LIESE, James Edward, 1943-
SHORT-TERM MEMORY FOR A MOTOR RESPONSE.

The Ohio State University, Ph.D., 1969
Education, physical

University Microfilms, Inc., Ann Arbor, Michigan
SHORT-TERM MEMORY FOR A MOTOR RESPONSE

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

James Edward Liese, B.A., M.A.

The Ohio State University
1969

Approved by

[Signature]

Advisor

School of Physical Education
To

My Parents
ACKNOWLEDGMENTS

The writer wishes to express his gratitude to Dr. Chalmer Hixson for his assistance and guidance in the preparation of this study. Special appreciation is given for his encouragement and friendship during the writer's years of graduate study.

A special note of appreciation is due Dr. Delos D. Wickens for his help in setting up the design of this study and in the interpretation of the data.

For his helpful suggestions, the writer is grateful to Dr. Richard Bowers.
VITA

January 25, 1943  Born - Oakland, California

1964 . . . . .  B.A., Chico State College, Chico, California

1965 - 1966 . .  Teacher, Physical Education Department, St. Bernard's Elementary School, New York City

1966 . . . . .  M.A., Teachers College, Columbia University, New York City

1966 - 1968 . .  Teaching Assistant, The Ohio State University, Columbus, Ohio

1968 - 1969 . .  Instructor, The Ohio State University, Columbus, Ohio

FIELDS OF STUDY

Major Field: Physical Education


Minor Field: Psychology

Experimental Psychology. Professors Delos Wickens and George Briggs.
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>VITA</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF ILLUSTRATIONS</td>
<td>viii</td>
</tr>
<tr>
<td>Chapter</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td>6</td>
</tr>
<tr>
<td>Sub-problem</td>
<td>7</td>
</tr>
<tr>
<td>Basic Assumptions</td>
<td>7</td>
</tr>
<tr>
<td>Limitations</td>
<td>7</td>
</tr>
<tr>
<td>Definitions</td>
<td>7</td>
</tr>
<tr>
<td>II. REVIEW OF RELATED LITERATURE</td>
<td>9</td>
</tr>
<tr>
<td>III. METHOD</td>
<td>23</td>
</tr>
<tr>
<td>Subjects</td>
<td>23</td>
</tr>
<tr>
<td>Apparatus</td>
<td>23</td>
</tr>
<tr>
<td>Design</td>
<td>24</td>
</tr>
<tr>
<td>Procedure</td>
<td>26</td>
</tr>
<tr>
<td>IV. ANALYSIS AND DISCUSSION OF THE DATA</td>
<td>28</td>
</tr>
<tr>
<td>Analysis</td>
<td>28</td>
</tr>
<tr>
<td>Discussion</td>
<td>36</td>
</tr>
<tr>
<td>V. SUMMARY AND CONCLUSIONS</td>
<td>46</td>
</tr>
<tr>
<td>Summary</td>
<td>46</td>
</tr>
<tr>
<td>Conclusions</td>
<td>47</td>
</tr>
</tbody>
</table>
CONTENTS--Continued

APPENDIX

PHOTOGRAPHS SHOWING TESTING INSTRUMENT AND POSITION OF SUBJECT ................... 48

BIBLIOGRAPHY .................................................. 51
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Summary of Retroactive and Proactive Inhibition Effects</td>
<td>12</td>
</tr>
<tr>
<td>2. Order of Treatment Presentation to Subject A and B</td>
<td>25</td>
</tr>
<tr>
<td>3. Mean and Standard Deviation Scores (in m.m.) of All Retention Intervals Using Absolute Error</td>
<td>29</td>
</tr>
<tr>
<td>4. Mean and Standard Deviation Scores (in m.m.) of All Distances Using Absolute Error</td>
<td>29</td>
</tr>
<tr>
<td>5. Summary of the Analysis of Variance for Absolute Error</td>
<td>30</td>
</tr>
<tr>
<td>6. Multiple Range Test for Retention Intervals (Absolute Error)</td>
<td>31</td>
</tr>
<tr>
<td>7. Multiple Range Test for Distance Means (Absolute Error)</td>
<td>32</td>
</tr>
<tr>
<td>8. Mean and Standard Deviation Scores (in m.m.) of All Retention Intervals Using Algebraic Error</td>
<td>33</td>
</tr>
<tr>
<td>9. Mean and Standard Deviation Scores (in m.m.) of All Distances Using Algebraic Error</td>
<td>33</td>
</tr>
<tr>
<td>10. Summary of the Analysis of Variance for Algebraic Error</td>
<td>34</td>
</tr>
<tr>
<td>11. Multiple Range Test for Retention Intervals (Algebraic Error)</td>
<td>35</td>
</tr>
<tr>
<td>12. Multiple Range Test for Distance Means (Algebraic Error)</td>
<td>36</td>
</tr>
</tbody>
</table>
## LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Two Stages of Forgetting</td>
<td>18</td>
</tr>
<tr>
<td>2.</td>
<td>Curve Showing Absolute Mean Error for All Retention Intervals</td>
<td>37</td>
</tr>
<tr>
<td>3.</td>
<td>Curve Showing Algebraic Mean Error for All Retention Intervals</td>
<td>38</td>
</tr>
<tr>
<td>4.</td>
<td>Curve Showing Algebraic Mean Error for All Distances</td>
<td>43</td>
</tr>
</tbody>
</table>
A significant amount of research has been completed by psychologists in the area of short-term memory (STM). Furthermore, some physical educators have attempted to examine the nature of STM in the last few years. The importance attached to short-term storage is evident when one realizes that all information processed and retained by an individual must pass through a STM. Therefore, any verbal or motor material that is to be learned must persist throughout STM until it can be placed into long-term storage. Thus, how much individuals forget during STM seems to be essential to the teaching-learning process.

