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I am submitting herewith a thesis written by Susan K. Lynn entitled "The Effect of Withdrawal of Knowledge of Results on Performance of Movement at Different Speeds." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Physical Education.

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THE EFFECT OF WITHDRAWAL OF KNOWLEDGE OF RESULTS
ON PERFORMANCE OF MOVEMENT
AT DIFFERENT SPEEDS

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S.K.L.

ABSTRACT

The present study addressed the extent to which KR, its initial presence and later withdrawal, influenced the learning of a motor skill performed at different speeds.

Forty eight right handed female students served as subjects for this study. Prior to the first day of testing, each subject was randomly assigned to one of four movement speed conditions. All subjects attempted to produce a 70 centimeter movement from a start button to a padded target. The four criterion times were established at 250, 500, 1000, and 2000 milliseconds, thus producing respective speeds of 280, 140, 70 and 35 cm/second. All subjects received 5 practice trials (Trials 1-5) with KR (error and direction in milliseconds), 40 trials (Trials 6-45) with KR, and then 40 trials (Trials 45-85) without KR.

Deviations from the criterion target were recorded (with respect to sign) to the nearest millisecond. The raw movement time data were converted into three dependent variables: (1) absolute error (AE), (2) constant error (CE), and (3) variable error (VE) scores. Analysis of variance was used to analyze the data. A Newman-Keuls post hoc test was administered where appropriate to examine all significant differences.

The results indicated that during practice with KR, performance accuracy (AE) and consistency (VE) significantly improved for all speed groups ($p < .01$). When KR was withdrawn consistency remained fairly constant however accuracy diminished significantly for all speed groups ($p < .01$) which indicated that subjects were unable to improve their performance without KR. The results also revealed that the faster movements, those at movement times of 250 and 500 milliseconds with respective speeds of 280 cm/second and 140 cm/second, were more accurate and more consistent than were the groups with slower criterion movement times of 1000 and 2000 milliseconds with speeds of 70 cm/second and 35 cm/second, respectively. From this analysis of CE, the results indicated that subjects with the slowest movement time criterion, 2000 milliseconds, with a speed of 35 cm/second, had the most erratic periods of bias, moving from the greatest extremes early to the greatest extremes late when KR was given and performance remained almost as erratic when KR was withdrawn.

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CHAPTER I

INTRODUCTION

One of the most important questions in the field of motor learning concerns what variables influence the acquisition of a motor task. For many years it has been concluded that some form of external error information must be available to the performer in order for the acquisition of a motor skill to occur. This external error information has typically been thought of as knowledge of results (KR) and has been presented as the discrepancy between the desired and the obtained response (Adams, 1971; Bilodeau, 1966).

Schmidt (1975a), in his schema theory of discrete motor skill learning, refers to KR as information which is provided by the experimenter concerning the subject's success. Another major motor learning theorist, Adams (1971) defines KR as "a source of information which results in corrections that eventually leads an individual to a correct response" (Adams, 1971, p. 122). KR is thought to be a function of error, and it can be of any precession e.g., qualitative or quantitative (Trowbridge and Cason, 1932). Adams (1971) viewed the learning of a motor task as a problem to be solved where the subject, over a series of trials with combinations of movement and information in the

form of KR, attempted to solve the problem. Adams (1971) reported that in order for learning to occur the subject used KR to correct errors and to make each response different from previous ones.

Studies investigating the performance of slow movements, lasting longer than 200 milliseconds (Schmidt, 1975a) have reported that when KR was given to the subject after each trial improvement in performance or learning occurred.

(Bilodeau & Bilodeau, 1958; Bilodeau, Bilodeau and Schumsky, 1959; Schumsky, Grasha & Seymann, 1966). However, these studies reported immediate decrements in performance when KR was withdrawn (Baker and Young, 1961; Bilodeau and Bilodeau, 1958; Schumsky, Grasha and Seymann, 1966).

Studies dealing with the performance of rapid movements, defined as movements less than 200 milliseconds (Schmidt, 1975a) have reported the same conclusion concerning learning with KR as did studies investigating the performance of slow movements. The results indicated that when KR was given to the subject after each trial, improvement in performance or learning occurred (Newell, 1974; Newell and Chew, 1974; Schmidt and White, 1972). However, studies dealing with the learning of rapid movements have reported a maintained level of performance following the removal of KR (Newell, 1974; Newell and Chew, 1974; Schmidt and McCracken, 1974; Schmidt and White, 1972; Schmidt and Wrisberg, 1973; Williams and

Roy, 1972). It therefore appears that performance maintenance following the withdrawal of KR is different for rapid versus slow motor tasks. However, no research has been conducted which independently manipulated speed of movement in order to determine its influence on learning with KR and after withdrawal of KR. Thus, the problem statement from the present study addressed the extent to which KR, its initial presence and later withdrawal, influenced the learning of a motor skill performed at different speeds.

I. STATEMENT OF PROBLEM

It was the intent of this study to determine for college age women if there was an effect on the performance of a discrete movement by (1) the speed of movement expected and/or (2) practice with KR presented initially and then withdrawn.

The following specific hypotheses were tested in the present study:

1. The criterion speed of the response has no effect on the (a) performance accuracy as measured by absolute error, (b) performance consistency as measured by variable error, and (c) performance bias as measured by constant error.

2. The performance across eight blocks of ten trials each, with KR provided on the first four blocks and

withdrawn on the last four blocks has no effect on (a) performance accuracy as measured by absolute error, (b) performance consistency as measured by variable error, and (c) performance bias as measured by constant error.

3. The pattern of performance across eight blocks with KR provided on the first four blocks and withdrawn on the final four blocks, and the criterion speed of the response have no effect on (a) performance accuracy as measured by absolute error, (b) performance consistency as measured by variable error, and (c) performance bias as measured by constant error.

II. LIMITATIONS OF STUDY

The study was limited to female students enrolled in service classes at The University of Tennessee, Knoxville, Spring Semester, 1979. It was also limited to four criterion movement times at 250, 500, 1000, and 2000 milliseconds resulting in four criterion speed conditions at 280, 140, 70, and 35 cm/second respectively.

III. ASSUMPTIONS

It was assumed that the subjects who participated in the study were naive to the task and performance apparatus employed. It was also assumed that the subjects attempted the task to the best of their ability.

IV. DEFINITION OF TERMS

The following terms are presented in relation to the theoretical perspective and to the operational definitions within this study.

Absolute Error (AE). A value used in the measurement of performance accuracy without respect to the sign of the errors. It is the average amount by which the subject was in error and is computed as the average difference, without respect to the direction of the error, between the subject's responses and the correct response. For the purpose of this study the definition of absolute error was the average absolute error of movement time within blocks of ten trials.

Augmented Knowledge of Results (KR). Feedback information provided by the experimenter which is used to assess to what degree the objective of movement is fulfilled. For the purpose of this study KR was defined as information given to the subject by the experimenter which told the subject the magnitude and direction (too fast or too slow) of error relative to the criterion response.

Constant Error (CE). A value used in the measurement of performance accuracy with respect to the sign of the errors. For the purpose of this study the definition of constant error was the algebraic average of performance scores within blocks of ten trials.

Learning. A relatively permanent improvement in responses in relation to the motor task in question.

Motor Program. A set of pre-structured motor commands that, when activated, results in movement oriented toward a given goal.

Proprioceptive Feedback. Information that may arise from one or a number of sources such as afferent information from the receptors in the tendons and joints, from touch receptors in the skin and from the vestibular apparatus in the inner ear.

Rapid Motor Tasks. A task completed in 101.60 cm/second or faster (Newell, 1976; Newell and Chew, 1974; Schmidt and White; Schmidt and Wrisberg, 1973; Wallace, DeOreo and Roberts, 1976). Specifically for the purpose of this study, a rapid motor task constituted a 70 centimeter movement in 250 and 500 milliseconds at respective speeds of 280 and 140 cm/second.

Slow Motor Tasks. A task lasting longer than 101.60 cm/second (Newell, 1976). Specifically for the purpose of this study, a slow motor task constituted a 70 centimeter movement in 1000 and 2000 milliseconds at respective speeds of 70 cm/second and 35 cm/second.

Variable Error (VE). A value used to measure within subject variations in performance accuracy and defined as the standard deviation of several constant error responses.

It reflects the consistency with which the subject tends to repeat his/her responses. For the purpose of this study the definition of variable error was the standard deviation of constant error of movement time scores within blocks of ten trials.

IV. SIGNIFICANCE OF THE STUDY

One of the most important problems physical educators strive to solve concerns how the greatest possible learning of motor skills could be facilitated. Since the early sixties, individuals involved in motor skills research have attempted to help the physical education practitioner by exploring what variables are involved and how these variables operate when a person performs and learns a motor response. During the initial learning stages of any motor task, the performer is faced with a motor problem and must determine what is to be done to solve the task. Feedback information in the form of KR during these initial stages has been shown to be essential in order for acquisition of a motor skill to occur (Baker and Young, 1960; Bilodeau, Bilodeau and Schumsky, 1959; Trowbridge and Cason, 1932).

In an attempt to determine what variables influence motor skill acquisition, two major motor learning theories have been developed (Adams, 1971; Schmidt, 1975). The frame of reference throughout Adams' (1971) closed-loop theory of

motor learning was the self-paced linear positioning task. However, implications for the learning of ballistic motor tasks were also made. Further implications for both classes of movements has been made by Schmidt (1975a) in his schema theory of discrete motor skill learning.

The significance of the present study was a result of the inconclusive evidence of previous studies concerning the learning of rapid motor tasks with KR and after KR was withdrawn (Newell, 1974; Schmidt and White, 1972; Schmidt and Wrisberg, 1973). Taken together, the literature suggests that performance maintenance following the withdrawal of KR may be different for rapid versus slow motor tasks. It was the intent of the present study to examine the performance accuracy and learning patterns of both response classes with KR presented initially and then withdrawn. The results may contribute to the understanding of how learning occurs with KR and the extent to which performance is maintained after KR is withdrawn. The results may also provide a clearer understanding of what factors constitute a rapid and a slow motor task, thus facilitating future research in this area.

