trainee who threw to a variety of target locations during initial learning.

The majority of experimental studies conducted to test Schmidt's (1975) theory have utilized discrete, closed timing tasks in which subjects are required to make a linear arm movement of a prescribed distance, attempting to produce the movement in a criterion time (McCracken & Stelmach, 1977; Newell & Shapiro, 1976; Wrisberg & Winter, 1982; Zelaznik, 1977). Typically, microswitches are used to mark the beginning and end points of the movement and movement time is defined as the time it takes to move between the two points; although the momentum of the movement always carries the limb past the finish point. The experimental paradigm adopted by these researchers includes a training phase, involving either constant or varied practice conditions, and a transfer phase in which a single "novel" (i.e., not previously practiced) version of the movement is performed. Knowledge of results are provided during the training phase but not the transfer phase. In all but one study (Wrisberg & Winter 1982), "versions" of the movement were defined by variations in either movement time or movement distance (one group of varied-practice subjects in the aforementioned study received variations in both movement time and movement distance). Varied-practice subjects received a variety of times project the grenade to targets located at various distances and angles from the thrower.

Experimental support for the specificity of learning hypothesis has primarily come from correlational studies which have revealed a low relationship between the level of performance proficiency on two different tasks (Bachman, 1961; Drowatsky & Zucatto, 1967; Henry, 1961; Lotter, 1960; Parker & Fleishman, 1960; Singer, 1966). For example, Bachman (1961) correlated the performance of a variety of subjects (classified by age and gender) on two different types of balancing tasks and found most correlations to be very close to zero, with the highest being only +.25. Such results seem to be in line with Henry's (1968) specificity of learning hypopthesis and suggest that the learning of a task which has demands which are not similar to those of a second task should not be expected to facilitate transfer to performance on the second task.

More recently, a second view as to the best way to structure motor skill training situations has received theoretical expression. According to Schmidt's (1975) schema theory, skill learning involves the development of rules governing the accurate production of movements of a particular class rather than the storage in memory of specific versions of the movement. According to this view, transfer to any new situation in which a particular class of movements might be performed (e.g., throwing a grenade to either a single target location or to a variety of locations), will be best facilitated by a training experience which requires variability of practice. Schmidt (1975) contends that by experiencing variety during training (with respect to constant-practice (i.e., one distance) conditions was compared to that of subjects who trained under varied-practice (i.e., three distance) conditions.

The mean AE's for these two comparisons are presented in Figure 6. For subjects transferring to the single distance situation, those who trained with three different distances had significantly lower AE ($\overline{X}$ = 60, SD = 27) than did subjects who practiced one distance during training ($\overline{X}$ = 79, SD = 39), $t(98) = 2.81$, $p < .01$. Not surprisingly, the errors of subjects transferring to three distances were higher than those of subjects who transferred to one distance. However, mean AE in the three-distance transfer situation was not significantly different between subjects who trained with one distance ($\overline{X}$ = 88, SD = 45) and those who trained with three distances ($\overline{X}$ = 88, SD = 43), $t(98) = 0.00$, $p > .05$.

Discussion

According to Henry's (1968) specificity of learning hypothesis, the best way to facilitate transfer from one motor skill situation to another is to construct a training situation which is as similar to the transfer situation as possible. Schmidt (1975), on the other hand, advocates training situations which provide variability of movement experiences. Such training presumably promotes the development of rules (i.e., the schema) governing a particular class of responses. According to Schmidt, training under varied-practice conditions will facilitate the production of novel movements performed in situations which may be either similar to or different from the

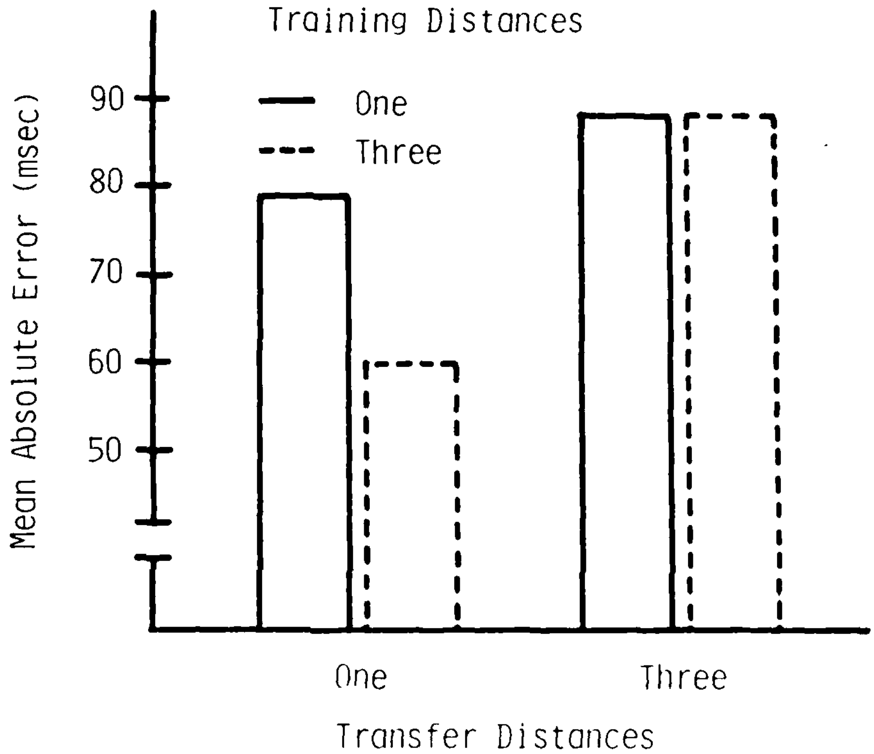

Figure 6. Mean Absolute Error During the Transfer Phase of Performance for Each of the Four Combinations of Training Distances (One or Three) and Transfer Distances (One or Three).

training situation. The present study represented an attempt to determine the relative influence of specificity of learning and variability of practice in the transfer of motor skills training.