STM refers to an individual's immediate memory span after a stimulus or learning experience. This span is measured in seconds immediately after the presentation of some learning material. Studies of verbal learning have found that subjects can usually recall material quite accurately if there is no intervening activity during the retention interval. Thus, most verbal studies assign some neutral activity during the retention interval to prevent rehearsal. When this technique is used, the ability to
recall disintegrates as a function of time between the stimulus and recall. Studies of motor learning have generally shown the same results when using the "rehearsal preventive" technique. A common method of distracting the subject during the retention interval is to assign the task of counting backwards. The present study did not use this method because the learning of motor skills in the class is not structured in this manner; i.e., students are allowed and encouraged to rehearse the skill being learned. Teachers want students to concentrate on the skill being learned. Activity which distracts the student would be detrimental to the learning process.

Presently, there are two theories which can be thought of as best explaining forgetting. The most popular and the most serviceable is the interference theory.¹ In contemporary psychology there are more advocates of this theory because the findings of the majority of forgetting studies support it. Interference theory explains forgetting on the basis of an associative bond between two or more elements. There are two associative interference factors: proactive interference (PI) and retroactive interference (RI). The ability to recall material "... from a learning experience is a function of experiences prior to learning that

interfere with recall (PI) and experiences that occur after learning that decrease performance on recall (RI)."\(^2\) The basic nature of interference factors in forgetting was first explained in 1932 by McGeoch.\(^3\)

The trace theorists state that upon presentation of some learning material a rapidly decaying memory trace is formed. This trace can be kept active only through rehearsal. If an individual is prevented from rehearsing, the trace will decay immediately until it is no longer available for retrieval. In this context, the amount of time spent on the distractor activity is more important than the similarity between original and interfering activities.

The impetus for two competing theories of forgetting began when psychologists started examining an individual's recall ability just a few seconds after being exposed to some learning material. Once research commenced in the area of immediate memory, scientists began to argue the reason for and the nature of forgetting. Immediately, the trace theorists argued that STM was qualitatively different than long-term memory (LTM), but the interference theorists felt that this was not true. In fact, the interference group argued that PI and RI effects could explain forgetting in both STM and LTM.

\(^2\)Dennis James Selder, "Proactive Inhibition for a Motor Response During Short-Term Memory" (unpublished Ph.D. dissertation, School of Physical Education, The Ohio State University, 1968), p. 2.

Currently, psychologists and educators are asking the question: do the principles of verbal learning differ from those of motor learning? Traditionally, individuals thought that a different set of principles governed the learning of motor skills. However, it seems that this distinction is no longer valid, and many of the rules utilized for learning verbal materials also apply to skill acquisition. For example, there are few scientists who would deny that practice is essential for any type of permanent retention. Even though the distinction between motor and verbal learning is not a meaningful one, much of the research in STM has dealt with verbal materials. Thus, with this verbal emphasis, there is a scarcity of motor learning studies dealing with STM.

The examination of short-term retention of motor skills has value for at least two reasons. First, as Gentile indicated, it has been fifty years since short-term retention of motor acts has been studied.\(^4\) She states that until just recently no studies had been done since the late 1890's when the accuracy of reproducing discrete movements following retention intervals of a few seconds was examined.\(^5\) One of the initial efforts at investigating


\(^5\)Ibid.
short-term retention of motor skills was that by Woodworth in 1899. Adams and Dijkstra (1966) and Posner (1966) were the first recent studies since the original efforts dealing with STM and motor skills. Thus, it is evident that a thorough understanding in the area of short-term retention of motor skills is absent. It seems that a study contributing to this area specifically, and to skill acquisition generally, would in itself be justified. Adams indicates the need for investigation in this area when he terminates a review of motor skills with the following questions.

And what of immediate motor memory? How does it differ from long-term motor memory or immediate verbal memory? These are the questions whose answers might move us a bit faster toward our goal of general lawfulness.

The second point to be made in discussing the need for this study involves efficiency in teaching motor skills. The teacher of physical education structures practice sessions so that maximum retention occurs. In the past, a notion has been developed that forgetting will decrease as


the repetitions of the skill increases. Thus, students are made to practice a skill as many times as possible in the allotted time.

In a way the present study is examining the legitimacy of this principle. What if students do not forget rapidly during the time interval up to thirty seconds after a learning experience or repetition? It might be true that their retention is essentially the same at two seconds, ten seconds, and thirty seconds. If this is so, then one can begin to question the validity of maximum repetitions, and possibly develop practice procedures that call for repetitions every ten, twenty, or thirty seconds. In essence, physical educators would need to re-examine the structuring of learning experiences.

Statement of the Problem

It is the purpose of this study to examine the forgetting of a linear motor response as a function of time. Forgetting is determined by accuracy in reproducing a specific distance on a pulley weight. The subjects are blindfolded, asked to pull the pulley weight until it is stopped, and then reproduce that distance after a specific retention interval. It is hypothesized that error will increase as time is increased.

It is also the purpose of this study to develop a forgetting curve for STM.
Sub-problem

A secondary purpose of this study is to examine the error variability of all distances at the specific retention intervals.

Basic Assumptions

1. Each subject attempted to do his best during each trial.
2. Testing procedure was identical for all subjects.
3. The motor response was novel to all subjects.

Limitations

1. The subjects were all male students enrolled in the basic instruction program of the Men's Physical Education Division at The Ohio State University.
2. A finite motor response was used which does not enable one to apply the results to gross motor skills.
3. The subjects backgrounds in regards to motor skills ability were not taken into account; however, none were physical education majors or college athletes.

Definitions

1. Short-Term Memory (STM): the immediate memory span of an individual measured in seconds after a learning experience. (Usually sixty seconds or less.)
2. Long-Term Memory (LTM): the memory span of an individual some time after a learning experience. (Usually greater than sixty seconds.)
3. Retention Interval: the temporal interval between the learning experience and recall.

