THE EFFECT OF PAST MOVEMENT EXPERIENCES ON THE REPRODUCTION OF DISCRETE MOVEMENTS

by

SERGE MICHEL LEVEILLE

B.Sc. (KINAN), Universite d'Ottawa, 1971

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE

REQUIREMENT FOR THE DEGREE OF

MASTER OF PHYSICAL EDUCATION

in the School of Physical Education and Recreation

We accept this thesis as conforming to the

required standard

THE UNIVERSITY OF BRITISH COLUMBIA

June, 1973

Department of **Physical Education and Recreation**

The University of British Columbia
Vancouver 8, Canada

Date **June 15, 1973**

ABSTRACT

The possible proactive inhibition effect of long-term past experiences upon the reproduction of discrete measurements was investigated. Ten subjects were assigned to each of the eight cells of a 2x2x2 factorial design. The two retention intervals were, 0 sec. and 30 sec.; the two locations, 60° and 120°; the two movement lengths, 10° and 50°. Each subject received five standard-reproduction trials with an intertrial interval of 30 sec. The biasing effect of long-term past experiences measured by constant error, was not significant. Different target locations did not influence the intraindividual variability of a given movement length. Significant differences were obtained between movement lengths for both constant error, in that the shorter movement was overshot to a greater extent than the longer movement; and variable error, showing a greater variability for the longer movement. The significant increase in variable error over the retention intervals indicates that the memory trace weakened as time elapsed between the presentation of the standard and its reproduction.

TABLE OF CONTENTS

LIST OF TABLES

ACKNOWLEDGEMENTS

I wish to express my appreciation to the members of my committee, Dr. R. G. Marteniuk, Dr. R. W. Schutz, Dr. W. G. Davenport and Dr. K. D. Coutts, for their comments and collaboration throughout the preparation of this thesis making it possible for me to complete the requirements in due time. To my chairman, Dr. Marteniuk, I wish to express special appreciation for his patience and guidance during my academic years at The University of British Columbia.

CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

In learning, short-term memory (STM) has always been associated with long-term memory (LTM). Information coming from the senses is placed in STM and if this information is rehearsed, it is then transferred into LTM. Recently, Schutz (1972) proposed that STM could also be used during retrieval tasks to facilitate retrieval of information. That is, information most likely to be used is brought back into STM where it is more readily available. Thus, information stored in LTM could possibly interfere with incoming information stored in STM, by means of proactive interference.

Williams (1971) and Stelmach (1969) have reported that proactive interference can influence motor short-term memory (MSTM). To study the possible influence of LTM on MSTM, there must be a form of movement information that is retained in LTM. Laabs (1973) has identified such a form of information in that he found location information from a movement is kept in a central memory code. From his results it is possible to hypothesize that through this central memory code, LTM could affect the retention of information in MSTM.

Such an effect would be mediated through what Laabs (1973) describes as an adaptation level (AL). It accounts for overshooting and undershooting in MSTM experiments where subjects are presented with a range of movements. When a subject reproduces a movement, he does so "in reference to an average movement," which is a combination of movements in the interpolated activity, in addition to the memory trace of the given movement. As the memory trace of a given movement decays and causes forgetting, more emphasis is given to the AL during reproduction.

This study is an extension of Laabs' work. Since interpolated activity in a given range is said to produce an AL in MSTM, it is also possible that such an AL could result from a person's long-term and daily past experiences (AL_{PE}). Such an AL_{PE} would be the mean of all movements (of a given limb) in the human range of movement. This mean would take into account the frequency as well as the location of the movements. Man usually works in front of himself as evidenced by writing, eating, or any precision work. The AL_{PE} would probably be located in front of the shoulder, perpendicular to the frontal plane. To make this prediction, one must accept the assumption that reproductions are more accurate when the target location coincides with the AL. Since movements reproduced on one side of the AL are undershot, while overshot on the other, then it is logical that movements reproduced at the same location as the AL would have zero constant error. Then, the fact that movement reproductions are more accurate in a well-practiced range (Lloyd and Caldwell, 1965) and that reproductions are more accurate near vertical in front of the shoulder (Brown et al., 1948; Stelmach, 1970) would support the prediction that such an AL_{PE} would exist at such a location. Also, as in other experiments in MSTM, this AL_{PE} would become more important over retention intervals just as the AL does.

The AL and AL_{PE} would not have the same influence on reproductions in time. A strength and recency trade-off would be in effect. A more recent AL would have more influence than a more distant AL_{PE}. In other words, an AL due to interpolated activity immediately preceding reproduction would cause most of the interference with the AL_{PE} having little or none. However, if the study is done within the context of MSTM and each subject reproduces only one length at one location, with an appropriate intertrial interval (ITI) to allow for sufficient trace decay, the occurrence of an AL, due to experimental conditions, would be minimized making it possible to investigate the presence of an AL_{PE}. This is the framework for this study.

Statement of the Problem

The purpose of this study is to investigate the possibility that an adaptation level resulting from long-term daily past experiences could influence the reproduction of a fine motor task when trace decay is allowed to take place.

Subproblems

The subproblems are:

1. To study the effect of different movement lengths on intra-individual variability while maintaining the target location constant.

2. To study the effect of different target locations on intra-individual variability while maintaining the movement length constant.

Hypotheses

The hypotheses are:

1. An adaptation level due to past experiences causes a shift in constant error (CE) towards the AL_{PE}. This shift is evident only in reproductions following a longer retention interval which will cause a larger variable error (VE) when compared to the shorter retention interval.

The shift in CE will not be evident in the 0 sec. interval becuase only one movement length and location will be in MSTM and the memory trace will be strong enought to guide the reproduction. As the memory trace decays over time and becomes weaker, the AL_{PE} will become more influential and its influence will be reflected in a shift in CE.

The weaker memory trace used to guide reproductions after the 30 sec. retention interval will be indexed by a larger VE score for that condition.

2. The VE is related to movement length in that the longer movement has a larger VE score when compared to the shorter movement.

The reasoning supporting this hypothesis is that the longer movement has a greater potential for variability. This is due to the fact that the longer movement is more complex and requires a longer time interval for its execution. Thus, the longer movement should be more variable.

3. The change in VE from the 0 sec. retention interval to the 30 sec. retention interval will be greater for the shorter movement than for the longer movement.

Laabs (1973) mentions that when discriminability of a given set of movements is decreased, the VE can be expected to increase. In this experiment, only one movement is given but the effect of discriminability could also apply to starting and target locations. This discriminability being less for the shorter movement should result in a greater change in VE when the memory trace is allowed to decay when compared to the change in VE of the longer movement under the same conditions.

4. The VE for a given movement length is not influenced by different target locations.

That is, the VE for a given movement length will not vary from one target location to the other. The effect of changing location should be mediated through an AL and reflected in CE, not VE. In this experiment, location is not a factor which causes interference resulting in a weakening of the memory trace (because each subject is presented only one target location). Since VE is an index of the strength of the memory trace, it will not be affected by changing the target location.

Definition of terms

Adaptation Level (AL). The adaptation level is the average movement made up from the combination of movements to be reproduced in the experimental situation (Laabs, 1973).

Adaptation Level Due to Past Experiences (AL_{PE}). The adaptation level due to past experience is the average movement made up from the combination of frequency and location of all past movements in daily activities.

Intertrial Interval (ITI). The intertrial interval is the time betwwen the end of the reproduction of a standard and the start of the execution of the next standard.

Memory Trace. The memory trace is the memory state which represents the correct response and develops as a function of practicing the correct response.

Movement Length. The movement length is the distance which the subject(s) has to move in order to reach the target location. In this study, the lengths are 10° and 50° counterclockwise.