CHAPTER II

REVIEW OF LITERATURE

This review of literature addressed the extent to which KR, its presence and absence, influences motor skill learning. Schmidt (1975a), in his schema theory of discrete motor skill learning, referred to KR as information which is provided by the experimenter concerning the subject's success. In a positioning task the experimenter might have said after a trial "long 12," which meant that the subject moved 12 units too far; alternatively, he could simply say "long," meaning the subject moved too far, or he could say "correct," if the movement was within some arbitrary set limit of correctness. Thus, KR could have nearly any degree of exactness. KR has usually referred to the subject's performance in relation to the score he/she was trying to achieve and was provided artificially by the experimenter or teacher (Schmidt, 1975a, p. 86).

The literature reviewed falls into three broad categories according to the occurrence of KR. Most of the studies which have been completed have investigated (1) learning without KR, (2) learning with KR, and (3) the deterioration of learning when KR was removed. Specifically, this review investigated the topic of learning with respect to the occurrence of KR in lieu of several different

subtopics: (1) learning with and without KR, (2) learning slow motor tasks following the removal of KR, and (3) learning rapid motor tasks following the removal of KR. A brief discussion of performance variables was included in the section concerning performance of rapid motor tasks following the removal of KR. This discussion of performance variables was included because recent findings of several experimenters showed that improvement in performance over trials without KR in rapid motor responses may be attributed to such things as warm up, range effects and regression toward the mean.

I. LEARNING WITH AND WITHOUT KNOWLEDGE OF RESULTS

It was appropriate to begin this review with the KR literature which was concerned with whether learning can occur at all without feedback information. Thorndike's (1927) "Law of Effect" experiment was the first of many studies concerning the extent to which a motor skill can be learned with and without KR. Thorndike's (1927) experiment was the first which revealed a marked drop in performance when feedback was no longer presented. Blindfolded subjects were instructed to draw 3, 4, 5, and 6 inch lines, 150 of each per day, for 9 days. No information was given concerning accuracy of performance on the first or pretraining day. In each of the following 7 days the experimenter said "right" or "wrong" after each line, depending on whether or

not the length of the line was within a chosen limit of correctness. All feedback was again withheld on the ninth or posttraining day. After the pretraining day without any accuracy information given, a marked improvement occurred on the first training day with KR. A gradual improvement continued throughout the remainder of the seven day training period. On the last training day 54 percent of the lines were reported correct. On the ninth day feedback was no longer given and a sudden drop in performance resulted. Thorndike (1927) reported only 25 percent of the lines the correct length. A control group of subjects given no feedback showed no improvement in performance over the nine days.

A classic study by Trowbridge and Cason (1932) required blindfolded subjects to draw 100, 3 inch lines with a pencil. One group received no KR, one group received a nonsense syllable as KR, one group received qualitative KR (e.g., long/short), and one group received quantitative KR (e.g., plus 1, minus 3). The results of the study showed that there was no improvement in performance with the group which received nonsense syllables as KR or in the group which received no KR. However, the groups which did receive KR improved and the group which received quantitative KR showed the largest improvement in performance. It was concluded from this study that (1) learning occurred only with KR and

(2) increased accuracy of KR with respect to magnitude and direction of error led to the greatest learning.

In a study conducted by Bilodeau, Bilodeau and Schumsky (1959), a positioning task was used where subjects attempted to move a lever through a range of 33 degrees. Subjects were given 20 trials in which to learn the movement. One group received KR after each trial and another group did not receive KR. No improvement occurred with the group which did not receive KR while considerable improvement was found with the group which received KR over the 20 trials. However, when the group which did not receive KR throughout the first 20 trials was given KR after the twentieth trial, improvement in performance occurred. The conclusion from this study was that learning cannot occur without some information, such as KR, about one's error in performance.

During a study by Baker and Young (1960) subjects attempted to draw 200 four inch lines per day. The task was very much like the one in the experiment by Trowbridge and Cason (1932). Over a period of 10 days, each subject drew 2000 lines. One group received KR after each trial while another group received no feedback information. The group which received KR showed improvements in performance in both absolute and variable error scores ($p < .01$). However, the group which did not receive KR demonstrated no improvement in performance.

The conclusion drawn from these studies investigating learning with and without KR is that, indeed, improvement in performance or learning did not occur when KR was not given and did not occur when KR was given (Baker and Young, 1960; Bilodeau, Bilodeau and Schumsky, 1959; Thorndike, 1927; Trowbridge and Cason, 1932). Furthermore, increased accuracy of KR with respect to direction and magnitude of error led to the greatest learning (Trowbridge and Cason, 1932).

There have been only a few studies conducted which suggest that motor learning can occur without KR being provided after the movement. Seashore and Bavelas (1941), using data from Thorndike's (1927) line drawing experiment demonstrated that over a series of trials without KR, subjects tended to reduce response variation. That is, subjects responded more consistently to a particular position, although this position was not the criterion location. Seashore and Bavelas (1941) suggested that, if subjects who were not receiving KR were operating about their own reference of the task criterion, then, with more practice an even higher correlation between movement and estimated movement time might occur.

In a more recent study, Newell (1974) reported a similar finding to that of Seashore and Bavelas (1941). In this study, subjects which did not receive KR began fairly

quickly to perform around their own reference of the task criterion. Newell (1974) suggested that these subjects were detecting directional trends of their own movement but their false conception of the task criterion resulted in their movement error.

Solley (1956) used a power driven tilt chair which the subject could maneuver himself to the right or left with a finger switch. Seated in the vertical position, the subject was told "vertical," and was then tilted 30 degrees either to the left or to the right. The subject's task was to position himself once again in the vertical position. After each trial the subject was "randomly" moved about before being brought back to the vertical position. Once again the subject was told "vertical," and the trial proceeded. Over 30 trials with KR never given, subjects reduced their absolute error ($p < .001$). Solley (1956) reported this data as evidence of learning without postresponse KR.

Wrisberg and Schmidt (1975) attempted to replicate Solley's (1956) findings using a task which required more movement. A linear positioning task was employed. Blindfolded subjects began each of the 12 trials by moving a slide 17 centimeters in a right to left direction to a step, remaining there for 3 seconds and then returning the slide to the start position. After either a 5 or 50 second retention interval the subject's task was to return the

slide to the target location without the aid of the stop. KR was never given. As in the Solley (1956) experiment, Wrisberg and Schmidt (1975) reported a significant increase ($p < .05$) in response accuracy (decrease in variable error) over the 12 trials.

Recently, Newell (1976) provided evidence which suggests that the subject's ability to reduce movement error in the absence of external information depends upon the extent to which feedback can be used during the production of the response. Newell conducted four experiments to investigate the ability of a response recognition mechanism to produce motor learning in the absence of KR. The response recognition mechanism was developed by presenting the subject with the auditory sensory consequences of the criterion response in the absence of actual movement practice over either 10 or 70 trials. A control group received no sound trials. In the first and second experiments a rapid linear timing task (101.6 cm/second) was used. Two slow movement time tasks (13.51 and 8.13 cm/second) and a linear positioning task were used in the third and fourth experiments respectively. In each experiment the subject attempted to produce the correct movement over a series of 20 trials. In the first and second experiments a significant reduction of absolute movement error ($p < .01$) occurred over the 20 trials without KR for both sound condition groups. In the third and fourth experiment no reduction of movement error occurred over the

trials without KR. Newell (1976) concluded from this study that the production of a motor task by the recognition mechanism in the absence of KR occurred only when that mechanism was eliminated from operation during the response, as in a rapid timing task.

II. LEARNING FOLLOWING THE REMOVAL OF KNOWLEDGE OF RESULTS

Slow Motor Tasks

One of the first studies concerning the removal of KR was conducted by Bilodeau and Bilodeau (1958). The study investigated the effect that frequency of KR had on performance. Absolute frequency of KR was concerned with how often KR was administered, or the total number of trials with KR given to an individual in a trial sequence. Relative frequency dealt with the proportion of trials on which KR was provided. In this study, Bilodeau and Bilodeau (1958) studied three groups using a blindfolded linear positioning task. One group received 10 trials with KR after each trial, one group received 30 trials with KR after every third trial, and a final group received 40 trials but was given KR only after every fourth trial. Thus, all groups received an equal number of trials with KR. An important conclusion to be drawn from this study was that only in the trial immediately following KR did there appear an improvement

in performance. On the trials when KR was not given, performance decreased. The results indicated that the number of trials with KR (absolute frequency) determined the amount of learning which took place.

A study by Baker and Young (1960) was designed to determine the nature of performance in a simple motor task over prolonged periods of KR withdrawal. There were four experimental groups and each member of each group drew 200 lines per day. Treatments given to each of the four groups were as follows: (1) 1 pretesting day, 1 day with feedback, and 3 post training days without KR; (2) 1 pre training day, 4 days with feedback, and 5 post training days without KR; (3) 1 pre training day, 7 days with feedback, and 7 post training days without KR; (4) 10 days without feedback, as a control. There was no evidence of improvement in performance of the control group over the 10 days without feedback. After withdrawal of KR there was an abrupt drop in the performance of each experimental group on the first post training day. This drop in performance was found to be the same for each of the experimental groups. A maintained level of performance occurred thereafter. However, this performance level was significantly better ($p < .01$) than that of the subjects who never had the benefit of KR training.

In a study by Schumsky, Grasha, and Seymann (1966), blindfolded subjects performed 6 trials with KR on a 3 inch line drawing task. These 6 trials were followed by 10 trials without KR. The study revealed a general reduction of error with KR. By the completion of the sixth trial this general reduction of error had leveled off. Over the 10 post-rest trials without KR, the three experimental groups showed a deterioration in performance.

