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DURING SHORT TERM MEMORY

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

By
Dennis James Selder, B.P.E., M.P.E.

* * * * * * *

The Ohio State University
1968

Approved by

[Signature]
Adviser
Department of Physical Education
To Fran
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CHAPTER I

INTRODUCTION

Short-term memory (STM) has been a topic of considerable importance and one which has stimulated a great deal of research over the last ten years. The reason for this position is the crucial role STM plays in the dispute concerning the manner in which people forget.

STM refers to the immediate memory span measured in seconds after a learning experience. It is during this stage in the learning process that individuals can repeat material correctly after it has just been presented. This ability appears to disintegrate as a function of the temporal interval between presentation of learning material and recall. Scientists are understandably interested in determining the true nature of STM. Some investigators such as Krech maintain that this period of accurate recall can be prolonged utilizing chemicals for some forms of learning.¹

Currently, however, there are two theories that are thought of as having the best explanations of forgetting. The

trace theorists, in short, say that a memory trace is formed upon presentation of the learning material. Providing there is no chance for further practice the memory trace will gradually decay as a function of time until it can no longer be recalled in any form.

The other theory, which Hilgard maintains as the most "serviceable" theory of forgetting, is interference theory. Scientists utilizing this theory explain forgetting through associative interference factors. These factors are proactive interference (PI) and retroactive interference (RI). The amount of material that will be recalled 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).

The trace theorists believe that STM is qualitatively different from LTM, while the interference group believe that this is not a meaningful distinction. The trace people feel that retention in STM is subject to disruption through overloading and not through associative interference. Therefore, the interference investigators have examined interference effects (RI and PI) during STM.

The majority of research in STM has been with verbal material with very little reported research in the motor area.

---

A study utilizing a motor response in STM presents particular problems. The investigator must isolate the motor action from other cues (visual) so as not to affect the measurement. The nature of the motor response also presents a particular problem with respect to background and experience involving a particular movement.

Motor learning has traditionally been thought of as utilizing a different set of rules and principles from other forms of learning. However, the most recent research on motor learning appears to be based on principles of verbal and perceptual learning. PI and RI effects have been established for verbal material, but PI effects have not been established for a motor response.

PI for a motor response during STM has important implications for those teaching motor skills. Our educational system is under increasing pressure to intensify the learning process in our schools and colleges. We have room for improvement in teaching motor skills to our children when we consider that some of our teaching in our college service programs is actually remedial. We are also finding that children not exposed to normal motor skills are having problems in visual and auditory discrimination. By increasing our teaching efficiency


\[^4\]L. E. Halverson, "Development of Motor Patterns in Young Children," Quest, Mon. VI (May, 1966), p. 44.
we might be able to improve this area. Therefore, if we are to obtain maximum efficiency in our teaching methods, we must increase our research efforts in order to understand the nature of learning motor skills. Essential to this learning process is the manner in which we forget.

Statement of the Problem

It is the purpose of this study to determine the existence of a principle. Simply stated this principle is that previous experience(s) may interfere with the retention of a motor activity during short-term memory. In short does PI exist for a motor response during STM.

It is also the purpose of this study to examine the nature of such interference. We are using a response with a linear measurement and wish to know if the distances of the response have any effect on the interference.

Null Hypotheses

1. There is no difference between a group of students pulling a pulley weight a different distance over each trial (experimental group) and another group pulling the same distance over each trial (control group).

2. There will be no significant difference within any of the four sub-groups in the experimental group over four trials.

3. There will be no significant difference within any of the four control sub-groups over four trials.
4. There will be no significant difference between any of the four experimental sub-groups.

**Basic Assumptions**

1. The instrument used for measurement was valid.
2. Each subject was adequately motivated to do his best.
3. Testing procedure was the same for all subjects.

**Limitations**

This study is limited by the fact that only male students enrolled in The Ohio State University Physical Education basic instruction program were utilized as subjects.

A finite motor response was utilized and, therefore, it cannot be assumed that the same results would hold for gross motor activity.

**Definitions**

1. **Short-Term Memory (STM)**: the immediate memory span after a learning experience measured in seconds.

2. **Long-Term Memory (LTM)**: the memory span some time after a learning experience. (Greater than one minute.)