Movement Location. The movement location is the target location which the subject has to reach in order to achieve perfect reproductions. In this study, when 0° is perpendicular to the sagittal plane, through the shoulder, the locations are 60° and 120° in a counterclockwise direction in front of the subject. When 90° is vertical to the frontal plane, in front of the right shoulder joint, the locations will be 30° away from the 90° and one on each side. Thesemovement locations and the associated movement lengths are presented in diagram form in Appendix A.

Retention Interval. The retention interval is any built-in time lapse between the presentation of the standard and its reproduction. In this study, the retention intervals will be 0 sec. and 30 sec.

Trace Decay. Trace decay is the weakening of the memory trace due to time.

Delimitations

The delimitations are:

1. The study is delimited to the recall of an arm movement in a counter-clockwise direction, in the horizontal plane, executed with the right arm.

2. The study is delimited to two measurement lengths; 10° and 50°.

3. The study is delimited to two target locations; 60° and 120°.

4. The study is delimited to two retention intervals; 0 sec. and 30 sec.

Assumptions and Limitations

The following assumptions are made:

1. Trace decay does not vary randomly but has a direct relationship with movement lengths, and retention intervals. That is, for a given length and/or retention interval, the amount of trace decay will always be the same.

2. Counting backward will have a uniform influence on all movement reproductions, either length or locations, because it is acting through the central mechanism.

3. It is assumed that the adaptation level for past experiences is located directly in frong of the shoulder but an exact location is not required for the validity of the study. A reproduction further away from the AL will be influenced to a greater extent (Laabs, 1973). For example, if the AL_{PE} was located at the 120° location, reproductions after the 30 sec. retention interval at that location would show very little or no biasing whereas reproductions at the 60° location after the 30 sec. delay would show a large biasing effect of the AL_{PE}.

The investigation is limited by:

1. The accuracy of the apparatus and of the experimenter.

2. The degree of randomness of the sample.

3. The integrity of the subjects.

Significance of the Study

The results of the study will enable a more appropriate selection of movements, with regard to length and location, for the first few practice trials when a mature individual is being trained at a new task. It will also indicate if intraindividual variability is related to movement length.

If such an AL_{PE} exists, then the movements in the first few practice trials should be located further away from the AL_{PE} than the desired final locations of the movement. If certain movements cause more VE than other movements, then they should be given more practice trials.

CHAPTER II

CRITICAL REVIEW OF THE LITERATURE AND ITS RELATIONSHIP TO THE PRESENT PROBLEM

Introduction

When an individual makes a certain movement, there are several factors acting upon the execution of that movement. A movement is never made in isolation but is influenced by the experiences which the individual has had prior to the movement. These forces acting subconsciously upon an individual at a given moment make up what Helson (1967) describes as an adaptation level. By eliminating immediate past experiences, which are usually present in short-term memory studies because each subject is given several different movements, an attempt can be made to evaluate the possible effects of long-term past experiences on the execution of discrete movements.

For long-term past experiences to influence the execution of movements, the AL formed would act on these movements in the form of proactive interference. Several other factors, such as distance, location, movement anchoring, practice, and cues, can influence movement reproductions and their influences must be taken into consideration.

Adaptation Level Theory

The theory of adaptation level is based upon the assumption that a certain order prevails over the judgements made by man (Helson, 1967).

Included in these judgements is the psychophysical realm. The AL works in such a way that stimuli located at the AL seem to be neutral whereas stimuli located above or below the AL value will elicit positive and negative responses from the subjects. Helson maintains that this AL is not static but changes in accordance with the prevailing conditions of stimulation. The AL which becomes the frame of reference for psychophysical judgements is a function of all the stimuli acting upon or within an individual at the time of judgement as well as those stimuli perceived in the past. Thus, the prevailing AL would be comprised of all long-term and immediate past experiences as well as the given stimulus.

Helson (1967) identifies three primary forces which make up the AL acting during a given experimental situation. The first one is the experimental stimuli which are the stimuli being judged; second is the contextual stimuli which are forming the background or standard for judgement; and third is a residual factor which represents the effects of all related previous stimulations. In the present study, the experimental stimulus will be the given distance at the given location. That part of the adaptation level made up from the contextual stimuli will be the same as that made up from the experimental stimulus. It must be noted that there will be only one distance at one location presented to the subject. Of special importance for this study is the residual factor which will be comprised of long-term past experiences only, because the subject is presented with only one distance at one location during the experiment. Of the three types of stimuli which combine to form the adaptation level, only the first and third will be present in the study.

Another aspect of the adaptation level theory is the importance given to the AL over time (Helson, 1967). As the time lapse from the presentation of a standard and the reproduction of that standard is increased, more importance is given to the AL when the reproduction of the standard is made. That is, the longer the interval between presentation and reproduction, the more the reproduction will approach the value of the AL. It is assumed that when the memory trace decays and becomes weaker, it is less able to guide reproductions, making them more susceptible to other factors such as the AL.

Also implied in this theory is the importance given to each factor in forming the prevailing AL. A strong memory trace would have the most influence in the formation of the adaptaion level because of its strength and recency. As the strength of the memory trace decreases as it decays, the contextual stimuli gain in importance and become more important in forming the AL. Although they are not as recent as the actual memory trace, the pooling of several contextual stimuli increase their strength in relation to the decaying memory trace. The last in importance are the residual factors or the long-term past experiences. If both experimental and contextual stimuli are present, then little importance would be given to the residual factors in forming the prevailing adaptation level; this is not the case for the present study.

A similar importance-recency trade-off has been reported by Levin, Craft and Norman (1971) when they tested an additive model for averaging motor movements. When their subjects had to make a movement which was the average of three or five given movements, the averaging responses could be predicted by a weighted average of the given stimuli. The influence of the last given movement was greater than the influence of the earlier movements. Thus, in AL terminology, the experimental stimuli would have more importance in forming the adaptation level than would have the contextual stimuli which in turn would have more importance than the residual factors.

The problem to be examined by this study is whether the residual factors can gain enough importance in the absence of contextual stimuli to influence the reproduction of precise motor movements.

Ellis (1973) attempted to evaluate the adaptation level theory using sounds as the experimental stimuli and varying the intensity (loudness). In the first part of the experiment, the subjects received seventy-two trials centered at either 50, 65 or 80 decibels. Three interstimulus intervals of one, four and seven seconds were employed separating the presentation of the standard from the comparison which was equal, plus, or minus one decibel. In the second part, all subjects received 72 trials centered on 65 decibels. The adaptation level theory would predict that in the second part, as the interstimulus interval increases, the errors of the subjects who were given the 50 decibel sound in the first part would become more negative whereas the error of the subjects who were given the 80 decibel sound would become more positive while the error of the 65 decibel group should be maintained. In accordance with the theory, a significant effect due to the prior sound level was found but the different time intervals produced a similar negative shift in errors which is contrary to the predictions. However, it is felt that these results could still be explained with reference to the adaptation level theory. On the one hand, the 72 trials of part one might not have been sufficient to create a contextual level strong enough to influence the judgement of the 72 trials of the second part, following the 5 minute rest between the parts. Furthermore, the three experimental levels of intensity might have been greater than the individual's AL for intensity before the experiment. Thus, the negative shift in error with increasing interstimulus intervals might reflect an adaptation towards the pre-experimental AL. The effect of the first 72 trials would be to slow down this adaptation to the pre-experimental level.

More closely related to the present study is the investigation by Laabs (1973) who proposes a model of motor short-term memory based on the adaptation-level theory and incorporating variable and constant error. The Laabs study uses movement reproduction as opposed to Ellis' sound recognition, making it more similar to the present experiment.