4. Intertrial Interval: the temporal interval between the end of one trial and the beginning of the next.

5. Learning experience: the distance controlled by the experimenter on each trial.

6. Recall score: the distance pulled by the subject when trying to reproduce the learning experience.

CHAPTER II

REVIEW OF RELATED LITERATURE

Scientists who have studied the neural basis for the retention of experiences have developed two conflicting viewpoints.

One view supposes that an experience sets up a continuing electrical activity in appropriate neural circuits and that the persistence of these active circuits is coordinate with the persistence of our memory of the experience coded in this way. When this active trace stops, we lose that memory. We may call this the "dynamic" view of the engram. Opposed to it is the "structural" view, that learning consists in some enduring physical or structural change in the nervous system, and that this physical change will persist even when the original neuronal circuits responsible for its having been established in the first place have long ago ceased activity.1

Research has lended firm support to the structural theory while the dynamic viewpoint has been rejected. The best known proponent of the structural position is Hebb.2

Hebb thought in terms of a short-term and long-term memory store.

The input of stimulation supposedly produces "reverberating" neural activity, representative of that experience, which persists for a while.


2Ibid., p. 447.
This dynamic neural trace is coincident with our short-term memory. While this reverberating activity lasts, the permanent structural change underlying the long-term memory is slowly developing. Once the reverberatory trace dies out, the structural change stops but remains at the level attained.\(^3\)

Hebb views short-term memory as a reflection of reverberating, neuronal circuits, reacting from sensory input, which are available for immediate recall, but will dissipate with time.\(^4\)

The recent emphasis and study on STM has provided a dispute concerning the manner in which people forget. Trace theorists maintain that forgetting during STM is through overloading alone; whereas, interference scientists explain forgetting through associative interference. Although it is not the primary intent of this study to support either theory, it seems appropriate to examine the research supporting each position.

Hebb, whose theory of STM has already been discussed, has been one of the major proponents of the trace-decay theory along with Broadbent.\(^5,6\) Broadbent feels that material presented to an individual is recirculated for

\(^3\)Ibid., p. 452.


\(^5\)Ibid.

permanent storage. When attention is shifted to another task, the material will decay with time and eventually will become unavailable. In essence, the latter material overloads the immediate memory store which eliminates the original materials.

The trace theorists feel that STM should be treated differently than LTM. However, interference theorists argue that this is not a meaningful distinction. This has been one of the prominent disputes in psychology. It was Melton, though, who outlined the main issues concerning a theory of memory:

1. Are memory traces permanent or do they decay?
2. Is memory enhanced through reverberation or not?
3. Do individuals remember in an all or none fashion or in an incremental manner?
4. Are there two kinds of memory storage, LTM and STM, or only one?

McGeoch first discussed the basic idea of interference theory. Retroactive inhibition was the major factor in forgetting; i.e., the amount of activity between original learning and recall. Since that paper in 1932, interference theory has received considerable empirical support. A paper by Slamecka and Ceraso reviewed much of the literature.

---

The following table summarizes their work. 10

**TABLE 1**

**SUMMARY OF RETROACTIVE AND PROACTIVE INHIBITION EFFECTS**

<table>
<thead>
<tr>
<th></th>
<th>Retroaction</th>
<th></th>
<th>Proaction</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental</td>
<td>Control</td>
<td>Experimental</td>
<td>Control</td>
</tr>
<tr>
<td>List 1</td>
<td>A - B</td>
<td>A - B</td>
<td>A' - C</td>
<td>Rest</td>
</tr>
<tr>
<td>List 2</td>
<td>A' - C</td>
<td>Rest</td>
<td>A - B</td>
<td>A - B</td>
</tr>
<tr>
<td>Recall Test</td>
<td>A - B</td>
<td>A - B</td>
<td>A - B</td>
<td>A - B</td>
</tr>
<tr>
<td>Per Cent Correct Recall</td>
<td>20</td>
<td>60</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Effect</td>
<td>60-20 = 0.67</td>
<td></td>
<td>80-60 = 0.25</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 demonstrates the effects of PI and RI. In testing for RI the experimental group learned list 1(A-B) and then list 2(A'-C) while the control group learned list 1(A-B) but rested instead of learning list 2(A'-C). Both groups were given a recall test on the same list, but the experimental group scored lower than the control group. Thus, the poor performance of the experimental group can be attributed to learning the second list. In essence, list 2 interfered with the retention of list 1. The same procedure was followed in testing for PI except for the learning of the interfering list first.


A major shift that has taken place in interference theory is the more powerful role played by proactive sources of interference. Underwood noticed that many studies claimed considerable forgetting over a twenty-four hour period. After closer examination he found that each study used the same subjects under many list-learning conditions. As the number of lists which the subjects learned increased, the more extensive was the forgetting. Thus, he makes a case for the idea that these subjects had considerable forgetting because proactive inhibition accumulated with each new list. By comparison, Underwood showed that subjects learning only one list had 75% - 80% recall after twenty-four hours.

Keppel and Underwood found a study by Peterson and Peterson that failed to identify the operating proactive interference effects. Keppel and Underwood demonstrated that proactive interference effects were maximum after three or four trials. The Petersons gave the subjects ten practice trials; thus, interference effects could not be detected because they were already at maximum before data collection.

12Ibid.
The experimental procedure for examining STM was introduced by Brown and Peterson and Peterson.\(^{14,15}\) Brown discovered a decrease in retention utilizing a five second interval, but he failed to examine a series of intervals.\(^{16}\) Peterson and Peterson used nonsense trigrams with an interpolated activity of subtracting three's from a random number during the retention interval. They showed a decreased probability of correctly recalling the trigram as the retention interval increased.\(^{17}\)

Brown feels that his study supports the decay theory of forgetting. The target trace decays were constant and did not depend on the type of interpolated activity.\(^{18}\) These results were disputed by Wickelgren and Bruning and Schappe.\(^{19,20}\) Presently, the explanation of this controversy


\(^{16}\) Brown, op. cit.