The studies reviewed which concerned the learning of a slow motor task following the withdrawal of KR (Baker and Young, 1960, Bilodeau and Bilodeau, 1958; Schumsky, Grasha and Seymann, 1966), have all shown immediate decrements in performance. When KR training was provided over a prolonged period initial decrements in performance still occurred followed by a maintained level of performance when KR was withdrawn. Data revealed this level to be significantly above the initial trials with KR ($p < .01$). However, it was significantly below the final trials with KR (Baker and Young, 1960). The findings from these studies (Baker and Young, 1960; Bilodeau and Bilodeau, 1958; Schumsky, Grasha and Seymann, 1966), indicate that the number of trials with KR determined the amount of learning which can take place when performing a slow motor task.

Rapid Motor Tasks

Adams (1971) predicted in his closed-loop theory of motor learning that as KR was provided over many training trials the performer gathered with each trial a picture of how the response felt, looked and sounded. Adams (1971) postulated that over the course of practice with KR the learner gained proficiency in a task. With this proficiency the learner formed a representation of the qualities from feedback of the correct response. Adams (1971) labelled this representation of correct responses the "perceptual trace" (p. 123). Adams (1971) predicted that with the formation of the perceptual trace the learner could take the feedback from a present response and compare it with the perceptual trace when KR was withdrawn. This was the basis for the error detection mechanism which allows performance to be maintained with the withdrawal of KR. Many researchers have tested Adams' (1971) theory using various rapid motor tasks, however, it should be clearly understood that Adams did not intend for his theory to apply to this general class of movements. Several of the studies which have tested Adams' (1971) theory will be discussed in this section of the review.

Schmidt and White (1972) tested Adams' (1971) closed-loop theory by investigating the effects of withdrawal of KR and the development of subjective reinforcement which is

the process of generating one's own error signal. The task of each subject was to move a slide along a trackway a distance of 9 inches in exactly 150 milliseconds (160.93 cm/second). This task, with a movement speed of 160.93 cm/second, eliminated the use of feedback control of the response. Thus, theoretically the memory trace initiated execution of the response, and the perceptual trace provided the evaluative criterion of its correctness when it had been completed. Each subject had to guess their movement time before KR about their actual time was given by the experimenter. At the conclusion of 170 trials which occurred over a two day period, subjects were fairly accurate at guessing their movement times. This led to the conclusion that subjects developed, over the course of practice with KR, subjective reinforcement.

Schmidt and White (1972) also found that when KR was withdrawn after the second trial, performance deteriorated, indicating that subjective reinforcement was not capable of maintaining performance. When KR was withdrawn after 20 trials or 150 trials, performance was maintained. With some caution Schmidt and White (1972) suggested that learning continued. The authors reported that the evidence suggested that subjective reinforcement was developed over practice which could detect errors and correct them on subsequent trials, thus, it could be substituted as KR effectively.

A study by Williams and Roy (1972) investigated closed-loop control of a ballistic response. The task entailed learning to strike a plunger with a certain amount of force. The subjects were given 70 trials with one group of subjects receiving KR after every trial, and another group of subjects receiving KR after every tenth trial. The data revealed that during the initial trials, performance of the group receiving KR after every tenth trial tended to deteriorate after one trial following KR. When the later trials without KR were analyzed they indicated a maintenance of performance, however it was not significant ($p \leq .05$).

A study by Newell (1974), which tested Adams' (1971) closed-loop theory, had subjects make a 24.03 centimeter movement in a movement time criterion of 150 milliseconds (160.27 cm/second). Of the five KR withdrawal groups, KR was withdrawn after either trials 2, 7, 17, 32, or 52. Another group had KR after every trial, and another had no KR after any trial. All groups performed a total of 77 trials. The groups which had KR withdrawn after trials 2, 7, or 17 showed a decrement in performance when KR was withdrawn. However, the group which had KR withdrawn later in practice, after trial 32 of 52, revealed a sustained performance.

Newell and Chew (1974) attempted to manipulate motor recognition but not recall as a test of Adams' (1971)

closed-loop theory. The same rapid linear timing task (160.27 cm/second) used in the preceding study by Newell (1974) was employed. Memory trace strength was represented as an inverse function of the absolute movement error and perceptual trace strength was represented as an inverse function of the absolute estimated error. The subjects were given 70 trials with KR and then were administered 40 trials without KR. During the KR withdrawal phase a decrement in response recognition but not recall occurred. This substantiated Adams' (1971) postulation of separate mechanisms for the initiation and subsequent recognition of a response. The data revealed that performance was maintained during the trials when KR was withdrawn.

To test Adams' (1971) closed-loop theory, Schmidt and Wrisberg (1973) had subjects attempt to make a 26 inch movement of a slide in exactly 200 milliseconds (330.20 cm/second). The experimenter provided the subject with either standard feedback (with vision or audition) or limited feedback (without vision or audition). The experiment consisted of 75 practice trials with KR given after each trial except for one group of subjects which had KR withdrawn on trials 21 to 45. Also one group which received KR throughout the experiment received an additional 25 trials without KR following the 75 practice trials. When KR was withdrawn the performance level of both groups

deteriorated, however much more so for the group with limited feedback. Concluded from this study was that standard feedback (i.e., vision and audition) facilitated the development of a strong perceptual trace which allowed the subjects to maintain performance through subjective reinforcement.

A study by Wallace, DeOreo, and Roberts (1976) investigated the development of the memory and perceptual trace as a function of the amount of practice with KR. Subjects attempted to produce a 24.13 centimeter movement in exactly 150 milliseconds (160.93 cm/second). On Day 1 three experimental groups received either 2, 5 or 10 initial trials with KR, followed by 20 trials without KR and then an additional 70 trials with KR. On the second day (24 to 36 hours later) all subjects received 20 trials with KR followed by 30 trials without KR. After each movement the subject was asked to estimate his movement time in milliseconds. Memory and perceptual trace performance were indicated by mean absolute and mean absolute estimated error, respectively. Both were shown to be dependent on the amount of KR practice. Wallace, DeOreo, and Roberts (1976) reported that the memory and perceptual trace remained reasonably strong during late KR withdrawal.

In his schema theory of discrete motor skill learning, Schmidt (1975a) postulated that after sufficient practice on

a rapid task with KR, subjects should be able to maintain performance effectively and continue to learn the movement under conditions when KR was withdrawn. However, this prediction was difficult to support because of a number of methodological problems. Schmidt (1975a) has concluded that in order for the task to have a strong recognition memory it should presumably be simple enough to allow the recognition memory or perceptual trace to be developed within the time constraints of the typical experiment (p. 252). However, in studies by Schmidt and White (1972) and Schmidt and Wrisberg (1973) which tested this prediction, improvement in performance was so rapid that nearly asymptotic conditions were reached in only a few trials. Because of these conditions, if KR was withdrawn at this point, subjects would be unable to improve because of a "floor effect" (Schmidt, 1975a, p. 252) in the task. In other words, a floor effect was reached and performance was at a point where scores (trend in absolute error) could not continue to improve. However, just because scores did not change was not evidence that learning had stopped. The study by Schmidt and White (1972) resulted in a slight indication that learning continued (downward trend in absolute errors) after KR withdrawal, however, it was very small and not statistically reliable.

In a study by Schmidt and McCracken (1974) an alternative approach was attempted to overcome this problem. The subjects performed 200 KR trials of a rapid movement with a movement time criterion of 200 milliseconds. After a week retention interval the subjects returned and performed 20 trials without KR. The data revealed that subjects began their trials without KR at a much lower level of performance compared to their last training trials with KR, but then exhibited significant improvements in absolute error across the trials without KR. However, the subjects final level of performance was still lower than the level of performance that was achieved during the final training trial with KR. Schmidt and McCracken (1974) interpreted their data as indicating the ability of the subjects to relearn a task in the absence of KR after initial practice with KR had been provided. However, in discussing this study it was extremely important to remember that no controls were employed to protect against the possibility that the upward trend in performance was due to a performance variable such as warm up.

The studies reviewed dealing with learning a rapid motor task following the removal of KR have demonstrated several conclusions. From some studies it appeared that when KR was withdrawn after a relatively long period of training trials with KR, a maintained level of performance

occurred (Newell, 1974; Newell and Chew, 1974; Schmidt and McCracken, 1974; Schmidt and White, 1972; Schmidt and Wrisberg, 1973). However, it has also been concluded that when KR was removed after only a limited number of training trials a deterioration in performance was observed (Newell, 1974; Newell and Chew, 1974; Schmidt and McCracken, 1974; Schmidt and White, 1972; Schmidt and Wrisberg, 1973).

III. SUMMARY

It appeared from the literature concerning information feedback or KR that it was the strongest, most important variable which controlled performance and learning in any motor task. Studies which investigated performance of slow movements, lasting longer than 200 milliseconds (Schmidt, 1975a), reported immediate decrements in performance when KR was withdrawn (Baker and Young, 1961; Bilodeau and Bilodeau, 1958; Schumsky, Grasha and Seymann, 1966). However, studies which investigated the learning of rapid movements, less than 200 milliseconds (Schmidt, 1975a), have reported a maintained level of performance following removal of KR (Newell, 1974; Newell and Chew, 1974; Schmidt and McCracken, 1974, Schmidt and White, 1972; Schmidt and Wrisberg, 1973; Williams and Roy, 1972). It therefore appeared that performance maintenance following the withdrawal of KR is different for rapid versus slow motor tasks.

However, no research has been conducted which independently manipulated speed of movement in order to determine its influence on learning with KR and after withdrawal of KR.

CHAPTER III

PROCEDURE

This study was conducted in order to determine the effect of movement on learning with KR and after withdrawal of KR. The procedure used in this study is presented in the following six areas: (1) selection of the subjects, (2) selection of performance apparatus, (3) selection of criterion speeds, (4) selection of trials with KR, (5) testing procedures and (6) data collection.