There were 6 movement lengths ranging from 10° to 35° in 5° steps and 12 final locations which were also separated by 5° intervals. The same standard-reproduction sequence was used, with reproductions being made with a movement length different from the one used in the standard to make the distance cue unreliable. In the group where the location cue was to be unreliable, the reproductions were made to different final locations. Two retention intervals were used, 0 sec. or 12 sec. with the latter being either a rest interval or filled with counting or a spatial reasoning test.

The data reported in the study support entirely the adaptation level theory. As the retention interval is increased, more emphasis is placed on the experimental or contextual AL which results in increased undershooting of the longer movements as opposed to increased overshooting of the short movements. Of importance for the present study is the fact that this tendency toward the AL is also postulated for location; that is, movement reproductions will be biased towards the AL after a retention interval. If, in the absence of contextual stimuli, the residual factors or long term past experiences are a major influence in the formation of the prevailing AL, then the biasing effect would be reflected in a shift of the constant error scores toward the adaptation level.

Anchor Theory

Another factor which can be of some help in movement reproductions is anchors. Anchors serve as points of reference to which the movement to be reproduced can be compared and/or located. MacKinnon (1972) has shown that the effect of anchors can combine with adaptation levels to influence the recognition of lifted weights. Three control groups were trained with two weights, 30 gm and 250 gm, 100 gm and 300 gm, or 150 and 350 gm, which were the positive stimuli. The three experimental groups were given negative stimuli of 150 gm, 200 gm, or 250 gm in addition to the positive stimuli. Subjects learned not to respond to the negative stimuli because reinforcement followed only a correct response to the positive stimuli and was withheld when the negative stimuli were presented. In the experimental situation, the subjects were presented with weights ranging from 50 gm to 500 gm at 50 gm intervals and were asked to recognize the learned weights. The values of subjective equality seemed to be pushed away from the negative stimuli in the experimental group when compared to the control groups. Thus, the effect of known or learned anchors can influence the judgement of weight when kinesthesis is used as a means of evaluation. These anchors work in a psychological manner similar to that of adaptation levels.

Caldwell and Herbert (1956) had previously shown that an anchoring effect was present in a horizontal straight arm movement originating from the shoulder joint. In their experiment, 0° was in front of the shoulder while 90° was perpendicular to the sagittal plane. They report clear evidence of perceptual anchoring at the ends of the range, 0° and 90° positions. There was only a slight evidence of increased accuracy near the midpoint of the range tested.

For the present investigation, considerations were given to the possible influence of anchors on the reproduction of movements when the selection of movement lengths and locations was made. The range of movement made possible through the combination of elbow flexion and shoulder rotation used in this study is much greater than that of Caldwell and Herbert (1956), covering approximately one hundred and eighty degrees in the horizontal plane. The two movement locations are approximately sixty degrees from the closer end of the range where the anchoring effect would be located and strongest. Unlike MacKinnon (1972), there are no negative stimuli used within the range to create an anchoring effect. Since all the movements are to be executed in a counterclockwise direction, the movement lengths were selected so that they could be easily executed without undue stretching of muscle fibers at both locations. A movement longer than fifty degrees could have been easily reproduced at the 120° location but would have caused greater stretching of the musculature to reach the starting location when the target location was 60°, making the two conditions dissimilar.

Proactive Inhibition

Comparisons are always made between verbal short-term memory and motor short-term memory; this is also the case for proactive inhibition (PI). In verbal STM, PI is a strong factor. On the other hand, several studies in MSTM have failed to find the effect of PI (Adams and Dijkstra, 1966; Posner and Konick, 1966). However these two studies used relatively long ITI which might prevent PI. Schmidt and Ascoli (1970) in an attempt to resolve the problem, gave their subjects either a 10 or 90 second ITI in the reproduction of a linear movement. Their results pointed to a null effect of ITI because no PI occurred in the experiment which is similar to the results of Montague and Hillix (1968).

On the other hand, a similarity between verbal and motor STM with respect to proactive inhibition has also been reported. Stelmach (1969a) showed that absolute errors at recall were directly related to the number of prior positions. The number of prior positions varied from 0 to 4. The same researcher (Stelmach, 1969b) related PI to the similarity of responses. He found that absolute errors at recall were inversely related to the similarity of the prior responses about the target position. This result was replicated later by Craft and Hinrichs (1971).

Ascoli and Schmidt (1969) used a simple linear positioning task to study the effect of PI in MSTM. The subject was presented with either 0, 2, or 4 positions before being given the criterion which he was to recall 10 or 120 seconds later. All the movements were recalled in reverse order. PI effects were found only in the group with 4 prior positions resulting in greater absolute error and greater undershooting with algebraic error when compared to the other two groups. In a similar study, Williams (1971) manipulated prior positions, practice reinforcements of the criterion distance, and retention interval. Absolute error scores at recall indicated a PI effect but only for the condition of five prior learning, with one criterion distance after 15 and 50 sec. retention intervals.

At best, proactive inhibition seems to be relatively weak in producing interference in MSTM. This indication is similar to that of Montague and Hillix (1968). They gave each subject seven trials with different lengths with each trial consisting of four standard-reproduction sequences. The between trial comparisons showed no effect of PI but such an effect was evident when only the first standard-reproduction sequence of each trial was compared. Thus, the PI effect was not strong enough or important enough in the formation of the prevailing AL to offset the importance given to two or more repetitions of the experimental stimuli in making up this AL. The negative effect of PI with decreased ITI when each subject is given repeated presentations of the same position could be due to the fact that with repeated presentations, the memory trace enters long term memory where it could not interfere with information coming into short-term memory. This null PI effect from long-term memory has been proposed for verbal memory by Scott, Whimbley and Dunning (1967).

Proactive inhibition seems to be the weaker factor when compared with retroactive inhibition. This was shown by Craft and Henrichs (1971) and Craft (1973) when they studied the effect of interfering movements either before the standard-reproduction sequence or interpolated between the standard and the reproduction.

Although weak, the proactive inhibition effect seems to be present. In the Levin, Craft and Norman (1971) additive model for motor movements, the subject when asked to average a series of given movements, subconsciously placed more emphasis on the movement presented just before, indicating a PI effect. When Ellis (1973), in his evaluation of Helson's adaptation level theory, mentions that a significant effect due to prior levels was evident, he is in fact proposing a PI effect. Similarly, PI, as well as retroactive inhibition, has to be a factor in both Laabs' adaptation level theory for movements (1973) as well as Pepper and Herman's assimilation theory (1970). If it wasn't for the interference factor, neither adaptation nor assimilation could result from a series of movements nor could they in turn affect the next movement.

In the present study the only source of PI expected to influence reproduction is that caused by long-term experiences prior to the testing situation. Some PI effect could be generated from trial to trial but the experimental procedures used attempt to minimize this effect. These will be discussed in the next section of this chapter.

Learning Effects

The amount of learning that the subject does during the experiment is very important. If a high level of learning is achieved, then the prevailing adaptation level would be formed primarily by the experimental stimuli with little importance given to long-term past experiences, defeating the purpose of this experiment. In the Williams study (1971) the PI effect appeared after a 15 sec. retention interval but disappeared when three practice reinforcements were given. Montague and Hillix (1968) report the disappearance of a PI effect after only two practice reinforcements. On the other hand, Adams and Dijkstra (1966) report that six reinforcements were needed to significantly influence absolute errors in reproduction. Similarly, a study by Leveille (1973) showed that in a linear task, the majority of learning took place in the first ten trials as reflected by a decrease in variable error. This was without verbal knowledge of results and zero ITI. It was also shown that twenty-five practice trials did not significantly affect constant error scores.