\(^{17}\) Peterson and Peterson, op. cit.

\(^{18}\) Brown, op. cit.


is lacking, although it will probably turn out to be attributed to the crucial differences in materials used.\textsuperscript{21}

In discussing the controversy between the trace and interference theorists, Brown makes the following point:

The two main reasons for the unpopularity of the decay theory are the existence of distortions in remembering and the importance of the similarity factor in PI and RI (pro- and retro- active inhibition).\textsuperscript{22}

The majority of studies examining the trace theory have utilized an intervening activity during the retention interval. However, a study by Conrad and Hille used a digit task with no distracting activity.\textsuperscript{23} Retention intervals of six and seventeen seconds were used. Their results supported the view that, in absence of rehearsal, memory decays rapidly with time.

As mentioned previously there is evidence supporting both theories of forgetting; however, the majority of the studies do support the interference position. Wickens, Born, and Allen found that a subject's retentive ability increased considerably with a shift from one class of

\begin{flushright}
\textsuperscript{21}Hilgard and Bower, \textit{op. cit.}, p. 507.

\textsuperscript{22}Brown, \textit{op. cit.}, p. 13.

\textsuperscript{23}R. Conrad and Barbara A. Hille, "The Decay Theory of Immediate Memory and Paced Recall," \textit{Canadian J. Psych.} 1958, 12, pp. 1-16. •
\end{flushright}
material to another. This study clearly established PI effects for verbal materials.

More recent verbal learning studies have also established interference effects during STM. Corman and Wickens found RI can occur in STM, and may be studied with the Peterson and Peterson paradigm. A significant level of PI for stimulus materials was established by Prost and Jahnke. Studies by Loess and Murdock have also supported the interference position.

In the literature there is a definite scarcity of studies dealing with motor skills and STM. Thus, it has been necessary to discuss the findings of several verbal learning studies. Those investigations that have dealt with skill acquisition and STM have failed to examine the retention interval (with no interpolated activity) as the


independent variable. Other conditions such as feedback, reinforcement, or retention intervals of minutes, hours, days, or weeks are used.

Bilodeau and Bilodeau examined a series of studies on temporal delay of feedback (seconds, minutes, hours, days, and weeks). They discovered that learning was not dependent upon feedback's temporal position, but rather the time interval between Response 1 and Response 2. In essence, the ability to recall decreased as time increased.

Bilodeau and Levy have proposed a two-stage curve of forgetting based upon their examination of lever data. They hypothesize forgetting in terms of a STM although the exact shape of this curve has not been determined. The figure below illustrates their findings.

There have been many studies dealing with motor skill retention during LTM. The typical finding is that motor


31 Ibid.
Fig. 1.—Two stages of forgetting.

Skills are highly resistant to forgetting. Battig observed almost no forgetting on a tracking task over a 223 day interval. Fleishman and Parker found a very small decrement in tracking over intervals from one to fourteen months. The correlation between final level of original


learning and retention performance ranged from .80 to .98 for the various groups.

Long-term retention of sports skills has been studied extensively by physical educators. Purdy and Lockhart used five novel skills, and found a high degree of skill retained after approximately one year of no practice. The entire sample retained ninety-four percent of its best performance from the original learning. They also found that relearning to the previously attained level was rapid. In fact, after three days of practice the entire group had attained the proficiency which took ten days of original learning.

Singer utilized a novel basketball skill and found high retention on tests administered one day, one week, and one month after original learning.

There has been three recently published studies which have examined various aspects of STM and motor skills. Adams and Dijkstra studied a lever position response with the vision blocked. Retention intervals ranging from five to 120 seconds were used. During each trial every subject was

---


showed that forgetting increased with the passage of time, and increasing the number of reinforcements stabilized performance.

Posner studied a kinesthetic-distance information task which essentially was a lever positioning response. Significant forgetting was found using retention intervals of zero, ten, twenty, and thirty seconds. He also examined the effect of interpolated tasks in retention intervals, and found no significant differences.

Norrie devised an unusual task in her study of STM. The subjects pushed against a vertical steel bar a specified distance, held it there for two seconds, and then released it. The subjects were then asked to reproduce that distance after a specific retention interval. In part A all subjects reproduced the distance immediately. For part B the subjects were divided into three subgroups with a specific retention interval assigned to each group. The intervals were one-half minute, one and one-half minutes, and four minutes. Using absolute and algebraic error no significant differences were found among the conditions; however, using algebraic error, she found significance from considerable

---


overestimation upon immediate reproduction to only slight overestimation after one-half minute.

There has been three unpublished studies dealing with motor skills and STM. Selder tried to determine proactive interference effects for a finite motor response. A pulley apparatus was devised so that linear responses by the subjects could be measured. A retention interval of twenty seconds was used for each trial. The results indicated definite proactive interference on the second trial.

Gentile developed an arm positioning device which allowed for arm movements over ninety-four degrees of angular displacement. The subjects sat in a chair and moved the non-dominant arm away from the body midline, parallel to the floor. Backwards counting activity by three's prevented the subjects from rehearsing. Retention intervals of zero, four, eight, twelve, and sixteen seconds were used. Measurements were taken at one-fourth degrees. Significant forgetting was found for both absolute and directional error scores.

Wilberg attempted to examine the extent to which

---

41 Dennis James Selder, "Proactive Inhibition for a Motor Response During Short-Term Memory" (unpublished Ph.D. dissertation, School of Physical Education, The Ohio State University, 1968).

competing tasks interfere with input-output performance. He felt that having to recall from STM while performing a continuous motor task could affect performance. The short-term recall tasks were either making a sinewave with a pen or operating a pair of foot pedals. He found a significant increase in tracking errors as the subjects were made to recall from STM. Furthermore, performance became increasingly worse as the recall task became more complex.