I. SELECTION OF SUBJECTS

The subjects for this experiment were 48 right handed female undergraduate students enrolled in Physical Education service classes, Spring Quarter, 1979 at The University of Tennessee, Knoxville. All subjects were randomly selected from a pool of volunteers. Individuals were not included as subjects if they had previous experience with the experimental task or the apparatus. None of the subjects were paid for their services. Each subject met with the experimenter and was given a letter explaining, (1) purpose of the study, (2) amount of time expected, and (3) request to participate. Each subject was also given and asked to sign an informed consent statement and a schedule from (Appendix A).

Each subject kept her letter of explanation after her selected time commitment was recorded by the experimenter. The consent form with personal information was kept by the researcher. The subject also signed a master time schedule which was kept by the researcher.

II. SELECTION OF THE PERFORMANCE APPARATUS

The apparatus used in this study to test each subject was a barrier task (Appendix B). The performance apparatus consisted of a microswitch (start button) and a hinged barrier target mounted on a platform on top of a large table. The microswitch and barrier were 70 centimeters apart. Both the microswitch and barrier were parallel to and 30 centimeters from the edge of the table. Each subject stood facing the performance apparatus with the microswitch on her right and the barrier opposite her left shoulder. The experimenter was seated at the table opposite the subject. A Reaction Movement Timer (Layfayette Instruments Model number 63017) was mounted on the table. A calculator (Digitronic-M) was positioned on the table in a comfortable and stable position to the experimenter. The Reaction Movement Timer was arranged so that the digital time displays were in full view of the experimenter. The apparatus was wired so that by depressing the microswitch (start button) a trial cycle could be initiated. When the

start button on the control unit was depressed, time began to accumulate on the Reaction Movement Timer. Releasing the start button stopped the reaction time display (Timer B) and knocking over the barrier stopped the total response time display (Timer A). Thus the trial time to move over 70 centimeters was indicated by the difference in time on the two clocks.

III. SELECTION OF CRITERION SPEEDS

The selection of the criterion speeds to be used in the present experiment was determined after reviewing the literature which dealt with the performance of both rapid and slow motor tasks. Schmidt (1975a) stated that a rapid motor task is a movement completed in less than 200 milliseconds. Schmidt (1975a) also defined a slow motor task as a movement lasting longer than 200 milliseconds. However, the distance moved may cause the speed of the movement to vary.

From this review the author found that previous studies dealing with the performance of rapid motor tasks used times of 100, 150 and 200 milliseconds. Most distances used varied from 10 to 66 centimeters. The speeds used in previous studies dealing with the performance of rapid motor tasks varied from 101.6 cm/second to 330.2 cm/second (Newell, 1976; Schmidt and Wrisberg, 1973). However, most

of the studies used a speed of approximately 160 cm/second (Newell, 1974; Newell and Chew, 1974; Schmidt and White, 1972; Wallace, DeOreo and Roberts, 1976).

Newell (1976) conducted a study which dealt with the performance of a slow motor task in which he used a distance of 10.16 centimeters with times of 750 and 1250 milliseconds. Therefore the speeds Newell (1976) used were 13.51 cm/second and 8.13 cm/second. No other studies which dealt with the performance of a slow motor task were found which reported time or speed.

The literature served as a basis for the selection of the criterion speeds for the present experiment. The four criterion movement times were established at 250, 500, 1000, and 2000 milliseconds with a fixed distance of 70 centimeters. Thus, the four criterion speeds used were: (1) 280 cm/second, (2) 140 cm/second, (3) 70 cm/second, and (4) 35 cm/second. The first two speeds, 280 and 140 cm/seconds, are within the rapid category as used in the literature, and the remaining two, 70 and 35 cm/second are below the rapid category.

IV. SELECTION OF TRIALS WITH KR

The selection of the number of trials with KR was determined after reviewing the literature. From this review, the author found that the number of KR acquisition trials varied from study to study. However, Newell (1974) found

that subjects which received 32 or 52 KR acquisition trials revealed a sustained performance when KR was withdrawn. Thus, it was determined that 40 trials with KR would be administered in the present study, with an additional 5 practice trials.

V. TESTING PROCEDURES

All assessments of data were made on a carefully scheduled basis by the experimenter. Prior to the first day of testing, each subject was randomly assigned to one of four movement speed conditions. All subjects attempted to produce a 70 centimeter movement from a start button to a padded target in one of the following four time periods:

Group I (N = 12) 250 milliseconds or approximately one fourth second (280 cm/second).

Group II (N = 12) 500 milliseconds or approximately one half second (140 cm/second).

Group III (N = 12) 1000 milliseconds or approximately 1 second (70 cm/second).

Group IV (N = 12) 2000 milliseconds or approximately 2 seconds (35 cm/second).

When the subject arrived at the testing area she was positioned directly in front of the apparatus opposite the experimenter with the center of her body in line with the center mark between the start button and the barrier

(marked with red tape on the apparatus and the floor). The experimenter then read the instructions which were to be followed throughout the testing session (Appendix C).

The study required the subject to be present one day for approximately 30 to 45 minutes. All subjects in each group received 5 practice trials (Trials 1-5) with KR (error and direction in milliseconds), 40 trials (Trials 6-45) with KR, and then 40 trials (Trials 45-85) without KR. The interresponse intervals were each 15 seconds.

VI. DATA COLLECTION

After each trial the experimenter recorded the subject's reaction time (RT) and total time (TT) which appeared on the digital displays of the Reaction Movement Timer. From these times, movement time (MT) and the subject's error (ERROR) from the desired response were calculated and recorded (Appendix D).

CHAPTER IV

RESULTS

Data for college age women were collected and analyzed in order to determine if there was an effect of the speed of movement expected on the performance of a discrete movement with KR present initially and then withdrawn. This chapter includes a description of (1) how the data were scored, (2) the analysis of the data, and (3) a discussion of the results.

I. SCORING OF THE DATA

The raw movement time data were converted into three dependent variables: (1) constant error (CE), (2) absolute error (AE) and (3) variable error (VE) scores. Each subject's error scores were calculated for eight blocks of ten trials each. Three separate one way analyses of variance were performed on the initial AE, CE, and VE performance scores (Trials 1-5) to determine if analysis of covariance (ANCOVA) should be used for the analysis of performance with KR and after KR withdrawal. There was a significant difference for AE, VE, and CE with $p \leq .05$, however, it was determined that ANCOVA would not be used so that the underlying assumptions governing ANCOVA would not be violated.

A two-way repeated measures design analysis of variance was performed on eight blocks of ten trials. Subjects were nested within groups and crossed with trial blocks. A Newman-Keuls post hoc test was administered where appropriate to examine all significant differences.

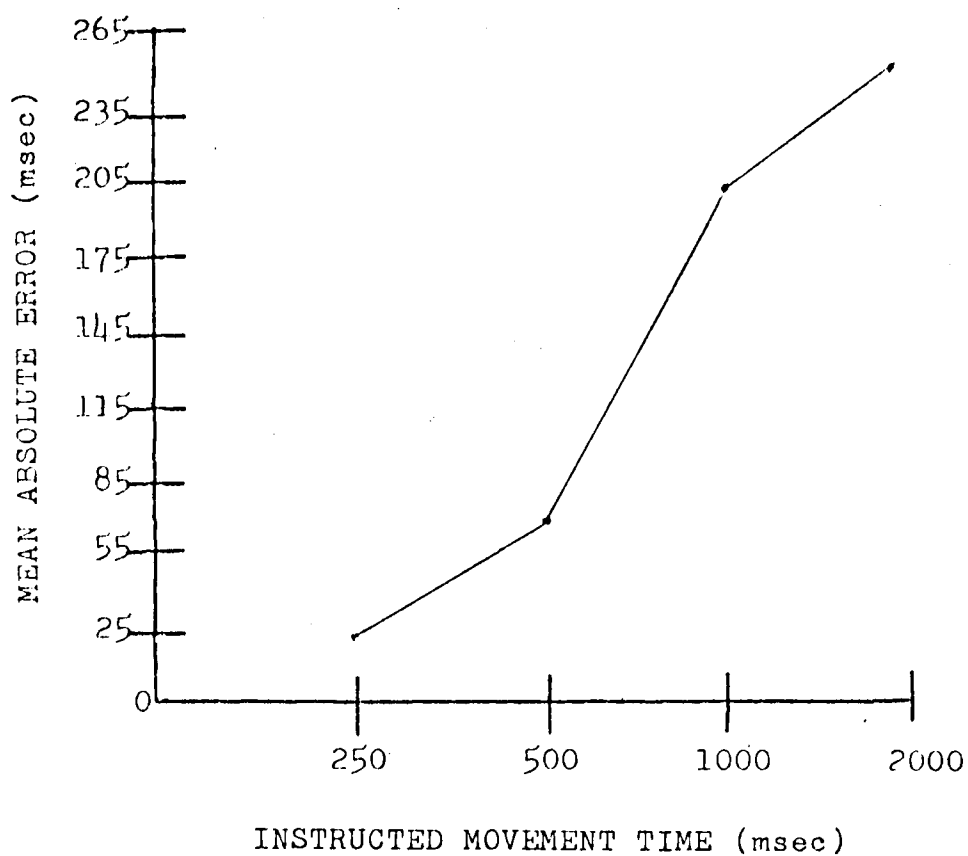
II. ANALYSIS OF THE DATA

Absolute Error

A time X blocks ANOVA with repeated measures on blocks was performed on the dependent variable AE (Table I). A variance analysis revealed a significant main effect of time, $F(3,44) = 46.89$, $p = .0001$ (Table I). Thus, the null hypothesis that the criterion speed of the response will have no effect on the accuracy of performance without regard to sign as measured by AE was rejected. Post hoc inspection of the means by the Newman-Keuls procedure indicated that the group with a movement time criterion of 250 milliseconds with a speed of 280 cm/second exhibited significantly smaller AE ($p < .01$) than did the group with a movement time criterion of 1000 milliseconds at a speed of 70 cm/second, and the group with a desired movement time of 2000 milliseconds at a speed of 35 cm/second (Figure 1). The Newman-Keuls procedure also revealed that the group with a criterion movement time of 500 milliseconds, 140 cm/second also had a significantly smaller AE ($p < .01$) than did the

TABLE I
SOURCE OF VARIANCE FOR ABSOLUTE ERROR

Source of Variance	<u>df</u>	Mean Square	<u>F</u>	<u>p</u>
Between Groups				
Time	3	1.0373	46.8908	.0001
ID (Time)	44	.0221		
Within Groups				
Blocks	7	.0140	3.5544	.0014
Time*Blocks	21	.0056	1.4128	.1095
Blocks*ID (Time)	308	.0039		
Total	383			



Speed (cm/sec)	280	140	70	35
Average AE (msec)	25	60	199	238
SD (msec)	10	26	100	119

Figure 1

Mean Absolute Error As a Function of
Instructed Movement Time

groups with criterion movement times of 1000 and 2000 milliseconds, 70 cm/second and 35 cm/second respectively (Figure 1). Thus, the results indicated that the two groups with the fastest movement times were significantly more accurate ($p < .01$) at producing their respective criterion response than were the slower movement time groups.