The results of this study fail to support the hypothesis that similarity of conditions between training and transfer phases of practice (Henry, 1968) is essential for accurate transfer of training in a closed timing task. Specifically, subjects in this study who transferred to a one-distance situation performed with higher accuracy if they were trained in a three-distance situation than if they practiced one distance during training. This result agrees with that of McCracken and Stelmach (1977) and represents support for Schmidt's (1975) variability of practice hypothesis. That this finding fails to concur with earlier results (Wrisberg & Winter, 1982; Zelaznik, 1977) showing no superior transfer by varied-practice subjects on a new movement distance is probably due to the fact that constant-practice subjects in those studies performed a training movement which was practically the same (at least with respect to movement velocity) as the transfer movement. Thus, for constant-practice subjects in those studies, performance of the transfer movement may have seemed like continued practice with the training movement.

The present findings more importantly suggest that transfer benefits which accrue due to varied movement experiences during training are the result of something other than the similarity of practice conditions between training and transfer phases of performance. Schmidt (1975) contends that increased variability of practice promotes the *abstraction of a relationship* among four sources of movement-related information (initial conditions, response specifications, sensory feedback, and response outcomes). In the theoretical tradition of Bartlett (1932), Schmidt portrays a constantly-developing memorial structure which at any point in time represents the performer's best estimate of the general rules or abstraction of a class of movements. Thus, it might be suggested that subjects in the present study who trained with three distances learned more about the rules governing timing responses than did subjects who trained with one distance. Thus, when the production of a new distance-time combination was required in the transfer phase, subjects with the "better rules" or stronger abstraction were able to more accurately produce that movement.

In a similar vein Battig (1978) has proposed that practice which is high in contextual interference (or variability) forces subjects to use multiple strategies which presumably results in more elaborate processing of information. According to Shea and Morgan (1979) such elaboration is presumed to increase the flexibility of memorial structures which are responsible for movement initiation and control. Future researchers will need to operationally distinguish between the concepts of "abstraction" (Schmidt, 1975) and "elaboration" (Battig, 1978) in order to determine which view, if either, best describes memory development.

What then can be said about the finding of no superior transfer to the three-distance situation by subjects who trained under three-distance (i.e., varied practice) conditions? This result conflicts with that of Shea and Morgan (1979) who found significantly higher transfer by subjects trained in a varied-context situation when they were asked to perform two novel spatial versions of a movement-speed task. However, it might be argued that moving as fast as possible during the production of two novel spatial patterns is considerably less difficult than producing a new movement time for three previously-unpracticed movement distances. Thus, it is suggested that for the type of timing task used in the present study, 150 trials may have represented insufficient training to allow varied-practice subjects to more accurately produce three novel versions of the movement.

It should be noted that the results of the present study further suggest the potential for variation of spatial parameters during initial acquisition of a timing movement. McCracken and Stelmach (1977) found superior transfer to an unpracticed movement distance by subjects who performed various distances during training on a timing task. In the present study subjects transferring to the single distance situation were required to produce both a new movement distance and a new movement time. Those who trained with a variety of movement distances transferred to the new combination with greater accuracy than did subjects given only one distance during training. Both Lordahl and Archer (1958) and Wrisberg and Winter (1982) reported that variations in the spatial parameters of a timing task caused less difficulties for subjects than did temporal variations. Moreover, the results of a study by Fleishman and Rich (1963) suggest that spatial factors (e.g., movement distance, directional shifts, etc.) may be more important during the early stages of skill acquisition than at a later stage of practice. Most of the studies which have tested Schmidt's (1975) theory by manipulating the spatial parameters of a timing task have varied movement distance (McCracken & Stelmach, 1977;

Wrisberg & Winter, 1982; Zelaznik, 1977). An exception is the work of Ragsdale (1981) which involved variations in the spatial pattern of a closed timing movement during training. When transferred to a novel pattern subjects who received varied-pattern training performed with significantly higher accuracy than did those who trained with only one pattern. Clearly, further work is needed to define the types of spatial variation which promote the development of memory for rapid timing movements.

The practical implication of the results of the present study is that for closed timing tasks (e.g., throwing hand grenades at stationary targets, executing finger jab movements in a hand-to-hand combat situation, performing bayonet thrusts) variation in movement distance during training may facilitate skill development and provide the trainee with the type of memory which allows more accurate adaptation to an unpracticed situation requiring the execution of a new version of the movement (e.g., throwing to a target located a different distance from the thrower or executing a different-length jab or thrust). Future work is needed to determine whether training which involves the variation of spatial parameters other than movement distance (e.g., hurling grenades using a variety of throwing motions or performing jabs or thrusts at targets located at a variety of angles from the subject) promotes accurate transfer to unpracticed spatial versions. Moreover, it remains to be determined what the amount or length of varied-practice training should be in order to facilitate transfer to more than a single unpracticed version of a timing movement. Answers to these and other similar questions should assist decision makers in the development of guidelines for the most efficient motor skills training of military personnel in the future.

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