The crucial difference between the present study and many of the other investigations discussed is the use of a distractor activity during the retention interval. For the reason discussed earlier a rehearsal preventive technique was not used in this study.

In conclusion, then, one may safely state that forgetting verbal or motor material does occur as a function of time, especially with a distractor activity. What happens when the distractor activity is eliminated in motor skill studies is still not known. The present investigation hopes to offer a partial answer to that question.

---

CHAPTER III

METHOD

Subjects

The subjects were twenty, volunteer, male students enrolled in the basic instruction program of the Men's Physical Education Division at The Ohio State University during the Autumn Quarter, 1968. They were incorporated into the study on a first to volunteer basis. Their ages ranged from seventeen to twenty-four years. Seventeen subjects were right-handed and three were left-handed.

Apparatus

A pulley weight was modified so that it could be stopped at any of five distances (see photograph, Appendix). The weight apparatus on the pulley was guided by two metal runners which were perpendicular to the floor and parallel to each other. One-eighth inch holes were drilled through one of the metal runners at each distance. A metal pin was inserted through one of the five holes depending on the desired distance for that trial. During recall the pin was removed so that the weight attachment could be moved to greater distances. In order to measure deviation from the
learning experience a centimeter ruler was fastened to the wall directly behind a runner. A wooden pointer was attached to the movable weight apparatus so that the tip of the pointer was directly adjacent to the ruler. Measurements were made in millimeters by the experimenter adjusting his head position so that the line of sight was parallel to the floor.

As suggested in Selder's study a five pound weight was used so that there would be enough sensory input without fatiguing the subject.\(^1\) The goggles were safety glass type used in industry. The lenses were painted over to block vision. A stopwatch was used to measure retention and inter-trial interval times.

**Design**

The twenty subjects underwent each of the twenty-five different treatments. Five different distances (5, 9, 13, 17, and 21 centimeters) and five different retention intervals (2, 4, 8, 16, and 32 seconds) were combined to make-up the twenty-five different treatments. Thus, a subject pulled 5 centimeters with a 2, 4, 8, 16, and 32 second retention interval. The same procedure was also followed at the other four distances. Table 2 shows the order of treatment presentation for two subjects. The letter refers to the subject,

\(^1\)Dennis James Selder, "Proactive Inhibition for a Motor Response During Short-Term Memory" (unpublished Ph.D. dissertation, School of Physical Education, The Ohio State University, 1968), p. 18.
and the number designates the order presentation for that cell.

**TABLE 2**

**ORDER OF TREATMENT PRESENTATION TO SUBJECT A AND B**

<table>
<thead>
<tr>
<th>Distance (centimeters)</th>
<th>5</th>
<th>9</th>
<th>13</th>
<th>17</th>
<th>21</th>
</tr>
</thead>
</table>

The order of treatment presentation was arranged so that one distance never occurred consecutively. This was done by drawing each of the twenty-five treatments from a lot. If the same distance were drawn twice in a row, the latter one was returned to the lot and another one drawn. This procedure was followed for each subject individually.

Twenty-five subjects volunteered for the experiment; however, the data for the first five subjects were discarded.
These first subjects enabled the experimenter to become accustomed to the procedure and apparatus.

Procedure

All subjects were told that they were to be tested on their ability to reproduce a specific distance on the pulley weight. They were read instructions for the experiment, and were given a demonstration on the proper way to pull the wall pulley. Each subject faced the pulley weight with his dominant arm extended toward the wall, parallel to the floor. His body position was then adjusted to the left or right so that his arm was in a direct line with the pulley. Forward and backward body adjustments were also made so that the rope attached to the pulley weight handle was tight. Once the proper body position was accomplished the subject was told to remain there for the entire experiment. The subject was then blindfolded, and the experimental trials were ready to begin.

The experimenter inserted the metal pin through the hole at the desired distance. Then the subject was instructed to "grasp" the handle. On the command "pull" the subject pulled until the weight made contact with the metal pin. At this time the subject immediately returned the pulley weight to its original position, and the experimenter started timing the retention interval. The subjects maintained their grip on the handle during the retention interval. The experimenter removed the metal pin during the
retention interval. After the retention interval the experimenter commanded "recall," and the subject tried to reproduce the previous distance as best he could. When he was satisfied with the recall pull the subject said "here," and the experimenter took the reading. As soon as the reading was made the subject was commanded to "release," and the thirty second intertrial interval time was started. Release meant the subject returned the pulley to its original position, released the handle, and placed his arm at his side. After twenty seconds of the intertrial interval had elapsed, the subject was commanded to "grip" the handle; thus preparing for the next trial.

The pull made by the subject was accomplished by drawing the hand directly toward the chest. The palm was kept down, facing the floor, and the elbow was pointed out away from the body. No subject pulled to or beyond ninety degrees flexion at the elbow joint.

All subjects underwent four identical practice trials to familiarize them with the procedure and apparatus. The practice trials were assigned by the experimenter so that a different distance and time was used for each one. The last practice trial was arranged so that the distance on it and the first experimental trial were not identical.
CHAPTER IV

ANALYSIS AND DISCUSSION OF THE DATA

Analysis

The data were analyzed by means of a three-way analysis of variance followed by the application of Duncan's Multiple Range Test. Mean and standard deviation scores were also calculated for the retention intervals and distances.

The analyses were conducted by the Statistics Laboratory at The Ohio State University which programmed all cards and processed them through the computer.

Two different analyses of variance were conducted on the data. The first F test used the absolute error while the second analysis of variance utilized algebraic error. The raw data were measurements of error in millimeters.

The mean and standard deviation scores (absolute error) for the retention intervals are summarized in Table 3.