3. **Proactive Inhibition (PI)**: interference that occurs before a learning experience and results in a decrease in performance.

4. **Retroactive Inhibition (RI)**: interference that occurs after a learning experience and results in a decrease in performance during recall.
5. Retention Interval: the temporal interval between a learning experience and recall.

6. Intertrial Interval: the temporal interval between the cessation of one trial and the onset of the next.

CHAPTER II

REVIEW OF RELATED LITERATURE

It is widely accepted today that learning consists of some "structural" change in the nervous system, which will persist even though the original cause of the change has been absent for some period of time.¹

The best statement of this hypothesis is that proposed by Hebb:

Any frequently repeated, particular stimulation will lead to the slow development of a "cell assembly," a diffuse structure comprising cells in the cortex and diencephalon (and also, perhaps, in the basal ganglia of the cerebrum), capable of acting briefly as a closed system, delivering facilitation to other such systems and usually having specific motor facilitation. A series of such events constitutes a "phase sequence"—the thought process. Each assembly action may be aroused by a preceding assembly, by a sensory event, or—normally—by both. . . .²

Many psychologists have not accepted Hebb's terminology, but the structural change is easier to conceptualize under his schema. Hence, once an individual is exposed to an experience a memory trace is set up. Hebb later elaborates on a dual trace


theory, that in addition to the structural change there may be
"a memory trace that is wholly a function of a pattern of neu-
ral activity, independent of any structural change." In short,
for the formation of cell assemblies to take place reverberation
(repetition of neural firing) would be necessary. As Hilgard
and Bower point out there is firm evidence in support of persist-
ing reverberatory neural circuits in the cortex.

Retention (or learning) and forgetting are simply two
different sides of a coin.

... retention refers to the amount of previously
learned material which persists or has been retained
by the subject, whereas forgetting refers to the amount
which has been lost or has not been retained. However,
it should be noted that a de facto distinction has been
made between these two concepts. If the experimenter
is interested in examining the lack of persistence of
previously learned material, with particular reference
to how certain kinds of environmental events or activi-
ties contribute to this lack, investigators frequently
use the term forgetting. On the other hand, if the ex-
perimenter is interested in the variables related to
persistence, with the events filling the temporal in-
terval between Trial N and N+1 being of no particular
concern, the term retention has been used to denote
this interest.

The manner in which people forget has been a matter of
considerable interest. McGeoch, in 1932, attacked the "law of

3Ibid., p. 61.

4Hilgard and Bower, op. cit., p. 452.

disuse" as a fundamental variable in forgetting. McGeoch felt that the condition basic to forgetting was the amount of activity which was interpolated between original learning and recall, which we call retroactive inhibition. Since McGeoch's 1932 study interference theory has developed as the forerunner in explaining forgetting. Principles were added and others discarded. Slamecka and Ceraso reviewed much of the data on both RI and PI parameters, illustrated by the following table. 

### TABLE 1

**SUMMARY OF RETROACTIVE AND PROACTIVE INHIBITION EFFECTS**

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

---


One of the major changes that took place in interference theory was the powerful role played by proactive inhibition. Underwood illustrated that because most of the studies in interference utilized subjects who had been repeatedly memorizing lists of syllables it distorted the results. He showed that the more lists a subject had learned, the more he tended to forget the last one if measured the next day. If a subject learned only one list his recall was 75-80 per cent after twenty-four hours.

The study of short-term memory has led to the dispute between interference theorists and others, notably Broadbent and Hebb. Hebb feels that immediate memory is a reflection of reverberating, neuronal circuits reacting from sensory input, which are available for immediate recall, but will dissipate with time. Long-term memories result from permanent structural change.

Broadbent maintains the short-term material is being recycled for permanent storage. If attention is switched to something else then the original material decays with time and eventually becomes unavailable. The second material that enters

\[8\] B. J. Underwood, "Interference and Forgetting," *Psychol. Rev.*, 64, pp. 49-60.

\[9\] Hebb, *loc. cit.*


over-loads the short-term store, thus eliminating original material. Broadbent attempted to determine the subjects' capabilities for handling information while simultaneously receiving other sensory input.

The interference theorists do not feel STM should be treated any differently from LTM assuming that the same principles hold for both.