In the present study, the subject will receive only five presentations of the criterion distance in a standard - reproduction sequence. There will be a thirty second ITI. The subject was told not to rehearse the previous movement during this interval in order to minimize the PI effect from trial to trial thus reducing the learning effect as shown by Bjork, Laberge and Legrand, 1968. The subjects in the thirty second retention interval group will have that extra time, in addition to the ITI, to allow for trace decay; again reducing the learning effect.

Cues Used in Reproduction

Researchers have investigated three types of cues which could subserve the kinesthetic process; location, distance and force (or tension).

Recently, Marteniuk and Ryan (1972) suggested that a horizontal straight arm movement was subserved by a metathetic (substitutive) process which would indicate that for the given task, judgements were made through the use of location cues rather than distance cues. Marteniuk and Roy (1973) mention, after reviewing the literature, that physiological evidence indicates the three types of kinesthetic receptors that subserve kinesthesis are found in the joint and project to the sensory cortex. These receptors would code position, direction, speed, and acceleration but not movement distance as such. These facts and the experimental data support the researchers' conclusion that distance cues, in the given task, provided less precise information about arm displacement than location cues. They further conclude that there might not be any receptors for distance making this type of information uncodeable.

For distance information to be codeable, the subserving receptors would have to be located in the muscle and monitor the extent of contraction. Granit (1972) mentions the fact that the large primary afferents from the muscle spindles project to the sensorimotor cortex. Thus, this would indicate that distance information can be encoded (assuming that effort can be equated with distance), which is contrary to Marteniuk and Roy (1973). On the other hand, these cues, as suggested by Marteniuk and Roy (1973) would be of lesser importance than location cues. According to Granit (1973), the information from the muscle spindles is integrated with the inflow of information from tendons and joints and is included in a mechanism for verifying the execution of movements and is not necessarily used in the guidance of the movement.

Several researchers have isolated and studied location and distance cues (Posner, 1967; Keele and Ells, 1972; Marteniuk and Roy, 1973, Laabs, 1973). The methodology is quite simple; changing the starting location and asking the subject to reproduce the end location makes the distance cue unreliable whereas changing the starting location and telling the subject to reproduce the movement extent renders the location cues unreliable. Maintaining the same starting and target locations for reproductions allows for both cues to be available simultaneously. The fact that movement distance information decays over an empty retention interval whereas movement location decays very little combined with the fact that interpolated activities requiring attention cause a relatively small increase in decay of distance information but a significant decay of location information led Laabs (1973) to suggest a two mode system of storage. Location information is rehearsable and stored in a central mode whereas distance information is not rehearsable and stored in a kinesthetic mode.

The effects of retention intervals and interpolated mental activity have been studied in relation to different movement lengths (Stelmach, 1970; Stelmach and Wilson, 1970). Longer movements decay over an empty retention interval with interpolated mental activity adding very little to the decay. However, shorter movements suffer little loss over an empty retention interval but significant loss when mental activity is introduced. Since short movements decay little unless a secondary task is introduced would indicate that such movements depend on location information which follow the same rule; similarly long movements would depend more on distance information. This deduction is contrary to Stelmach's (1970) who maintains that short movements depend on distance cues.

The effects of force have been studied by Wilberg (1969). He showed that constant pressure did not appear to have an effect upon the storage of information and its decay from STM. In addition to proprioceptive feedback, Adams, Marshall and Goetz (1972) studied the effect of visual and auditory feedback. The greatest loss in retention occurred for the longer interval of 90 sec. with the least amount of feedback available. That is, making all sources of feedback (auditory, visual and proprioceptive) unreliable.

In all the experiments reported in this section, the same subject had to reproduce several movements which vary in length at several locations. That is, confounded in the experimental results, are the possible influences of changing movement length and target location as well as the influence of the experimental treatment. Such an influence has been proposed by Brown (1948) Lloyd and Caldwell (1965) and Stelmach (1970) who have indicated that accuracy in reproductions might vary with the amount of practice and the target location. These two factors of movement length and movement location are especially confounded in experiments where distance or location cues are made unreliable. A reproduction using either a different movement length or a different target location, depending on the situation, is compared to the standard, which means that the effect of the experimental manipulation is not tested under the same conditions. Then the variations in reproductions obtained could result from the experimental treatment or the procedures used or both. This experiment is designed to investigate the possible effects of changing the distance or location for the reproduction of a standard.

Assimilation Theory

For MSTM, Pepper and Herman (1970) have proposed an assimilation theory. In their model, a single memory trace either interacts with interfering movements and/or decays over time. When the memory trace of a short movement interacts with that of a long movement, the resulting memory trace is a combination of both traces along the extent dimension. At recall the short movement will be overshot whereas the long one will be undershot. When the memory trace is allowed to decay, it does so along the extent dimension resulting in a shorter movement at recall. Interpolated mental activity is said to cause a positive shift in CE at reproduction.

It must be remembered that the AL theory of MSTM presented by Laabs (1973) makes the same predictions as the assimilation theory and is more closely related to the present investigation.

Summary

It has been shown that an adaptation level can be set up by the combination of several movements in STM and that such an adaptation level could influence movement reproduction through proactive inhibition. The experiment is designed to investigate the possibility that a similar AL could be set up from long-term past experiences stored in LTM and influence movement reproductions in a similar manner.

The experimental design will permit an evaluation of the effect of changing movement length and target locations for the reproduction of criterion movements. Comparison of the results of the present experiment with those of experiments exposing the subject to a range of movement lengths and location will also permit an evaluation of the effect of such a range on accuracy and variability of movements.

CHAPTER III

METHODS AND PROCEDURES

Subjects

Eighty right-handed male subjects participated in the experiment. Fifty-six of these subjects were from undergraduate and graduate studies at The University of British Columbia. The remaining twenty-four were either involved in training or members of the Vancouver Y.M.C.A. The subjects were assigned to each of the eight groups in a systematic, unbiased fashion making a total of ten subjects per group. The age of the subjects ranged from 18 to 47, giving a mean of 23.4 years. The group means ranged from 20 to 27 years.

Apparatus

The movement apparatus utilized for the experiment is the same as that used by Marteniuk and Roy (1973). A pictorial description of the apparatus is shown in Appendix A. The apparatus consisted of a half-circle of masonite board which had a diameter of 5.0 feet. On the board an arc and half degree calibrations were drawn. A lever was attached to a near frictionless pivot at the midpoint of the chord describing the arc. On the lever arm, one foot away from the centre of the pivot, there was a 5.5 inch handle which was used to move the lever. A pointer extended from the lever arm to the circumference where vertical indicators projected downward making it easier to read the performance score. The subject moved the lever in the horizontal plane in a counterclockwise direction. Wooden blocks were used to indicate the starting and target locations.

The frictionless pivot was fastened to a table. The base of the handle on the lever arm was approximately 45 inches from the floor, 7 inches higher than the table top.

Organization

The same experimenter tested all the subjects at the rate of approximately ten minutes per subject for a total of approximately twenty testing hours. The majority of the subjects were tested in The University of British Columbia Motor Learning Laboratory. The other subjects were tested at the Vancouver Y.M.C.A. The same apparatus was used at both testing locations and environmental factors such as noise level, air temperature, and size of testing room were almost identical.