The increase in mean error with regards to time is minimal. In fact, less than three millimeters separates the shortest and longest retention interval. The amount of
TABLE 3
MEAN AND STANDARD DEVIATION SCORES (IN M.M.)
OF ALL RETENTION INTERVALS
USING ABSOLUTE ERROR

<table>
<thead>
<tr>
<th>Time (seconds)</th>
<th>2</th>
<th>4</th>
<th>8</th>
<th>16</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>14.32</td>
<td>14.49</td>
<td>16.31</td>
<td>16.11</td>
<td>17.01</td>
</tr>
<tr>
<td>S.D.</td>
<td>12.81</td>
<td>10.69</td>
<td>13.48</td>
<td>13.70</td>
<td>15.37</td>
</tr>
</tbody>
</table>

error does have a systematic increase with time except for the 16 second retention interval. The error for that interval was less than the 8 second interval but more than the 4 second interval. The standard deviation scores also have a systematic increase except for the 4 second interval which was less than the 2 second retention interval.

Table 4 summarizes the mean and standard deviation scores (absolute error) for distance.

TABLE 4
MEAN AND STANDARD DEVIATION SCORES (IN M.M.)
OF ALL DISTANCES USING ABSOLUTE ERROR

<table>
<thead>
<tr>
<th>Distance (centimeters)</th>
<th>5</th>
<th>9</th>
<th>13</th>
<th>17</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>9.44</td>
<td>13.47</td>
<td>18.25</td>
<td>18.25</td>
<td>18.83</td>
</tr>
</tbody>
</table>
The table indicates a definite increase in mean error as the distances become longer. However, it is interesting to note that the last three distances remained somewhat constant. Only .58 millimeters separates the middle and last distance, whereas 8.81 millimeters separates the first and middle distances. The variability of the scores had a systematic increase as the distance lengthened.

The analysis of variance applied to the absolute error data is summarized in Table 5.

**TABLE 5**

**SUMMARY OF THE ANALYSIS OF VARIANCE FOR ABSOLUTE ERROR**

<table>
<thead>
<tr>
<th>Sources of Variance</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>4</td>
<td>561.128</td>
<td>140.282</td>
<td>.901</td>
</tr>
<tr>
<td>Distance</td>
<td>4</td>
<td>6694.888</td>
<td>1673.722</td>
<td>10.749a</td>
</tr>
<tr>
<td>Subjects</td>
<td>19</td>
<td>8580.260</td>
<td>451.593</td>
<td>2.900b</td>
</tr>
<tr>
<td>Time x Distance</td>
<td>16</td>
<td>2213.632</td>
<td>138.352</td>
<td>.889</td>
</tr>
<tr>
<td>Error</td>
<td>456</td>
<td>71003.070</td>
<td>155.709</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>499</td>
<td>89052.978</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*P < .01

Two significant effects are shown in Table 5: distance (P < .01) and subjects (P < .01).

Duncan has devised a test which helps one determine where significant differences lie. Even though the time effect was not significant, the Multiple Range Test was conducted to determine the homogeneity of the retention
intervals. The Multiple Range Test for time is summarized in Table 6. With an F of .901 it may be concluded that the intervals are a homogeneous group at the .05 level.

TABLE 6
MULTIPLE RANGE TEST FOR RETENTION INTERVALS (ABSOLUTE ERROR)\(^a\)

<table>
<thead>
<tr>
<th>Ordered Means</th>
<th>Time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Mean</td>
<td>14.32</td>
</tr>
</tbody>
</table>

\(^a\)(1) Any two means not underscored by the same line are significantly different.
(2) Any two means underscored by the same line are not significantly different.

A significant effect for distance was found in the analysis of variance, therefore the Multiple Range Test will help determine what caused this effect. The results are summarized in Table 7.

Table 7 indicates that the first two distances are significantly different from each other, and the other three distances, at the .05 level. At the .01 level they are only different from the last three distances.
## TABLE 7

MULTIPLE RANGE TEST FOR DISTANCE MEANS (ABSOLUTE ERROR)

<table>
<thead>
<tr>
<th>Ordered Means</th>
<th>Distance (centimeters)</th>
<th>5</th>
<th>9</th>
<th>13</th>
<th>17</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td>9.44</td>
<td>13.47</td>
<td>18.25</td>
<td>18.25</td>
<td>18.83</td>
</tr>
<tr>
<td></td>
<td>-----------------------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
</tbody>
</table>

---

1) Any two means not underscored by the same line are significantly different.
2) Any two means underscored by the same line are not significantly different.

P < .05

---

An identical set of analyses were conducted on the data using algebraic error instead of absolute error. It is possible that effects or interactions which do not arise with absolute error will demonstrate significance when algebraic error is utilized.

The mean and standard deviation scores (algebraic error) for the retention intervals are summarized in Table 8. Examination of this table indicates an interesting pattern for mean error. Error increases until the middle retention interval is reached, and then it decreases systematically to the last retention interval. Variability scores indicate no definite pattern except for the increasing variation from the 8 to the 32 second retention interval.
TABLE 8
MEAN AND STANDARD DEVIATION SCORES (IN M.M.)
OF ALL RETENTION INTERVALS
USING ALGEBRAIC ERROR

<table>
<thead>
<tr>
<th>Time (seconds)</th>
<th>2</th>
<th>4</th>
<th>8</th>
<th>16</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-3.00</td>
<td>-6.67</td>
<td>-9.75</td>
<td>-7.11</td>
<td>-5.55</td>
</tr>
<tr>
<td>S.D.</td>
<td>19.46</td>
<td>17.78</td>
<td>18.82</td>
<td>19.96</td>
<td>22.31</td>
</tr>
</tbody>
</table>

The mean and standard deviation scores (algebraic error) for distance are shown in Table 9. Positive mean error is only seen in the shortest distance while the longer distances have a systematic increase in negative error. Variability scores are constant for the three longest distances with the shortest distance having the smallest deviation score.