Analysis of AE also revealed a significant blocks effect, $F(7,308) = 3.55$, $p = .0014$ (Table I). Thus, the null hypothesis that the performance across eight blocks of ten trials each, with KR provided on the first four blocks and withdrawn on the last four blocks will be the same was rejected. The Newman-Keuls post hoc test indicated that blocks 3 and 4 had significantly smaller absolute movement error ($p < .01$) than block 1 (Figure 2). Thus, these data indicated that subjects improved their performance (decrease in absolute error) over practice with KR. Newman-Keuls test also revealed that block 8 had significantly greater AE ($p < .01$) than block 4. This indicated that subjects were unable to maintain their performance or continue to learn after KR was withdrawn and therefore exhibited an increase in AE.

The time X blocks interaction effect failed to reach significance with $p \leq .05$. The time X blocks effect produced and $F(21,308) = 1.41$, $p = .1095$ (Table 1). Thus, the null hypothesis that time groups are not different in

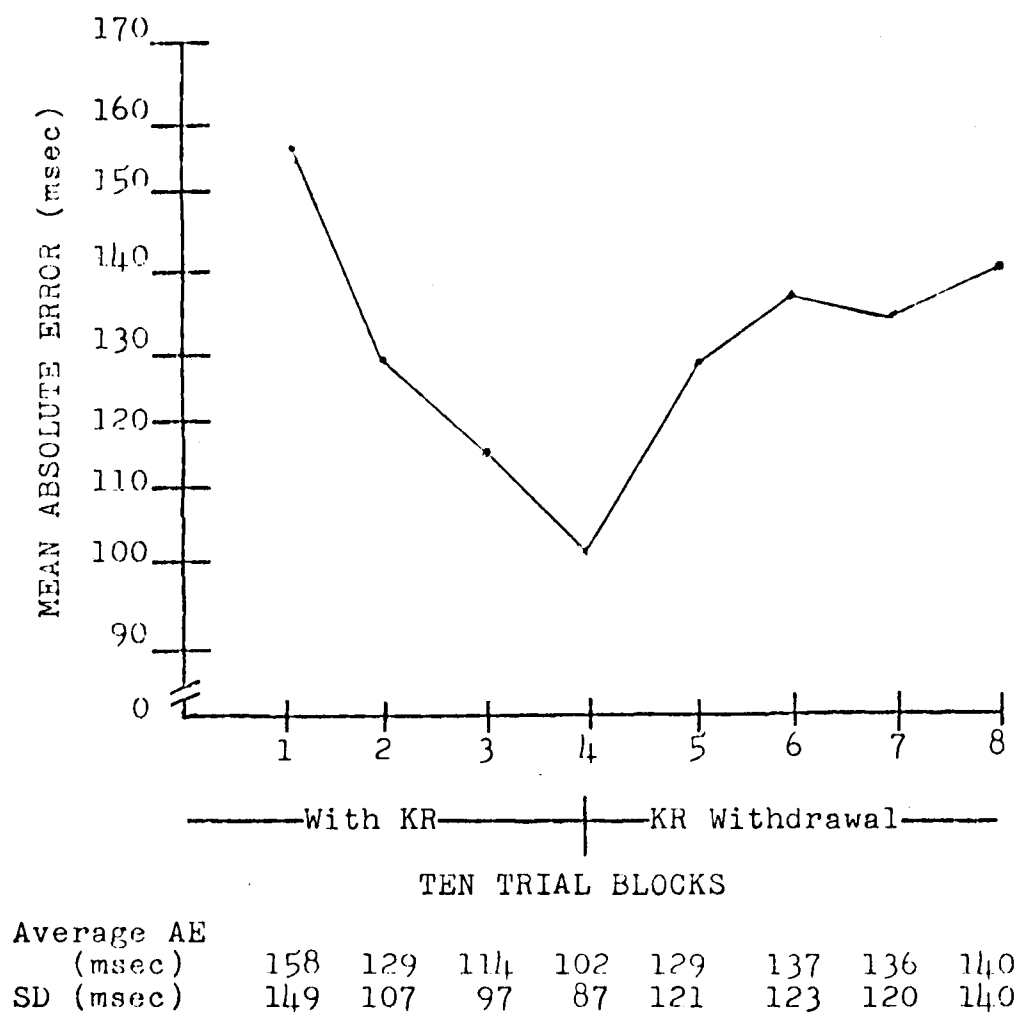


Figure 2

Mean Absolute Error for Ten Trial Blocks

performance accuracy with and/or without KR as measured by AE could not be rejected.

Variable Error

A time X blocks ANOVA with repeated measures on blocks was performed on the dependent variable VE (Table II). The ANOVA performed on VE revealed a significant main effect on time, $F(3,44) = 43.40$, $p = .001$ (Table II). Thus, the null hypothesis that the criterion speed of the response will have no effect on the consistency of performance as measured by VE was rejected. Post hoc inspection of the means by the Newman-Keuls procedure indicated results similar to those found with the analysis of AE (Figure 3). The post hoc test revealed that the groups with movement times of 250 and 500 milliseconds with speeds of 280 and 140 cm/second, respectively, exhibited significantly smaller VE ($p < .01$) than did the slower movement time groups of 1000 and 2000 milliseconds with respective speeds of 70 and 35 cm/second. This indicated that the two fastest movement time groups produced significantly greater consistency in responding ($p < .01$) than did the two slower movement time groups. Unlike AE, the Newman-Keuls test of VE revealed that the group with a movement time criterion of 1000 milliseconds, 70 cm/second had a significantly smaller VE ($p < .05$) than did the group with a criterion movement time of 2000 milliseconds at 35 cm/second.

TABLE II
SOURCE OF VARIANCE FOR VARIABLE ERROR

Source of Variance	<u>df</u>	Mean Square	<u>F</u>	<u>p</u>
Between Groups				
Time	3	1.0456	43.3965	.0001
ID (Time)	44	.0241		
Within Groups				
Blocks	7	.0146	5.7947	.0001
Time*Blocks	21	.0027	1.0822	.3657
Blocks*ID (Time)	308	.0025		
Total	383			

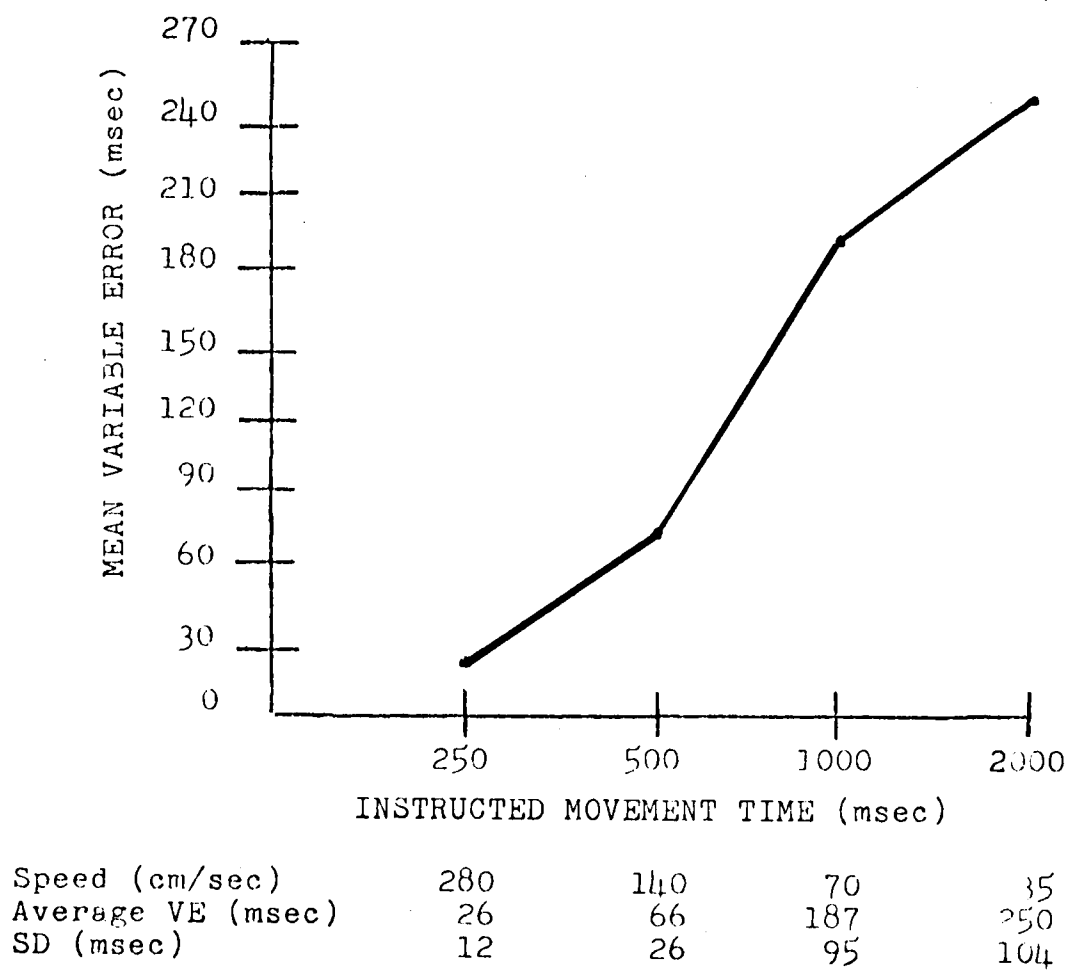


Figure 3

Mean Variable Error As a Function of
Instructed Movement Time

Analysis of VE also revealed a significant blocks effect, $F(7,308) = 5.79$, $p = .0001$ (Table II). Thus, the null hypothesis that the performance across eight blocks of ten trials each with and/or without KR will have no effect on performance consistency as measured by VE was rejected. The Newman-Keuls post hoc test indicated that blocks 1 and 2 had significantly greater VE ($p < .01$) than all other blocks (Figure 4). Variable error tended to decrease over practice reaching its lowest point on the final trial with KR (Trial 4) and the following two trials without KR (Trials 5 and 6).