Experimental Design

The subjects were divided into eight groups. Each group was given only one experimental treatment. There was one group for each of the movement lengths (10°, 50°), at each of the two locations (60°, 120°), and for each of the two retention intervals (0 sec., 30 sec.). Thus, a subject received five trials for a given length at a given location for a given retention interval. These lengths and locations were selected to minimize the possible effect of "anchors" as discussed in Chapter II. The design used was a 2x2x2x5 (retention interval x movement location x movement length x trials) factorial design with repeated measures on the last factor.

A diagram illustrating the different movement locations and movement lengths is included in Appendix A. As can be seen, each location (60° and 120°) is the movement location for two movement lengths (10° and 50°). In addition, each movement length at each location will have two groups; one for the 0 sec. retention interval and one for the 30 sec. retention interval.

Procedures

The subjects were not allowed to see the experimental apparatus to minimize the visualization of the task before the actual testing. They were asked to strip from the waist up to prevent extraneous cues from the stretching of their clothing around the shoulder and elbow joints and along the arm. The subjects were blindfolded and given ear mufflers before entering the testing area.

The subject was guided to a standard position in front of the apparatus by the experimenter. The apparatus came approximately to a height half-way between the standing subject's shoulder and hip. The subject stood as close as possible to the table without touching it with his frontal plane parallel to the table. The subject's right shoulder was directly in line and perpendicular to the pivot. The subject was instructed to remain in this position for the duration of the experiment.

Once in the standard position, the subject's right hand was placed on the handle. He was told to move the lever to get accustomed to the easiness of movements made possible by the near frictionless pivot. After a few seconds, he was told to bring both arms down to his side. To move the lever in the horizontal plane, a combination of elbow flexion and shoulder rotation is required.

The subject was instructed to maintain his movement as consistent as possible throughout the experiment. It was pointed out that time in movement was not a factor and that the movement should be of a comfortable and uniform velocity. On the command "ready" the subject was told to move his hand from his side to the handle of the lever which was at the starting position. Verbal directions were given by the experimenter to facilitate finding the handle. The command "move" told the subject that he was to move the lever at a constant speed in a counterclockwise direction until hitting a block. The subject remained at the block for two seconds, then released the handle and brought his hand back to his side. This was the beginning of the retention interval during which the experimenter returned the lever to the starting position. After the retention interval, the experimenter gave the command "ready" which signaled the subject to regrasp the lever. On the command "reproduce", the subject tried to reproduce the standard, which he had been given before, as accurately as possible. When the subject felt he was accurate, he released the handle and brought his hand back to his side. This was the start of the inter-trial interval. The subject was given five such pairs of movements to make up the five trials required for the experiment.

The retention intervals used in the experiment were zero and thirty seconds. In the 0 sec. retention interval, the experimenter returned the lever to the starting position while the subject returned his hand to his side, as soon as this was executed, the experimenter gave the command "ready" followed by "reproduce". The subjects in the 30 sec. retention interval groups were given a three digit number as soon as they released the lever after the standard movement. They were instructed to count backward from the given digit by three's, out loud and as fast as possible. After 30 seconds of counting, the experimenter gave the command "ready" followed by "reproduce" when the subject had regrasped the handle. The thirty second retention interval was chosen because it was felt that this time lapse would allow sufficient decay of the standard to allow the AL_{PE} a sufficient gain in importance so that its effect could be noticed in the reproductions. Some studies in STM have used longer retention intervals of 120 sec. (Ascoli and Schmidt, 1969); and 90 sec. (Marshall, 1972) but other researchers have had significant results using retention intervals of 30 sec., (Stelmach and Barker, 1970) 20 sec. (Stelmach and Bassin, 1971, Stelmach and Wilson, 1970), 15 sec. (Williams, 1971) and 12 sec. (Laabs, 1973).

The mental task was introduced to prevent the rehearsal of location information. Laabs (1973) has shown that location information decays very little over a rest period unless rehearsal is prevented. In this study, the availability of both distance and location cues at reproduction, made it necessary to introduce this mental activity to promote trace decay.

During the 30 sec. ITI, the subject was asked not to rehearse the previous movement in order to allow for it to decay in STM; Bjork, LaBerge and Legrand (1968) found that instructions to forget a prior item reduced the proactive inhibition effect, hence the learning capacity. Here again, the thirty second delay was judged sufficient for sufficient trace decay thus limiting the amount of learning from trial to trial.

Analysis of the Data

The two dependent variables were constant error (CE) and variable error (VE). CE is defined as the mean algebraic error for each subject, while VE is the standard deviation of each subject's algebraic error scores about his CE. These measures have been shown to be statistically independent (Schutz and Roy, 1973).

Pepper and Herman (1970) suggested that CE measured the biasing effect of the experimental treatment on the memory trace. Laabs (1973) contends that VE measures the strength of the memory trace; the smaller the VE, the greater the strength of the memory trace. In the present study, CE is postulated to measure the biasing effect of the AL_{PE} whereas VE is thought to measure the strength of the memory trace.

The CE was calculated as the mean of the S's five trials. These CE means were analyzed in a 2x2x2 (retention interval x movement length x movement location) analysis of variance.

The VE, or the standard deviation, for each S's five trials, was determined. These VE scores were analyzed in a 2x2x2 (retention interval x movement length x movement location) analysis of variance.

CHAPTER IV

RESULTS AND DISCUSSION

Results

Analysis of Constant Error

The analysis of variance of CE (Table 1, Appendix B) revealed a significant main effect for distance $F\ (1, 72) = 6.61$, $p<.05$. The other two main effects of retention interval $F\ (1, 72) = 1.33$, and location $F\ (1, 72) = 0.04$ did not reach significance nor did any of the interactions. Thus the only significant difference in CE was between the two movement lengths of 10° and 50°. The CE values for these main effects are represented in Table 1.

Table I

The Main Effects in Constant Error

Main Effect (degrees)					
Retention		Distance*		Location	
0 sec.	30 sec.	10°	50°	60°	120°
1.5	2.5	3.1	0.9	1.9	2.1

* Effect significant, p<.05

Analysis of Variable Error

The analysis of variance of VE (Table II, Appendix B) revealed a significant main effect of retention interval $F(1,72) = 23.14$, $p < .01$ and distance $F(1, 72) = 27.19$, $p < .01$. The other main effect of location $F(1, 72) = 2.93$ did not reach significance nor did any of the interactions. Thus, there was a significant difference in VE between the two retention intervals of 0 sec. and 30 sec. Similarly, the VE for the short movement of 10° was significantly different from the VE for the long movement of 50°. The VE scores for these main effects are represented in Table II

TABLE II

The Main Effects in Variable Error

Main Effect Degrees					
Retention **		Distance **		Location	
0 sec.	30 sec.	10°	50°	60°	120°
2.6	4.5	2.5	4.6	3.9	3.2

** Effect significant; $p < .01$

Test for Homogeneity

A test for homogeneity of variance was applied to the data. Since only the main effects in CE and VE were significant (Table I and Table II), it was decided to apply Hartley's test (Winer, 1962: 92-96) only to those groups, giving two treatment groups with forty subjects per group. The results of the test are summarized in Table III.

As evident in Table III there is a borderline case of heterogeneity in error variance of both dependent measures CE and and VE at the .01 level. Even though that is the case, it is felt that the significant effects obtained are still valid because the analysis of variance would be fairly robust to deviations from homogeneity of error variance due to the equally large number of subjects (40) per group (Edwards, 1960: 132).