TABLE 9
MEAN AND STANDARD DEVIATION SCORES (IN M.M.)
OF ALL DISTANCES USING ALGEBRAIC ERROR

<table>
<thead>
<tr>
<th>Distance (centimeters)</th>
<th>5</th>
<th>9</th>
<th>13</th>
<th>17</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>5.38</td>
<td>-4.23</td>
<td>-7.95</td>
<td>-11.15</td>
<td>-13.93</td>
</tr>
<tr>
<td>S.D.</td>
<td>12.73</td>
<td>16.82</td>
<td>20.78</td>
<td>20.41</td>
<td>20.44</td>
</tr>
</tbody>
</table>
The analysis of variance for algebraic error is summarized in Table 10.

TABLE 10
SUMMARY OF THE ANALYSIS OF VARIANCE FOR ALGEBRAIC ERROR

<table>
<thead>
<tr>
<th>Sources of Variance</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>4</td>
<td>2401.111</td>
<td>600.278</td>
<td>2.172</td>
</tr>
<tr>
<td>Distance</td>
<td>4</td>
<td>22514.033</td>
<td>5628.508</td>
<td>20.370a</td>
</tr>
<tr>
<td>Subjects</td>
<td>19</td>
<td>36921.418</td>
<td>1943.233</td>
<td>7.032b</td>
</tr>
<tr>
<td>Time x Distance</td>
<td>16</td>
<td>3306.167</td>
<td>206.635</td>
<td>.748</td>
</tr>
<tr>
<td>Error</td>
<td>456</td>
<td>126005.800</td>
<td>276.329</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>499</td>
<td>191148.529</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As in the analysis of variance for absolute error, the same two significant effects are indicated in Table 10: distance (P < .01) and subjects (P < .01). Although the time effect did not achieve the .05 level of confidence, it should be noted that it did fall within the .08 level.

In order to determine the homogeneity of the retention interval means, and to possibly ascertain the cause of the .08 effect, Duncan's Multiple Range Test was administered. The results of this analysis can be seen in Table 11. The 2 and 8 second retention intervals are significantly different at the .05 level of confidence.
The Multiple Range Test was then applied to the distance means. Those results are summarized in Table 12. The shortest distance was significantly different from the other distances at the .01 level of confidence. It should be noted that at the .05 level of confidence each of the remaining four distances is different from at least three of the other distance means.
TABLE 12
MULTIPLE RANGE TEST
FOR DISTANCE MEANS
(ALGEBRAIC ERROR)\textsuperscript{a}

<table>
<thead>
<tr>
<th>Ordered Means</th>
<th>Distance (centimeters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Means</td>
<td>5.38</td>
</tr>
</tbody>
</table>

\begin{itemize}
  \item \textsuperscript{a}1) Any two means not underscored by the same line are significantly different.
  \item \textsuperscript{a}2) Any two means underscored by the same line are not significantly different.
\end{itemize}

\textit{Discussion}

Although there was a significant subjects effect for both analyses of variance, further discussion is not warranted. This statistical procedure merely enabled the partitioning of the subject effect out of the error term; thus, making the model more complete.

The analysis of variance for absolute error (Table 5) indicated no significant increase in error as the retention intervals lengthened. Table 3 gives one an indication as to why this occurred. Although the error systematically increases as a function of time (except for the 16 second
retention interval) the difference between the retention intervals is very small. Only 2.69 millimeters separates the shortest and longest time interval. Figure 2 illustrates these results.

![Graph showing absolute mean error for all retention intervals.](image)

Fig. 2.—Curve showing absolute mean error for all retention intervals.

However, when the retention intervals are examined using algebraic error, different conclusions can be made. Although the F ratio (Table 10) for time was not significant at the .05 level of confidence, the 2.172 value did achieve the .08 level of confidence. Thus, there seemed to be some effect regarding the time intervals. The Duncan
Multiple Range Test located a significant difference between the 2 and 8 second interval had a mean error of -3.00 millimeters while the 8 second interval had a mean error of -9.75 millimeters: a difference of 6.75 millimeters.

When the mean scores (Table 8) for time are examined, an interesting pattern emerges. These results are illustrated in Figure 3. The subjects error increased up to and including the 8 second interval. After that, a reminiscence effect occurred during the 16 and 32 second intervals.

![Curve showing algebraic mean error for all retention intervals.](image)
Reminiscence is a performance improvement due to the introduction of rest intervals.²

Reminiscence effects have been established for both motor and verbal learning. In the area of verbal learning, Keppel and Underwood studied the reminiscence of paired associate lists.³ They used three sets of lists with high, medium, and low meaningfulness. Retention intervals of 4, 19, 64, 184, and 304 seconds were utilized. They concluded that for all four experiments, the phenomenon of reminiscence was demonstrated for lists with medium meaningfulness. Peterson also used paired associate lists, but he had retention intervals that were considerably shorter: 0, 8, 16, and 24 seconds.⁴ His findings indicated increased recall ability with the passage of time.

Research in the area of motor skills have found results similar to those of verbal learning studies. Jahnke discovered that those groups having the smallest amounts of prerest distributed practice exhibited the


the greatest amounts of reminiscence. Fox and Young examined the reminiscence effect on badminton skills. They instructed two groups of subjects in badminton skills: one for six weeks and the other for nine weeks. The subjects were then tested on wall volley and short serves after six and twelve weeks of no practice. The nine week group exhibited reminiscence on the six week test while the six week group had reminiscence on the twelve week test.

Purdy and Lockhart found that after one year of no practice on five novel skills, eighty-nine percent of the subjects displayed reminiscence on one or more of the skills. Irion and Gustafson used a tracking task to demonstrate reminiscence. They had two groups of subjects follow a moving target with a stylus for five minutes. After this practice session, one group started immediately with the opposite hand while the other group


6Margaret C. Fox and Vera P. Young, "Effect of Reminiscence on Learning Selected Badminton Skills," Research Quart., 1962, 73, pp. 386-394.


rested for five minutes. The group that rested was significantly better with the non-preferred hand.