The time X blocks interaction failed to reach significance with $p \leq .05$. The time X blocks effect produced $F(21,308) = 1.08$, $p = .3657$ (Table II). Thus, the null hypothesis that time groups are not different in performance consistency with and/or without KR cannot be rejected.

Constant Error

A time X blocks ANOVA with repeated measures on blocks was performed on the dependent variable CE (Table III). The variance analysis indicated that both time and blocks main effects were nonsignificant with $p \leq .05$. The main effect on time produced $F(3,44) = .29$, $p = .8340$ (Table III). Thus, the null hypothesis that the criterion speed of the response will have no effect on performance bias as measured

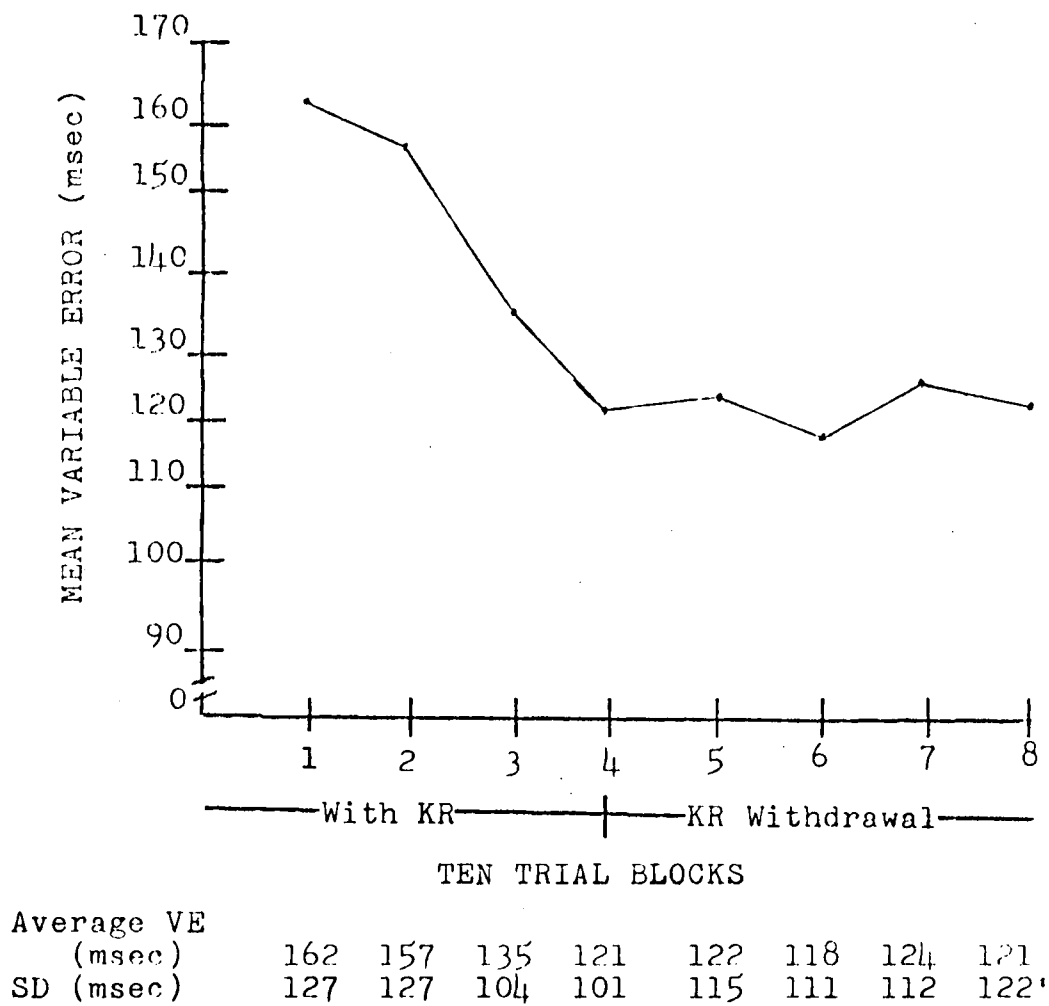


Figure 4

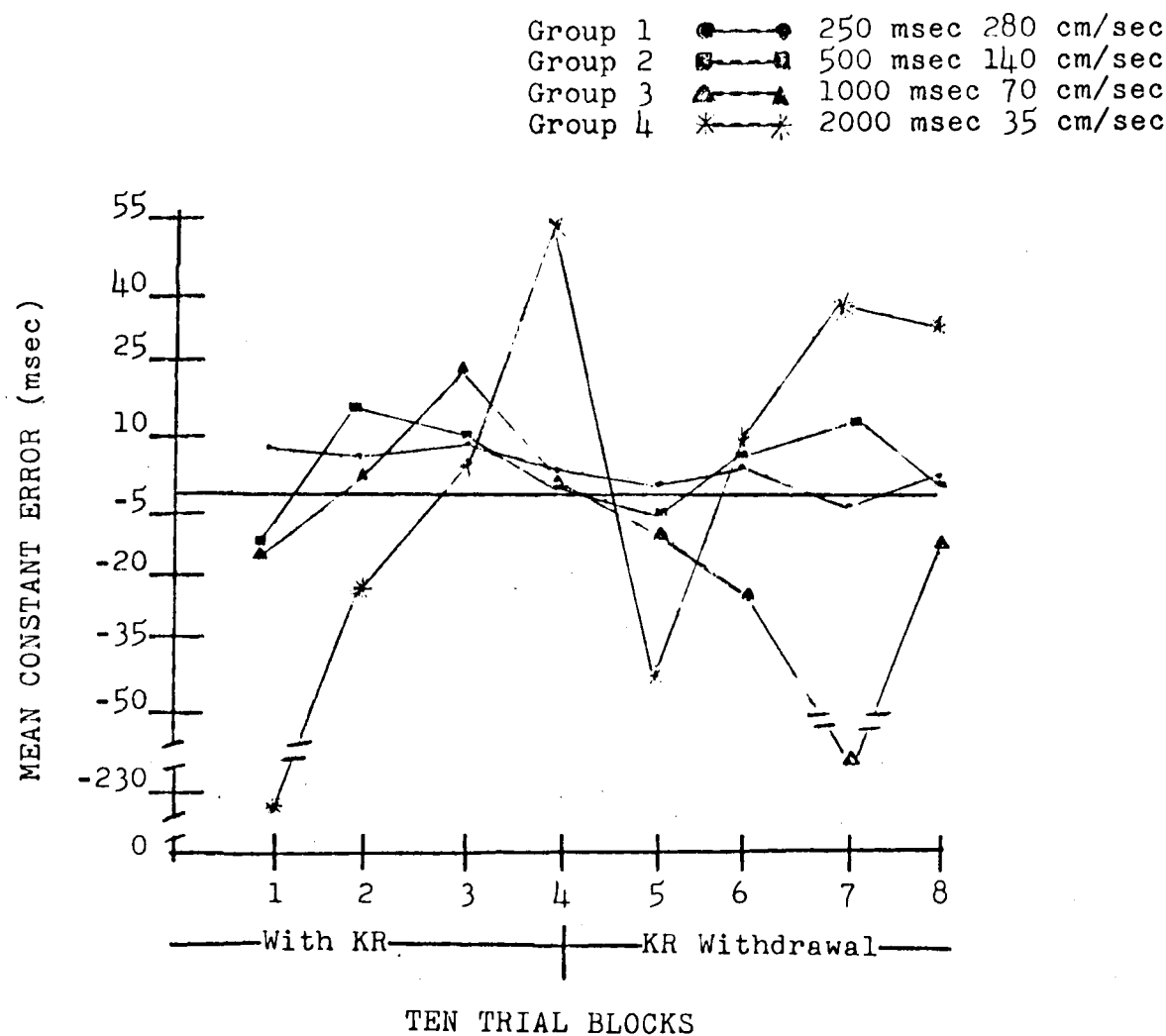
Mean Variable Error for Ten Trial Blocks

TABLE III
SOURCE OF VARIANCE FOR CONSTANT ERROR

Source of Variance	<u>df</u>	Mean Square	<u>F</u>	<u>p</u>
Between Groups				
Time	3	.0159	.2898	.8340
ID (Time)	44	.0550		
Within Groups				
Blocks	7	.0288	2.0014	.0541
Time*Blocks	21	.0285	1.9847	.0070
Blocks*ID (Time)	308	.0144		
Total	383			

by CE could not be rejected. The main effect on blocks produced $F(7,308) = 2.00$, $p = .0541$ (Table III). Thus the null hypothesis that performance across eight, ten trial blocks with and/or without KR will have no effect on performance bias could not be rejected.