Table III

Homogeneity of Error Variance in Data
for CE and VE Measures

Dependent Variable	Group	Variance	Fmax
CE	D_1	7.4	2.4
	D_2	18.0	
VE	R_1	2.4	2.4
	R_2	5.7	
	D_1	2.2	2.6
	D_2	5.7	

Fmax (2, 39) = 1.96 $p<.05$
Fmax (2, 39) = 2.44 $p<.01$

Also to be taken into consideration is the level of significance reached by the different main effects. The main effect of distance in CE reached a value of F (1, 72) = 6.61 which is much closer to the F (1, 72) = 7.01 value which is required for significance at the .01 level than the F (1, 72) = 3.98 value which is required for significance at the .05 level. Here again, this significance is probably valid because of the strength given to the analysis of variance by the large and equal number of subjects per group.

Similarly, the F value obtained on VE scores for the main effects of retention interval F (1, 72) = 23.14 and distance F (1, 72) = 27.19 are highly significant at the .01 level which requires an F value of only F (1, 72) = 7.01. Thus, it is felt that these significant differences are valid.

Discussion

Since no significant differences were obtained in the CE measure for retention intervals and locations, the first hypothesis must be rejected. That is, long-term past experiences do not affect the reproduction of discrete movements. To ensure that the possible effect of long-term past experiences had not been influenced by a practice effect of the five trials, the scores for CE of the first trial of each subject were entered in an analysis of variance. As shown in Table III, Appendix B, none of the main effects or interactions reached significarce. This being a second proof that past experiences in LTM do not affect movement reproductions.

The null effects show that either no AL_{PE} is formed in LTM or there is no PI from LTM or both of these. On the other hand, an AL for LTM acting through PI might not be strong enough to influence reproductions. It seems that the first two suggestions are likely to be occurring.

If one accepts Hebb's physiological point of view (Hebb, 1961:41) that on unstable activity trace becomes a more stable structural trace with reinforcement, without getting involved in arguments concerning a single mechanism memory theory (Gruneberg, 1964, 1970) or a dual mechanism memory theory (Scott, Whimbley and Dunning, 1967a, 1967b), then it is possible that after sufficient reinforcements the resulting structural trace is an entity in LTM and as such is treated individually during retrieval. Thus, all traces in LTM would be kept separate, although probably in some hierarchial way, and would not combine to form an AL for LTM.

Scott, Whimbley and Dunning (1967a, 1967b) have shown that in verbal memory, there is no PI effect from previously learned items in LTM acting upon newly learned items in STM. This lack of PI could be explained for motor memory using the model for MSTM developed by Craft (1973). His results indicate that the interfering effect of one movement on the recall of another occurs at the time of completion of the second movement rather than at recall. Furthermore, the degree of interference is related to the amount of time elapsed between establishment of the memory trace and the trace which interferes with it. According to this model, the effect of PI is represented in this form; I - Δt - S - R where I is the interfering trace, Δt is the time elapsed between the interfering trace (I) and the stimulus (S). R is the reproduction of S. In the present study, I is located in LTM but is not actively reproduced in the experimental situation. The time elapsed between I and S (Δt) is indefinite but greater than any time interval used in studies of STM. Thus, only the remaining two factors S and R are physically present. Because of the very weak or non-existent I and the relatively long Δt, PI in the present study could not influence the reproduction of the stimulus.

Of interest, concerning constant errors, is the lack of significant change over retention intervals for either of the distances at either location. This is in contrast to the study by Laabs (1973) and other similar studies (Stelmach, 1970; Stelmach and Wilson, 1970) which, after a retention interval, report increasing undershooting for long movements and increasing overshooting for short movements. Perhaps those biases toward an AL can only be seen in studies where the same subject is given different movement lengths at different locations thus setting up what could be called an experimental AL. Therefore Laabs' (1973) prediction that forgetting in the central mode of storage will cause a biasing effect toward the location AL, could only be applied to experiments where a subject is presented with a range of distances and locations. The same restriction could be applied to the prediction that forgetting in the kinesthetic mode of a storage will cause a biasing effect toward the movement length AL although the significant effect of distance on CE found in the present study might indicate the presence of an inherent adaptation level for movement length. Since the longer distance was only slightly overshot, this AL would be represented by a movement slightly longer than 50°. Hirschfield, Leveille and Thomas (1973), also using independent groups, did not find such a trend in CE for linear movements of 6 cm., 12 cm., 18 cm., 24 cm. and 30 cm. Unlike the present study, the movements were reproduced at different locations to the left of the right shoulder, which could be moving away from the location of greatest accuracy, apparently located at 90° in front of the shoulder. More research is needed in this area but Brown, Knauft and Rosenbaum (1948) and Stelmach (1970) hint to its existence. In the present study, the two locations were symmetrical about the 90° which could explain why the CE were similarly inaccurate.

Another point of interest concerning constant error is the positive shift over retention interval. These findings were not significant but are in agreement with Pepper and Herman (1970) who postulate such a shift when the retention interval is filled with a mental activity such as counting. A quick look at the R x D interaction reveals that both distances have a similar shift in CE. The 10° distance went from 2.6 to 3.5; the 50° distance, from 0.4 to 1.4. Thus, it seems that the assumption concerning the effect of counting on different movement lengths was valid although this cannot be given unequivocal status because the experiment was not designed to look at this problem. It is possible that shorter movements decay less and are influenced to a lesser degree by counting whereas longer movements could decay more but at the same time be more susceptible to counting; such a combination would yield results similar to those obtained. Such an interaction could be possible since the VE scores did differ in the predicted direction for movement lengths with VE here being interpreted as an index of the strength of the memory trace.

The first hypothesis also suggested that intra-individual variability would increase following a retention interval. The main effect of retention interval for VE was highly significant. This result is similar to Laabs (1973) and is seen to undermine the assimilation theory of Pepper and Herman (1970) which requires that the subject reproduce faithfully the extent represented by the decaying trace yielding a negative shift in CE. However, it has been shown that the variability increases when the memory trace decays.

The second hypothesis which related VE directly to movement length was supported. The main effect of distance was significant for the VE scores with the shorter movement being less variable than the longer one. This result is similar to those of Hirschfield, Leveille and Thomas (1973) who found that VE scores increased as the movement length increased. This finding could be important, unless steps are taken to balance the effect, in studies which have different movement lengths for the standards and reproductions. When the reproduction length is shorter, the subject reproduces with a movement which is less variable and could conceivably be less affected by manipulations. However, a longer movement in reproduction is more variable than that of the standard and could be influenced to a greater degree by biasing factors. Unfortunately, studies attempting to look at the different cues subserving kinesthesis have confounded this effect. To make the distance cue unreliable, different movement lengths are used to reach the same location; the present study has shown that different movement lengths have different VE.

The third hypothesis predicted a significant interaction between movement lengths and retention intervals. The greater increase in VE for the shorter movement when compared to the VE increase of the longer movement did not materialize. In fact both movement lengths changed in a similar manner. Thus, when different movement lengths are subjected to the same conditions, their changes are similar. It seems that discriminability of starting and target locations is not an important factor.

The predictions of the fourth hypothesis, that changing the target location for a given movement length, would not influence the variability of that movement, was correct. The main effect of location as well as the interactions of location and distance and location and retention interval did not reach significance. Thus, in independent groups, changing the target location of a given movement does not affect that movement's variability. In studies attempting to investigate the location cues, the same movement length is used, hence having the same variability, but the reproduction might be affected by PI since the same subject experiences both locations. Marteniuk and Roy (1973) have reported such bias.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The main purpose of this study was to investigate the possibility that an adaptation level made up of long-term past experiences could influence the reproduction of discrete movements. Interference from the experimental situation was kept to a minimum allowing such an AL to possibly influence movement reproduction. Other problems investigated were (1) the evaluation of VE for different movement lengths at the same location and (2) the differences of VE for a given movement length at different locations.