Thus, the present study lends support to the reminiscence effect found in earlier research. The major difference is that the present experiment found reminiscence during a relatively short period of time (16 and 32 seconds) while previous motor learning studies found reminiscence over more extended periods of time.

This finding has implications for the teaching of motor skills. Table 8 indicates that there was less than 3 millimeters difference between the 2 and 32 second retention intervals. In fact, the error was less for the 32 second interval than the 4 second one. This demonstrates that an isolated motor response can be retained over a period of time. Since there was no distractor activity performed during the retention interval, one may safely assume that the subjects were concentrating on and rehearsing the position of the learning experience. This opportunity to think about the position might have given the subject more accuracy when reproducing the learning experience. It is likewise possible that the longer retention intervals enabled the subjects to forget any previous interfering responses.

Although a linear positioning response was used, it might be possible to apply these results to sports skills.
During practice sessions one might require repetitions every thirty seconds somewhere during the early stages of learning. This would enable the learner to concentrate on the task being performed, and possibly enable him to have higher retention. Further research is needed in this area, but dealing with sports skills that can be easily isolated and measured.

The significant effect of distance was expected. Whenever different distances are used which range from close to the body to far away from the body, some are going to be more easily retained than others. The Duncan Multiple Range Test for both absolute and algebraic error indicates the same trend. The shortest distance had the smallest error while the longest distance had the largest error. This was contrary to Selder's findings where the greatest error came in pulling the shortest distance.\(^9\)

This finding raises an interesting point. One would expect that the distances at each extreme would be the easiest to retain, while the middle distances would be the hardest to remember. The longest distance was quite close to the body, but this cue did not help the subjects.

\(^9\)Dennis James, Selder, "Proactive Inhibition for a Motor Response During Short-Term Memory" (unpublished Ph.D. dissertation, School of Physical Education, The Ohio State University, 1968), p. 36.
An interesting pattern emerges when Table 9 is examined. Except for the shortest distance, the subjects consistently undershot the other four distances. Figure 4 illustrates this finding. The negative error becomes increasingly larger as the distances become longer.

![Graph showing mean error vs. distance](image)

**Fig. 4.**—Curve showing algebraic mean error for all distances.

In order to offer some type of explanation two sources of information were examined. Harry Helson has developed an Adaptation Level Theory of behavior. The content of his theory is far too complicated and extensive.

---

to deal with here. However, in his explanation of judging different weights in adaptation level terms, Helson states that experiencing heavier sets of weights results in making succeeding weights lighter, and experiencing lighter weights makes succeeding weights heavier.\textsuperscript{11} It is possible that in the present study each subject, through fatigue, thought that extra weight was being added during the experiment. In this case a subject might pull harder because the weight seemed to be getting heavier. In fact, several subjects did ask if extra weight was being added during the experiment.

Woodworth and Schlosberg have developed a Time Error Theory.\textsuperscript{12} In weight judging experiments they found that a subject will lift more strongly on the second weight. However, there was only a three second interval before lifting the second weight.

It is evident that the two theories discussed above would lead one to think that the subjects should have overshot the learning experience rather than undershoot it. Because of the differing tasks between the present study and previous research, it is not possible to say that these results definitely conflict with the results already

\textsuperscript{11}\textit{Ibid.}, pp. 593-594.

discussed. However, some interesting points are raised.

The writer can offer only a partial answer to the question of undershooting. Fatigue might have interfered with the kinesthetic feedback mechanisms of the subjects. This interference could have come in a form which made them undershoot the distances. The reason it did not cause undershooting for the shortest distance is because the margin of error from the starting position to the first distance was so small (5 centimeters) as to make it very difficult to pull less than it.
CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to examine the forgetting of a motor response as a function of time. It was also the intent of this experiment to examine whether some distances are more easily retained than others.

Twenty volunteer, male, Ohio State University students were tested on their ability to retain a motor response during STM. A pulley weight was modified so that (1) the apparatus could be stopped at any of five desired distances, and (2) error measurements, in millimeters, could be made.

Five different retention intervals (2, 4, 8, 16, and 32 seconds) and five different distances (5, 9, 13, 17, and 21 centimeters) were combined to make-up the twenty-five treatments. The combination of the same time and distance never occurred more than once. Treatment presentation was devised so that no distance occurred twice in a row. Intertrial interval was thirty seconds.

The blindfolded subject faced the wall pulley with his dominant arm pointing towards the pulley, parallel
to the floor. The pull was made by pulling the handle towards the chest with the palm down and elbow out.

Using absolute and algebraic error, the following statistics were processed in a computer: (1) three-way analysis of variance, (2) Duncan's Multiple Range Test, (3) Mean, and (4) Standard Deviation.

Conclusions

1. The analysis of variance showed no significant effect for time using algebraic and absolute error. However, the F test using algebraic error did achieve the .08 level of confidence.

2. Duncan's Multiple Range Test showed a significant difference \((P < .05)\) between the 2 and 8 second retention intervals using algebraic error.

3. A reminiscence effect occurred when the data were analyzed using algebraic error. Subject error was maximum at the 8 second retention interval, and decreased systematically as time increased.

4. A significant effect for distance occurred using absolute and algebraic error \((P < .01)\). Subject error was smallest for the two shortest distances, and error increased as the distances became longer.
APPENDIX

PHOTOGRAPHS SHOWING TESTING INSTRUMENT AND POSITION OF SUBJECT
BIBLIOGRAPHY
BIBLIOGRAPHY

Books


Articles


52


Fox, Margaret C., and Young, Vera P. Effect of Reminiscence on Learning Selected Badminton Skills," Research Quart., 1962, 73, 386-394.


Unpublished Material