However, the analysis of CE revealed a significant time X blocks interaction effect, $F(21,308) = 1.98$, $p = .0070$ (Table III). Thus, the null hypothesis that time groups are not different in performance bias with and/or without KR as measured by CE was rejected. Post hoc inspection of the means using the Newman-Keuls procedure indicated that the constant errors of the group with a 2000 millisecond movement time with a speed of 35 cm/second were initially negative on the first two blocks (Figure 5). This indicated that the subjects were undershooting the criterion movement time of 2000 milliseconds. However, over blocks, the subjects in this group significantly changed their CE ($p < .01$) to a much greater degree than any other time group (Table IV) with blocks 4 (KR) and 7 and 8 (No KR) being late to a greater extent than blocks 2 (KR) and 5 (No KR) were early. The largest change came from block 1 to block 4 ($p < .01$) and the next largest from block 1 to block 5 and block 2 to block 4. Thus, subjects with the slowest movement time criterion had the most erratic periods of bias, moving from the greatest extremes early to the greatest extremes



Average CE (msec)								
Group 1	9.1	6.8	7.2	3.9	3.7	4.9	-1	4.1
Group 2	-13	14	7.5	1.8	-5	5.2	13	3.6
Group 3	-14	3.7	20	2.2	-11	-22	-97	-12
Group 4	-232	-19	4.8	53	-38	9.6	33	29

Figure 5

Mean Constant Error Time by Blocks

TABLE IV
RANK ORDER OF MEAN CONSTANT ERROR
(EARLY TO LATE)

Rank	Time	Block	Mean CE (msec)	Rank	Time	Block	Mean CE (msec)
1	4	1	-232	17	1	4	3.9
2	3	7	-97	18	1	8	4.1
3	4	5	-38	19	4	3	4.8
4	3	6	-22	20	1	6	4.9
5	4	2	-19	21	2	6	5.2
6	3	1	-14	22	1	2	6.8
7	2	1	-13	23	1	3	7.2
8	3	8	-12	24	2	3	7.5
9	3	5	-11	25	1	1	9.1
10	2	5	-5	26	4	6	9.6
11	1	7	-1	27	2	7	13
12	2	4	1.8	28	2	2	14
13	3	4	2.2	29	3	3	20
14	2	8	3.6	30	4	8	29
15	1	5	3.7	31	4	7	33
16	3	2	3.7	32	4	4	53

late when KR was given and performance remained almost as erratic when KR was withdrawn.

II. DISCUSSION OF THE RESULTS

In discussing performance accuracy with respect to rapid and slow motor tasks, Schmidt (1975a) referred to each movement class in relation to movement time. A rapid motor task, as defined by Schmidt (1975a) is a movement completed in less than 200 milliseconds and a slow motor task is a movement lasting longer than 200 milliseconds. The results of the present study indicated that the speed of the movement and/or movement time may be the factor(s) which influenced the performance accuracy of rapid and slow motor tasks. The movement times used in the present study were consistent with the rapid and slow speeds of movement in the literature which reflected Schmidt's definitions (Chapter III, p. 30).

With this in mind, an interesting result from the present experiment was the significant time effect ($p < .01$) observed on both AE and VE scores. The means indicated that the groups with the fastest criterion movement times, 250 milliseconds with a speed of 280 cm/second and 500 milliseconds with a speed of 140 cm/second, exhibited a more accurate performance (smaller AE), and less variable performance (lower VE) than did the groups with much slower

criterion movement times of 1000 and 2000 milliseconds with speeds of 70 cm/second and 35 cm/second, respectively. Thus, it may be concluded that the movements performed in less time or the fastest movements were more accurate and more consistent than were the longer lasting or slower movements.

This finding is consistent with those reported by several recent studies (Newell, Hoshizaki, Carlton, and Halbert, 1979; Wrisberg and Hardy, 1979). Wrisberg and Hardy (1979), using a coincidence anticipation task found that timing accuracy appeared to be more prominently influenced by stimulus velocity than by movement distance. In other words, the movement speed required for task success determined that rapid tasks (i.e. high stimulus velocity) had lower AE than did slower tasks (i.e., low stimulus velocity). Although the present study did not involve the same task, the conclusion that the velocity of the movement influenced performance accuracy is consistent with that of Wrisberg and Hardy (1979).

The most relevant study to the present one is that of Newell, Hoshizaki, Carlton, and Halbert (1979). Newell et al. (1979) reported that slow movements are less accurate and more variable than fast movements when the average velocity of the slow movement is about 15 cm/second. It was concluded by Newell et al. (1979) that the velocity of the movement influenced performance accuracy and that slow

movements appeared to cause some breakdown in the motor pattern. Thus, the findings of the present study are consistent with those reported by Newell et al. (1979), because the present study also indicated that (1) slow movements up to 70 and 35 cm/second were less accurate and more variable than faster movement speeds of 280 and 140 cm/second, and (2) the slowest movement of 35 cm/second produced the most erratic bias with KR and after KR withdrawal.

Newell et al. (1979) reported several factors which could contribute to increased error in slow movements. It was suggested by Newell et al. (1979), (1) that it may be more difficult to generate a slow velocity movement which could account for the velocity effects; (2) that as the movement progresses faster the excitatory drive on the skeletomotor neurons through the muscle-spindle reflex loop decreases, immediately causing reduction in the amplitude of spindle activity which results in a smoother movement (p. 56); and (3) that after initiation, fast movements are unaffected by agonist or antagonist action which would also result in a smoother movement (p. 56).

The results of the present study provided several lines of support for two major motor learning theories: (1) Adams' (1971) closed-loop theory of motor learning and (2) Schmidt's (1975a) schema theory of discrete motor skill learning.

One of the fundamental predictions of Adams' (1971) closed-loop theory is that for improvement in performance to occur, KR must be provided to the learner over a period of acquisition. Many studies have investigated this prediction with the conclusion being that, indeed, improvement in performance occurred when KR was given (Baker and Young, 1960; Bilodeau, Bilodeau and Schumsky, 1959). The present experiment presented subjects with KR for a period of 45 trials. The results indicated that over the course of practice with KR, subjects exhibited a significant improvement in performance ($p < .01$) (decrease in absolute error), thus clearly lending support to Adams' (1971) prediction concerning learning with KR.

Adams (1971), in reference to slow, self paced movements and Schmidt (1975a), in reference to rapid movements have suggested that after sufficient practice with KR, the subject should be able to continue to maintain performance effectively during KR withdrawal and should also be able to continue to learn the movement. Studies investigating this prediction using rapid motor tasks have provided some supportive evidence, however these results have not always been statistically reliable (Schmidt and White, 1972). The results of the present study failed to provide support for this prediction. Following KR withdrawal a significant increase across blocks in AE resulted ($p < .01$), thus this

experiment clearly showed that subjects were unable to continue to learn or even maintain performance accuracy to the criterion after KR was withdrawn (Figure 2, p. 39). However, the analysis of VE (Figure 4, p. 44) revealed that the subjects maintained low variability of response. Thus, during practice with KR, accuracy (AE) and consistency (VE) improved for all speed groups. When KR was withdrawn consistency (VE) remained fairly constant but accuracy (AE) diminished significantly for all speed groups ($p < .01$).

Schmidt (1975a) suggested that one possible reason for lack of improvement in accuracy after KR withdrawal, i.e., continued learning, was that floor and/or ceiling effects were occurring. In the present study, no floor effect was present. Also accuracy diminished (i.e., AE increased) after KR withdrawal. This study therefore provided evidence that floor effects are not one of the confounding variables affecting accuracy during KR withdrawal.

Schmidt's (1975a) schema theory predicted that learning can take place in the absence of KR only after an accurate recognition schema had been developed. In Schmidt's (1975a) theory, the recognition schema was the relationship developed between actual outcomes and the expected sensory consequences. Schmidt (1975a) suggested that this relationship is thought to become more accurate as the subject performs a task under KR conditions with sensory feedback channels available. The question could be raised as to

whether this study provided sufficient opportunity for learning to occur. It may always be a debatable question as to how many KR trials are necessary for the formation of an accurate recognition schema. Thus, it is possible that this study did not provide a sufficient opportunity for the recognition schema to adequately develop in some of the groups.

To support Schmidt's (1975a) prediction that subjects could not continue to learn a slow, self paced task following KR withdrawal would necessitate a significant interaction effect on AE and/or VE. This did not occur in the present study, therefore it must be reported that patterns of performance were not different for time groups across blocks. However, it was concluded that slow tasks produced least accuracy (AE) and greatest variability (VE), and rapid tasks produced greatest accuracy (AE) and least variability (VE).

The data from the present experiment also indicated a significant time X blocks interaction effect ($p < .01$) on CE scores for time Group 4. This time group has the slowest movement time criterion at 2000 milliseconds with a speed of 35 cm/second. The CE means indicated that subjects in time Group 4 were undershooting the criterion movement time of 2000 milliseconds on the first two blocks. However, over blocks, the subjects in time Group 4 significantly changed

their CE ($p < .01$), with the largest change occurring from block 1 to block 4 ($p < .01$). On blocks 1 to 4, when KR was provided, subjects with the slowest movement time criterion displayed the most erratic periods of bias, moving from the greatest extremes early to the greatest extremes late.

When KR was withdrawn on Blocks 5 to 8, subjects in time Group 4 continued to perform with a similar erratic pattern of bias. It is feasible that the performance of time Group 4 occurred because there are very few motor tasks which require a 2000 millisecond movement time criterion with a speed of 35 cm/second. Therefore, the subjects with the slowest movement time criterion in the present study revealed no consistent response bias with and without KR.