Eighty right-handed male subjects were tested. Ten subjects were assigned to each group.

The task involved the reproduction of a given standard after a given retention interval at a given location. One group was assigned to each of the cells of a 2x2x2 factorial design. The two retention intervals were 0 sec. and 30 sec.; the two movement locations, 60° and 120°; and the two movement lengths, 10° and 50°. Each subject was given five standard-reproduction sequences of the given standard for the given retention interval at the given location with an ITI of 30 sec.

The results indicated that long-term past experiences did not influence movement reproduction and that the target location did not affect the variability of a given movement. A significant difference in variability between the two movement lengths was evident, as well as between the two retention intervals.

Conclusions

The conclusions were:

1. Long-term past experiences do not influence the reproduction of discrete motor movements.

2. Changing the target location for a given movement length does not change the variability of that movement.

3. The variability of a movement is related to the movement length. In this experiment, the longer movement was significantly more variable than the shorter movement.

4. The variability of a given movement increases as the retention interval increases. This variability is seen as an index inversely related to the strength of the memory trace.

BIBLIOGRAPHY

ADAMS, J.A., A closed-loop theory of motor learning. Journal of Motor Behavior, 3:111-149, 1971.

ADAMS, J.A. and DIJKSTRA, S., Short-term memory for motor responses. Journal of Experimental Psychology, 71:314-318, 1966.

ADAMS, J.A., MARSHALL, P.H. and GOETZ, E.T., Response feedback and short-term motor retention. Journal of Experimental Psychology, 92:92-95, 1972.

ASCOLI, K.M. and SCHMIDT, R.A., Proactive interference in short-term retention. Journal of Motor Behavior, 1:29-36, 1969.

BJORK, R.A., LABERGE, D. and LEGRAND, R., The modifications of short-term memory through instructions to forget. Psychonomic Science, 10:55-56, 1968.

BROWN, S.S., KNAUFT, E.B. and ROSENBAUM, G., The accuracy of positioning reactions as a function of their direction and extent. American Journal of Psychology, 61:167-182, 1948.

CRAFT, J.L., A two process theory for the short-term retention of motor responses. Journal of Experimental Psychology, 98:196-202, 1973.

CRAFT, J.L. and HINRICHS, J.V., Short-term retention of simple motor responses: similarity of prior and succeeding responses. Journal of Experimental Psychology, 87:297-302, 1971.

EDWARDS, A.L., Experimental Design in Psychological Research. New York: Holt, Rinehart and Winston, 1960.

ELLIS, H.D., An examination of the adaptation-level theory account of time errors. Journal of Experimental Psychology, 98:160-163, 1973.

GRANIT, R., Constant errors in the execution and appreciation of movement. Brain: A Journal of Neurology, 95:649-660, 1972.

GRUNEBERG, M.M., The limited capacity hypothesis and short-term memory. Acta Psychologica, 31:326-339, 1969.

GRUNEBERG, M.M., A dichotomus theory of memory - unproved and unprovable. Acta Psychologica, 34:489-496, 1970.

HEBB, D.O., Distinctive features of learning in the higher animal. In J.F. DELAFRESNAYE (Ed.), Brain Mechanisms and Learning. Oxford: Blackwell, 37-46, 1971.

HELSON, H. and BEVAN, W., Contemporary Approaches to Psychology. Toronto: D. Van Nostrand Company, Inc., 273-310, 1967.

HIRSCHFIELD, T., LEVEILLE, S.M. and THOMAS, G., The effect of multiple movement lengths on constant and variable errors. Unpublished data, 1973.

KEELE, S.W. and ELLS, J.G., Memory characteristics of kinesthetic information. Journal of Motor Behavior, 4:127-135, 1972.

LAABS, G.S., Retention characteristics of different reproduction cues in motor short-term memory. Journal of Experimental Psychology, 1973, in press.

LEVEILLE, S.M., The effect of practice on constant error and intraindividual variability. Unpublished data, 1973.

LEVIN, I.P., CRAFT, J.L. and NORMAN, K.L., Averaging of motor movements: tests of an additive model. Journal of Experimental Psychology, 91: 287-294, 1971.

LLOYD, A.J. and CALDWELL, L.S., Accuracy of active and passive positioning of the leg on the basis of kinesthetic cues. Journal of Comparative and Physiological Psychology, 60:102-196, 1965.

MARTENIUK, R.G. and ROY, E.A., The codability of kinesthetic location and distance information. Acta Psychologica, 1973, in press.

MARTENIUK, R.G. and RYAN, M.L., Psychophysics of kinesthesis: angular movements. Journal of Motor Behavior, 4:135-142, 1972.

MONTAGUE, W.E. and HILLIX, W.A., Intertrial interval and proactive interference in short-term motor memory. Canadian Journal of Psychology, 22:73-78, 1968.

PEPPER, R.L. and HERMAN, L.M., Decay and interference effects in the short-term retention of a discrete motor act. Journal of Experimental Psychology, Supplement, 83:1-18, 1970.

POSNER, M.I., Characteristics of visual and kinesthetic memory codes. Journal of Experimental Psychology, 73:103-107, 1967.

POSNER, M.I. and KONICK, A.F., Short-term retention of visual and kinesthetic information. Organic Behavior and Human Performance, 1:71-86, 1966.

SCHMIDT, R.A. and ASCOLI, K.M., Intertrial intervals and motor short-term memory. Research Quarterly, 41:432-438, 1970.

SCHUTZ, R.W., A theory of motor memory retrieval. Unpublished doctoral dissertation, University of Wisconsin, 1972.

SCOTT, K.G., WHIMBLEY, A.E. and DUNNING, G., Separate LTM and STM systems? Psychonomic Science, 7:55-56, 1967a.

SCOTT, K.G., WHIMBLEY, A.E. and DUNNING, G., A functional differentiation of STM and LTM. Psychonomic Science, 7:143-144, 1967b.

STELMACH, G.E., Prior positioning responses as a factor in short-term retention of a simple motor task. Journal of Experimental Psychology, 81:523-526, 1969a.

STELMACH, G.E., Short-term motor retention as a function of response-similarity. Journal of Motor Behavior, 1:37-44, 1969b.

STELMACH, G.E., Kinesthetic recall and information reduction activity. Journal of Motor Behavior, 2:183-194, 1970.

STELMACH, G.E. and BASSIN, S.L., The role of overt motor rehearsal in kinesthetic recall. Acta Psychologica, 35:56-63, 1971.

STELMACH, G.E. and WILSON, M., Kinesthetic retention, movement extent and information processing. Journal of Experimental Psychology, 85:425-430, 1970.

WILBERG, R.B., Response accuracy based upon recall from visual and kinesthetic short-term memory. Research Quarterly, 40:407-414, 1969.

WILLIAMS, I.D., The effect of practice trials and prior learning on motor memory. Journal of Motor Behavior, 3:205-211, 1971.

WINER, B.J., Statistical Principles in Experimental Design. New York: McGraw-Hill Book Co., 1962.