This dispute stimulated a great deal of research and writing not only in STM but more inclusive, in discerning how people forget. In 1963 Melton clarified the principle issues in memory theory:

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?

For purposes of this study our interest is in No. 4. Melton identifies the major dispute—that trace theorists (notably Broadbent) feel that retention in STM is subject to disruption through overloading alone and not through associative interference. Hence, the prime focus of the dichotomy centers around interference effects (PI and RI) in STM. Are the effects of these variables the same for STM or different?

The experimental procedure for examining STM was introduced in 1958 by Brown and in 1959 by Peterson and Peterson.  

Brown maintains his study supports the trace decay theory in that the target trace decays at the same rate no matter what material is interpolated. This finding was disputed by Wickelgren, who found that the absolute level of recall was lower when similar material was interpolated. This finding was substantiated by others, notably Bruning and Schappe.

Hebb tested immediate memory with strings of nine digits, giving each subject many strings to recall. Unknown to the subject, every third string of digits was the same. By the twenty-fourth trial, which was the eighth with the critical string, about 26 subjects got it right. Only five had succeeded on the first trial. Melton reported support for Hebb's findings. It appears that a string of digits can, at least on occasion, make

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18 A. W. Melton, loc. cit.
a relatively permanent impression under adverse circumstances. Interference investigators have identified the following variables in support of their theory:

1. RI effects from intervening stimuli, responses and information feedback signals,

2. opportunity for PI from previously presented items, and

3. number of responses to be recalled during any test sequence.

The debate is continuing with each side adding and deleting as experimental evidence demands. Hilgard and Bower state, "... as in many scientific debates, there is no completely clear resolution of this one." However, the bulk of experimental evidence does seem to support interference theory.

The majority of research has been in the verbal area, with a relatively small amount of research reported relative to motor learning and short-term memory.


22 K. B. Lloyd, R. S. Reid, and J. B. Feallock, "Short-Term Retention as a Function of the Average Number of Items Presented," J. Exp. Psychol., 1960, 60, pp. 201-207.

23 Hilgard and Bower, op. cit., p. 511.

24 Hall, loc. cit.
The initial report discussing the role of short-term running memory in the learning of perceptual motor skills was Cattell's study in 1886.\textsuperscript{25} Cattel suggested a relationship between the effect of memory limitation on the speed of perceptual motor performance.

Adams and Dijkstra used a linear motor response to examine short-term memory and a motor response.\textsuperscript{26} Their results parallel the findings in verbal learning; retention decreases rapidly as a function of retention interval time and memory is strengthened with reinforcement. These results were duplicated by Selder, using measurements obtained from a push and pull strength dynamometer.\textsuperscript{27}

Bourne reviewed a number of motor skill studies on information feedback during short-term memory.\textsuperscript{28} He feels that these investigations support the contention that overall performance is a function of RI effects, PI effects and the number of responses to be recalled.


\textsuperscript{27}D. J. Selder, "Short-Term Memory and a Motor Response." Unpublished research. The Ohio State University, 1967.

The type of motor response that is to be utilized is of significant importance. Motor skills apparently have an extremely high resistance to forgetting. A logical explanation of relative permanence of motor learning according to Irion is due to:

1. overlearning of motor skills,
2. absence of competing responses, and
3. verbal studies are biased to produce higher interference and motor studies are biased to produce greater accuracy.

Henry maintains that the initial attempts to perform a new skill are awkward and carried out under conscious control if there has been no similar "program" recorded on the "memory drum."

The importance of short-term memory in learning motor skills is illustrated by Fitts, who states:

It is clear that most perceptual-motor tasks require discrimination (usually on an absolute basis), classification, and other perceptual processes, as well as short-term memory and response differentiation. . . . the capacity for absolute judgments of stimulus magnitude, span of perception, short-term memory, capacity for discrimination of proprioceptive feedback, and capacity for reproduction of


quick movements all seem to be very closely matched when viewed as information and central processes.\textsuperscript{32}

Crossman, in 1960, in a theoretical analysis of "perceptual anticipation" hypothesized a limit on capacity for processing information, and a limit on capacity for short-term memory, with one or the other of these capacities determining performance in a given situation.\textsuperscript{33}