It is also possible that the erratic performance of the group with the slowest criterion time (35 cm/second) may have distorted the results of the analysis because of their extremes of performance which did not coincide with the performance of the other groups. Thus, future research in this area might be facilitated by (1) varying the distance with the 2000 millisecond movement time criterion, (2) using a movement time criterion which is not as slow as the 35 cm/second movement used in the present study, or (3) dropping the 35 cm/second time and using only the other speeds which were used in the present study.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

I. SUMMARY

The purpose of this study was to determine for college age women if there was an effect of the speed of movement expected on the performance of a discrete movement with KR presented initially and then withdrawn.

Forty-eight right handed female undergraduate students enrolled in Physical Education service classes, Spring Quarter, 1979 at The University of Tennessee, Knoxville served as subjects for this study. All subjects were randomly selected from a pool of volunteers.

All assessments of data were made on a carefully scheduled basis by the experimenter. Prior to the first day of testing, each subject was randomly assigned to one of four movement speed conditions. All subjects attempted to produce a 70 centimeter movement from a start button to a padded target. The four criterion times were established at 250, 500, 1000, and 2000 milliseconds, thus producing respective speeds of 280, 140, 70 and 35 cm/second.

The study required the subject to be present one day for approximately 30 to 45 minutes. All subjects in each group received 5 practice trials (Trials 1-5) with KR (error

and direction in milliseconds), 40 trials (Trials 6-45) with KR, and then 40 trials (Trials 45-85) without KR. The interresponse intervals were each 15 seconds.

The raw movement time data were converted to AE, VE, and CE scores for further analysis. A two way-repeated measure design analysis of variance was performed on eight blocks of ten trials. Subjects were nested within groups and crossed with trial blocks. A Newman-Keuls post hoc test was administered where appropriate to examine all significant differences.

The results of the present study indicated that during practice with KR, accuracy (AE) and consistency (VE) improved for all speed groups thus supporting Adams' (1971) prediction concerning learning with KR. When KR was withdrawn consistency remained fairly constant, however accuracy diminished significantly for all speed groups ($p < .01$) which indicated that subjects were unable to improve their performance without KR. The present data also indicated that faster movements, those at movement times of 250 and 500 milliseconds with respective speeds of 280 cm/second and 140 cm/second, were more accurate and more consistent than were the groups with slower criterion movement times of 1000 and 2000 milliseconds with speeds of 70 cm/second and

35 cm/second, respectively. The analysis of CE indicated that subjects with the slowest movement time criterion, 2000 milliseconds with a speed of 35 cm/second, displayed the most irregular periods of bias, moving from the greatest extremes early to the greatest extremes late when KR was given. Performance remained almost as irregular when KR was withdrawn.

II. CONCLUSIONS

Based on this study the following conclusions were drawn:

1. The speed of the movement or movement time is the primary factor which influenced the performance accuracy (AE). Slow movements are less accurate than rapid movements.
2. The speed of movement or movement time is the primary factor which influenced performance consistency (VE). Slow movements are more variable (VE) than fast movements.
3. When KR is provided, performance accuracy (AE) and consistency (VE) improve for all speed groups.
4. During KR withdrawal, performance consistency (VE) remains fairly constant but performance accuracy (VE) diminishes for all speed groups.
5. The group with the slowest movement time has the most erratic pattern of bias during performance with KR and after KR withdrawal.

III. RECOMMENDATIONS

The results of this study suggest the need for the following additional research:

1. More KR trials should be used to insure the development of the recognition schema so that it can provide accurate subjective reinforcement when KR is withdrawn. More trials without KR might also be beneficial.

2. Studies using a task with greater complexity should be used so that additional KR trials can be administered and to prevent the occurrence of a performance ceiling.

3. The results of the present study revealed that the 250 (280 cm/second) and the 500 (140 cm/second) millisecond time groups displayed similar patterns of performance while the 1000 (70 cm/second) and the 2000 (35 cm/second) millisecond time groups also displayed similar patterns of performance. Therefore, it would be appropriate and justifiable to conduct studies using groups with varied times, speeds, and/or distances to determine the critical factor(s) which is/are affecting accuracy and what range of the effect(s) is/are producing the differences in accuracy.

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APPENDICES

APPENDIX A

LETTER TO SUBJECTS AND
INFORMED CONSENT

LETTER TO SUBJECTS

The University of Tennessee
School of Health, Physical Education and Recreation
Knoxville 37916

Division of Physical Education

May, 1979

You have been specially selected to participate in a study to determine if there is a difference in performance for accuracy of speed of an arm movement. During some trials you will be told how accurate you are and on later trials no accuracy information will be given. The study will be conducted by Susan Lynn and is a thesis research project required to complete the Masters of Science degree in Physical Education.

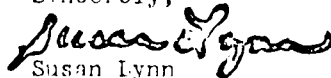
If you are willing to participate, the maximum time commitment will be one 30 minute testing session arranged at your convenience. During this session you will be asked to perform trials on a barrier task in which you move your hand from a pre-determined position to a barrier in a designated time period. On some trials you will be given information concerning the response you made; other trials no information will be given. No names will be recorded on score sheets and your scores will be treated as confidential information.

This study can be accomplished only with your help. You will be performing a real service if you agree to participate. No portion of your grades or academic standing are dependent upon participation in this study.

Please complete the attached form and sign on the master schedule when you can come. Come to Room 144 HPER on the day and time you selected.

Thank you very much for your assistance.

Sincerely,



Susan Lynn
Home phone - 546-4635
Office phone - 974-5111
Mailbox in HPER Building

Test Session:

M	T	W	Th	F		AM
						PM
Date						Time

An Academic Unit of the College of Education

INFORMED CONSENT

I understand that the purpose of this study is to determine if there is a difference in the learning of movements performed at different speeds.

I confirm that my participation as a subject is entirely voluntary. No coercion of any kind has been used to obtain my cooperation. I understand that no portion of my grades or accademic standing is dependent upon participation in this experiment.

I understand that I may withdraw my consent and terminate my participation without penalty at any time during the investigation.

I have read the letter explaining the procedures that will be used in the study and what will be required of me as a subject. I understand that any further questions I might have will be answered to my satisfaction by the experimenter.

I understand that all my responses and scores will remain completely confidential.

I wish to give my cooperation as a subject.

Date _____ Signed _____

Witness _____

Campus Address: _____

Local phone number: _____

Do you have any physical limitations? Yes _____ No _____

If yes, please describe: _____

Do you wear glasses? Yes _____ No _____

During physical activity? Yes _____ No _____

For distance? Yes _____ No _____

Do you wear contacts? Yes _____ No _____

During physical activity? Yes _____ No _____

For distance? Yes _____ No _____

Other explanation: _____

APPENDIX B

PERFORMANCE APPARATUS



Figure 6
Performance Apparatus



Figure 7
Performance Apparatus and
Subject Operation

APPENDIX C

SPECIFIC INSTRUCTIONS

SPECIFIC INSTRUCTIONS

The apparatus on which you are going to perform is in front of you. The task you are going to perform is one in which you press this button (pointed to by the experimenter) with your right index finger, then release the button and move your right hand across and knock over this barrier (pointed to by the experimenter) in * msec or approximately * sec(s). The task is not to see how fast you move your hand across and knock over the barrier. But what is important is the length of time that elapses between when you release the button and when you knock over the barrier. In your case the desired time is * msec or approximately * sec(s). The timer will start when you release the button and will stop when you knock over the barrier.

On trials 1-45 when I say "Ready," you are to press the start button (pointed to by the experimenter) and watch for the green light to appear (pointed to by the experimenter). When you see the green light you may make your response whenever you are ready. Remember, your time begins when you release the button and will stop when you knock over the barrier. After completing your response you are to remain in your finished position. Following this, I will tell you your error in msec and the direction (too fast or too slow).

Then you are to reset the barrier, return to the start position and wait for the "Ready" signal.

Do you have any questions?

Let's begin.

After completing trial 45 the following directions were read:

On trials 46-85, I will not be giving you any information concerning your response. When I say "Ready," you are to: press the start button; watch for the green light to appear; make your response; reset the barrier, and return to the start position.

Do you have any questions?

Let's begin.

* 250 msec or approximately 1/4 sec.

500 msec or approximately 1/2 sec.

1000 msec or approximately 1 sec.

2000 msec or approximately 2 sec.

APPENDIX D

EXPERIMENTER'S SCORE SHEET

EXPERIMENTER'S SCORE SHEET

Lynn (1979)

	A TT	B RT	MT	ERROR	SE	
1.						250 msec.
2.						500 msec.
3.						1000 msec.
4.						2000 msec.
5.						
6.						26.
7.						27.
8.						28.
9.						29.
10.						30.
11.						31.
12.						32.
13.						33.
14.						34.
15.						35.
16.						36.
17.						37.
18.						38.
19.						39.
20.						40.
21.						41.
22.						42.
23.						43.
24.						44.
25.						45.

	A	B						A	B					
	TT	RT	MT	ERROR	SE			TT	RT	MT	#	ERROR	SE	
46.								66.						
47.								67.						
48.								68.						
49.								69.						
50.								70.						
51.								71.						
52.								72.						
53.								73.						
54.								74.						
55.								75.						
56.								76.						
57.								77.						
58.								78.						
59.								79.						
60.								80.						
61.								81.						
62.								82.						
63.								83.						
64.								84.						
65.								85.						

COMMENTS:

VITA

Susan Kay Lynn was born in Greenville, South Carolina, on July 5, 1956, to Mr. and Mrs. C. B. Lynn.

She attended elementary schools in that city and was graduated from Wade Hampton High School in June 1974. The following September she entered Coker College, Hartsville, South Carolina and in June 1978 she received a Bachelor of Science Degree in Physical Education. In the spring of 1978, she accepted a teaching assistantship in the School of Health, Physical Education, and Recreation at The University of Tennessee, Knoxville, and began study toward a Master of Science degree in September, 1978. She expects to receive the Master of Science degree in August, 1979.