APPENDIX A

Apparatus

MOVEMENT APPARATUS

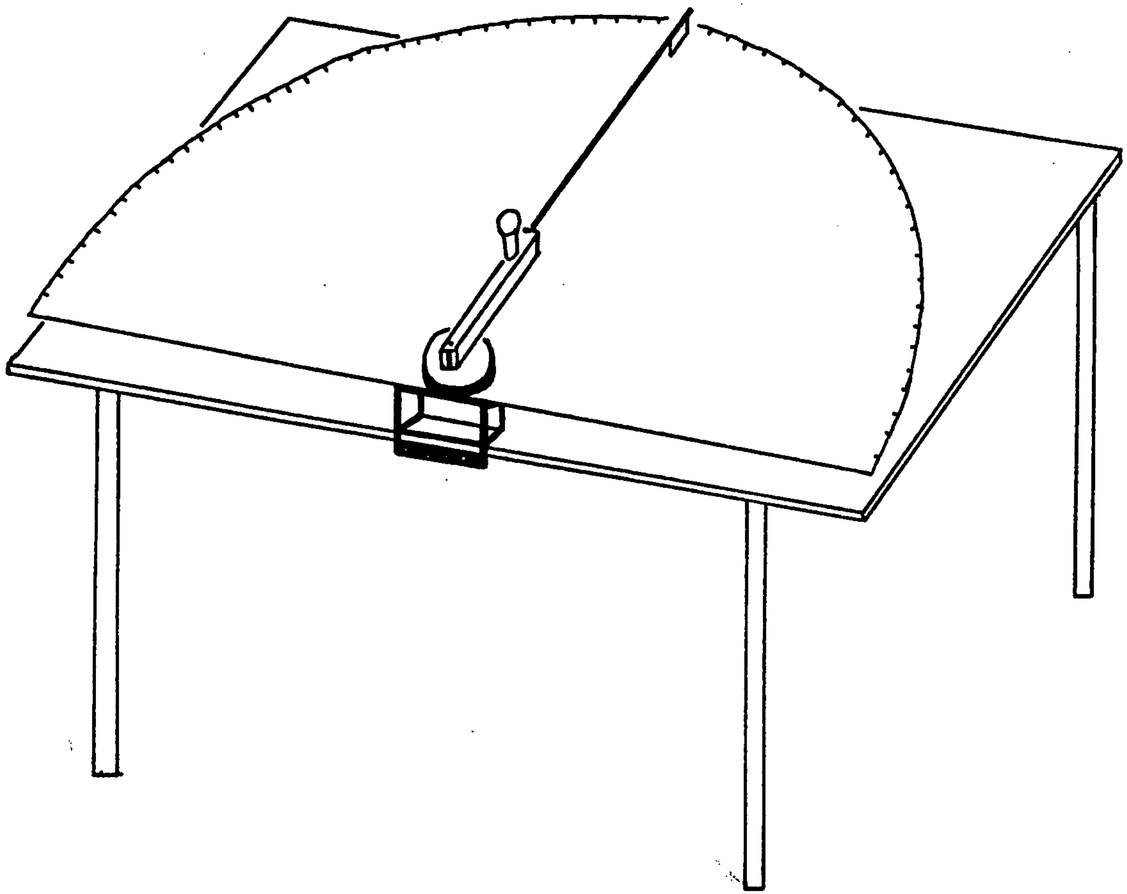
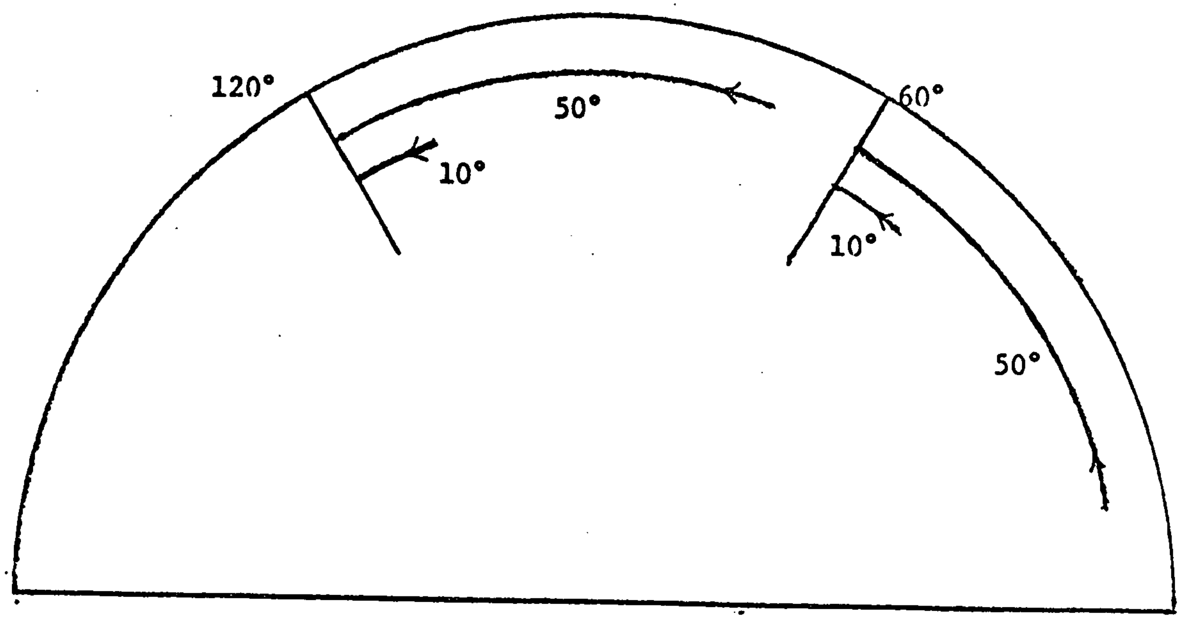


ILLUSTRATION OF MOVEMENT LENGTHS AND LOCATIONS



APPENDIX B

Statistical Analysis

TABLE I

Analysis of Variance of Constant Error

Source of Variance	df	M S	F
Retention	1	17.9	1.3
Location	1	0.5	0.0
Distance	1	88.8	6.6 *
RxL	1	0.5	0.1
RxD	1	0.6	0.
LxD	1	19.3	1.4
RxLxD	1	10.8	0.8
SwRxLxD	72	13.4	

* $p<.05$

TABLE II

Analysis of Variance of Variable Error

Source of Variance	df	M S	F
Retention	1	72.5	23.1 **
Location	1	9.2	2.9
Distance	1	85.2	27.2 **
RxL	1	3.4	1.1
RxD	1	2.4	0.8
LxD	1	0.1	0.0
RxLxD	1	0.4	0.1
SwRxLxD	72	3.1	

** $p<.01$

TABLE III

Analysis of Variance of Constant Error

for the First Trial

Source of Variance	df	M S	F
Retention	1	124.3	2.0
Location	1	1.4	0.0
Distance	1	102.4	1.6
RxL	1	7.9	0.1
RxD	1	0.6	0.0
LxD	1	94.8	1.5
RxLxD	1	9.6	0.2
Sw(RxLxD)	72	62.7	

F (1, 72) = 3.98 p .05

APPENDIX C

Table of Means

TABLE I

The Effect of Retention Interval, Location, and Distance on Movement Reproduction in Terms of CE

Retention	Location	Distance	Error (deg)
0 sec.	60°	10°	2.6
		50°	0.2
	120°	10°	2.6
		50°	0.7
30 sec.	60°	10°	4.4
		50°	0.6
	120°	10°	2.6
		50°	2.3

TABLE II

The Effect of Retention Interval, Location, and Distance on Movement Reproduction in Terms of VE

Retention	Location	Distance	SD (deg)
0 sec.	60°	10°	1.8
		50°	3.7
	120°	10°	1.7
		50°	3.2
30 sec.	60°	10°	3.9
		50°	6.2
	120°	10°	2.7
		50°	5.2

TABLE III

Table of Means for the First Trial

Retention	Location	Distance	Mean
0 sec.	60°	10°	2.7
		50°	-1.1
	120°	10°	1.6
		50°	0.7
30 sec.	60°	10°	6.4
		50°	1.4
	120°	10°	2.7
		50°	3.3