The importance of preceding factors in learning a motor skill are important aspects of the learning process. Past experience and related cues are crucial precedents for effective motor learning. In discussing complex motor skills, Lawther feels that recognition of cues to respond become increasingly important as skill level advances.\textsuperscript{34} Russian studies have noted that, "The participant must 'mentally fulfill' voluntary movement ideas before he can produce them; perception thus starts the beginning of sensory-motor connections. Making the initial concept clear and accurate is the 'most important condition in instruction of sports techniques,' a condition


\textsuperscript{34}J. D. Lawther, "Directing Motor Skill Learning," \textit{Quest}, Mon. VI (May, 1966), pp. 68-76.
frequently underestimated in importance." The importance of past experience is emphasized as an important prerequisite to motor learning by Lockhart.36


CHAPTER III

METHOD

Subjects

The eighty male subjects used in this experiment were all Ohio State University students registered in men's physical education basic instruction conditioning classes. The subjects' ages ranged from eighteen to twenty-six years. All were volunteers.

Apparatus

A pulley weight was modified so that the weight could be stopped and measured accurately at any point along the runners (see photograph, Appendix A). A five-pound weight was utilized so that it would be heavy enough for adequate sensory input and still not so heavy that fatigue would be a factor. A ruler scaled in centimeters was fastened to the wall directly behind the runners. A "c" clamp was fastened to the runner at the height desired; the exact point on the runner was determined by placing a square against the runner and taking the reading on the ruler fastened to the wall. In the absence of the "c" clamp during recall, a rubber stopper was placed on the top of the weight, which was pushed up with the weight, staying on the
runner at the highest point of the weight. If the subject
adjusted his pull, the experimenter adjusted the stopper. Meas-
urements were made with the square against the runner under the
bottom face of the rubber stopper.

A Gra Lab Timer was utilized to measure retention and
intertrial interval times.

Design

Eighty subjects were placed at random into two groups,
with forty subjects in each group. The subjects were assigned
to one of four treatment levels in each group. The ten subjects
in each of the four experimental treatment levels were required
to pull a different distance on the pulley weight over each
trial. However, the order of these distances was altered for
each of the four treatment levels. On the first treatment level
\(B_1\) the subjects went from a smaller distance to a greater dis-
tance over each of the four trials \(T_1-17\text{cm.}, T_2-25\text{cm.}, T_3-33\text{cm.}, T_4-41\text{cm.}\). In the next two treatment levels \(B_2\) and \(B_3\) the
order of distance pulled was randomized. In the fourth experi-
mental treatment level \(B_4\) the subjects pulled from a greater
distance to a smaller distance \(T_1-41\text{cm.}, T_2-33\text{cm.}, T_3-25\text{cm.}, T_4-17\text{cm.}\).

In the control group ten subjects were randomly assigned
to each of four treatment levels. All subjects in the control
group were tested at the same distance over four trials. Treat-
ment level one \(B_1\) pulled 17 centimeters, treatment level two
(B\(_2\)) pulled 25 centimeters, treatment level three (B\(_3\)) pulled 33 centimeters, and treatment level four (B\(_4\)) pulled 41 centimeters. Please refer to Table 2 for the program summary. As can be seen in Table 2, no distance appears more than once over any of the trials for either group.

**TABLE 2**

SUMMARY OF PROGRAM ADMINISTERED FOR EXPERIMENTAL AND CONTROL GROUPS (IN CENTIMETERS)

<table>
<thead>
<tr>
<th>Treatment Level</th>
<th>T(_1)</th>
<th>T(_2)</th>
<th>T(_3)</th>
<th>T(_4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experimental Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B(_1)</td>
<td>17</td>
<td>25</td>
<td>33</td>
<td>41</td>
</tr>
<tr>
<td>B(_2)</td>
<td>33</td>
<td>17</td>
<td>41</td>
<td>25</td>
</tr>
<tr>
<td>B(_3)</td>
<td>25</td>
<td>41</td>
<td>17</td>
<td>33</td>
</tr>
<tr>
<td>B(_4)</td>
<td>41</td>
<td>33</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td><strong>Control Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B(_1)'</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>B(_2)'</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>B(_3)'</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>B(_4)'</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>41</td>
</tr>
</tbody>
</table>
Procedure

All subjects were told that they were going to be tested on how well they could remember the distance they pulled the pulley weight, after a certain time interval. The subjects were then given a demonstration as to the sequence of events for one trial. The subjects were placed, back to the pulley weight, with the edge of the right shoe perpendicular to the edge of the pulley weight. The subjects were told to focus their eyes on a picture on the wall facing the subjects, so their were no visual cues. The right arm was hyperextended as far as possible, while still keeping the shoulders square (all subjects were right handed). The experimenter then placed the handle of the pulley weight in the subject's hand and trial one was about to begin. The experimenter placed a "c" clamp on the runner at the desired distance. On the command "pull," the subject pulled until the weight made contact with the "c" clamp. At this instant the experimenter commanded "release" and began timing the retention interval of twenty seconds.

In this study it was not necessary to examine the retention interval time. Both Peterson and Peterson¹ and Adams and Dijkstra² found that the retention curve levels off when the retention interval is lengthened to eighteen seconds and twenty


seconds respectively. A shorter interval would result in a higher degree of accuracy. A longer retention interval would not be necessary since forgetting would not be significantly different from the twenty second retention interval.

During the retention interval, the experimenter removed the "c" clamp and put the rubber stopper on the top of the weight, by sliding it down the runner, from its position at the top. After fifteen seconds of the retention interval had passed the subject was instructed to "grasp." The experimenter placed the handle in the subject's hand. At twenty seconds the experimenter issued the next instruction, "recall." Upon this instruction the subject attempts to repeat the previous pull with as little margin of error as possible. As soon as the subject was satisfied with his pull, the experimenter again commanded release and began timing the thirty second intertrial interval. This process was repeated for each of the four trials. The program over each of the four trials was explained earlier (Table 2). Treatment order was also randomized.
CHAPTER IV

ANALYSIS OF THE DATA

The data were analyzed initially by means of analysis of variance. The design was a repeated measurement with nesting, with two between and one within-subjects variables. The additive model was assumed.

This design has high precision and requires fewer subjects because error terms are not inflated by individual differences (the subject effect is treated as a main effect, removing it from the error term).

A detailed outline of the statistical model appears in Appendix B. The raw data were measurements of error, measured in centimeters. A summary of the analysis of variance applied to these data is shown in Table 3.

The analysis of variance was the first step in the overall analysis, with the main purpose to show if any further analysis was warranted and if so, where the emphasis could be placed.


\[2\] Ibid., p. 209.
<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>Total</td>
<td>79</td>
<td>481.2</td>
<td>7.9</td>
<td>1.55</td>
</tr>
<tr>
<td>Between S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>7.9</td>
<td>7.9</td>
<td>1.55</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>34.0</td>
<td>11.3</td>
<td>2.22</td>
</tr>
<tr>
<td>AB</td>
<td>3</td>
<td>73.4</td>
<td>24.5</td>
<td>4.80a</td>
</tr>
<tr>
<td>S/AB</td>
<td>72</td>
<td>365.9</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>Within S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>10.7</td>
<td>3.6</td>
<td>1.71</td>
</tr>
<tr>
<td>AC</td>
<td>3</td>
<td>20.1</td>
<td>6.7</td>
<td>3.19b</td>
</tr>
<tr>
<td>BC</td>
<td>9</td>
<td>29.8</td>
<td>3.3</td>
<td>1.57</td>
</tr>
<tr>
<td>ABC</td>
<td>9</td>
<td>30.2</td>
<td>3.4</td>
<td>1.62</td>
</tr>
<tr>
<td>S/ABC</td>
<td>216</td>
<td>443.1</td>
<td>2.1</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

- A = Group effect
- B = Treatment level
- C = Trial effect
- AB = Group and treatment level interaction
- AC = Group and trial interaction
- BC = Treatment level and trial interaction
- ABC = Treatment level, trial and group interaction
- S/AB = Error term for between S's "F" ratio
- S/ABC = Error term for within S's "F" ratio

Two significant interactions are shown in Table 3: group and treatment level (P < .005) and group and trial interaction (P < .05).

The next step in the analysis was to determine what caused these interactions. This is a difficult problem and one which
must be determined by rational judgment due to the lack of powerful statistical tools that are within practical limits.³ The trend analysis as outlined by Myers would determine by point, each contributor to the total variance, but the procedure is beyond the realm of the normal investigator.⁴

Hartley has devised a test that is very conservative for determining what means within a group of means are significantly different from one another.⁵ Hartley's test was applied to the group means for each trial; refer to Table 4.

The means of trial 2 and 4 of the experimental group are both shown to be significantly different from the mean on trial 4 of the control group. This, in part, would begin to explain the significant interaction between trials and groups.

Due to the conservative nature of Hartley's test, a "t" ratio was run on the means of the experimental group and separately on the means of the control group. This was done in order to examine more carefully both the trial-group interaction and the treatment level-group interaction.

The "t" ratio test for the trial means was a one-tailed test of significance, since we could expect PI in the

³Ibid., pp. 281-300.
⁴Ibid., p. 357.
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean</th>
<th>$\bar{x}$</th>
<th>$\bar{x} - 1.7$</th>
<th>$\bar{x} - 2.3$</th>
<th>$\bar{x} - 2.4$</th>
<th>$\bar{x} - 2.6$</th>
<th>$\bar{x} - 2.7$</th>
<th>$\bar{x} - 2.8$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1 T_2$</td>
<td></td>
<td>2.9</td>
<td>1.2$^{a}$</td>
<td>0.6</td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1.1)</td>
<td>(1.1)</td>
<td>(1.1)</td>
<td>(1.0)</td>
<td>(0.9)</td>
<td>(0.8)</td>
</tr>
<tr>
<td>$A_1 T_4$</td>
<td></td>
<td>2.8</td>
<td>1.1$^{a}$</td>
<td>0.5</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1.1)</td>
<td>(1.1)</td>
<td>(1.0)</td>
<td>(0.9)</td>
<td>(0.8)</td>
<td></td>
</tr>
<tr>
<td>$A_2 T_2$</td>
<td></td>
<td>2.7</td>
<td>1.0</td>
<td>0.4</td>
<td>0.3</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1.1)</td>
<td>(1.0)</td>
<td>(0.9)</td>
<td>(0.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A_1 T_3$</td>
<td></td>
<td>2.6</td>
<td>0.9</td>
<td>0.3</td>
<td>0.2</td>
<td></td>
<td></td>
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</tr>
<tr>
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<td></td>
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<td>(1.0)</td>
<td>(0.9)</td>
<td>(0.8)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$A_2 T_1$</td>
<td></td>
<td>2.6</td>
<td>0.9</td>
<td>0.3</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
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<td>(1.0)</td>
<td>(0.9)</td>
<td>(0.8)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$A_2 T_3$</td>
<td></td>
<td>2.4</td>
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<td>(0.9)</td>
<td>(0.8)</td>
<td></td>
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</tr>
<tr>
<td>$A_1 T_1$</td>
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<td></td>
<td></td>
<td></td>
<td>(0.8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A_2 T_4$</td>
<td></td>
<td>1.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^{a}$Significant Difference $P < .05$

( ) = $D$
experimental group and learning in the control group. Precedent for utilizing a one-tailed test occurred in several studies with verbal material.\textsuperscript{6,7,8}

The statistical procedure for obtaining the "t" ratio was outlined by Edwards.\textsuperscript{9} If the "t" ratio resulted in differences significant under the .05 level, subsequent smaller differences were not reported. Mean error was compared over the trials and over treatment levels. The results of these tests are summarized in Tables 5 and 6.

The trial means comparison allowed closer examination of the trial-group interaction and the treatment level means comparison was utilized to shed light on the treatment-group comparison.


TABLE 5

SUMMARY OF ONE-TAILED "t" RATIOS
COMPARING TRIAL MEANS

<table>
<thead>
<tr>
<th>Trial</th>
<th>Mean Difference (in Centimeters)</th>
<th>t</th>
<th>df</th>
<th>Level of Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>((t_2 - t_1))</td>
<td>.64</td>
<td>1.65</td>
<td>40</td>
<td>.05</td>
</tr>
<tr>
<td>((t_4 - t_1))</td>
<td>.50</td>
<td>1.45</td>
<td>40</td>
<td>.10</td>
</tr>
<tr>
<td>((t_1' - t_4'))</td>
<td>.85</td>
<td>2.30</td>
<td>40</td>
<td>.025</td>
</tr>
<tr>
<td>((t_2' - t_4'))</td>
<td>.93</td>
<td>2.31</td>
<td>40</td>
<td>.005</td>
</tr>
<tr>
<td>((t_3' - t_4'))</td>
<td>.62</td>
<td>1.60</td>
<td>40</td>
<td>.10</td>
</tr>
<tr>
<td>((t_2 - t_4'))</td>
<td>1.20</td>
<td>3.03</td>
<td>40</td>
<td>.001</td>
</tr>
<tr>
<td>((t_3 - t_4'))</td>
<td>.81</td>
<td>2.23</td>
<td>40</td>
<td>.01</td>
</tr>
<tr>
<td>((t_4 - t_4'))</td>
<td>1.07</td>
<td>2.94</td>
<td>40</td>
<td>.001</td>
</tr>
</tbody>
</table>

\(t_a\) = experimental group; \(t'_a\) = control group.

TABLE 6

SUMMARY OF TWO-TAILED "t" RATIOS COMPARING
TREATMENT LEVEL MEANS

<table>
<thead>
<tr>
<th>Treatment Levels</th>
<th>Mean Difference (in Centimeters)</th>
<th>t</th>
<th>df</th>
<th>Level of Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>((B_2 - B_1))</td>
<td>1.26</td>
<td>3.01</td>
<td>40</td>
<td>.005</td>
</tr>
<tr>
<td>((B_2 - B_4))</td>
<td>1.01</td>
<td>2.24</td>
<td>40</td>
<td>.05</td>
</tr>
<tr>
<td>((B_2 - B_4'))</td>
<td>1.75</td>
<td>3.99</td>
<td>40</td>
<td>.001</td>
</tr>
<tr>
<td>((B_1' - B_4'))</td>
<td>1.88</td>
<td>4.27</td>
<td>40</td>
<td>.001</td>
</tr>
<tr>
<td>((B_2' - B_4'))</td>
<td>.44</td>
<td>1.65</td>
<td>40</td>
<td>.10</td>
</tr>
</tbody>
</table>

\(B_a\) = experimental group; \(B'_a\) = control group.
Null-Hypotheses

1. There is no difference between a group of students pulling a different distance over each of four trials (experimental group) and another group pulling the same distance over each of four trials (control group).

This null-hypothesis was rejected. The three means of the experimental group over trials 2, 3, and 4 all differed significantly ($P < .025$) from the mean of trial 4 of the control group. A summary of these results appeared in Table 5.

2. There will be no significant difference within any of the four trial means in the experimental group over four trials.

This null-hypothesis was rejected on the basis of the difference between the means on trial 1 and trial 2 ($P < .05$). Refer to Table 5 for summary.

3. There will be no significant difference within any of the four trial means in the control group.

This null-hypothesis was rejected on the basis of the difference that occurred between trial 1 and trial 4 ($P < .025$) and trial 2 and trial 4 ($P < .025$). These results were summarized in Table 5.

4. There will be no significant difference between any of the eight treatment levels.
This null-hypothesis was also rejected. Table 6 illustrates that significant differences occurred between $B_1$ and $B_2$ ($P < .005$), $B_4$ and $B_2$ ($P < .05$), $B_4'$ and $B_2$ ($P < .001$), and $B_4'$ and $B_2'$ ($P < .001$).
CHAPTER V

SUMMARY AND CONCLUSIONS

The main purpose of this paper was to determine if proactive inhibition has any effect on a motor response during short-term memory.

Figure 1 illustrates the results, comparing the experimental and control groups. There is an increase in error, with a slight dip on trial 3 over the four trials in the experimental group. The control group decreases in error over four trials.

The analysis of variance and subsequent statistical analysis showed that the difference between the two groups was significant. Since the mean error on trial 1 in the control group is significantly different from trial 4 of the same group ($P<.025$, Table 5), learning definitely accounts for some of the difference between the two groups.

The increase in error in the experimental group was similar to verbal studies in that there was marked PI on the first trial. As stated in the Keppel and Underwood study, "There is a large drop in proportion correct from T-1 to T-2, suggesting a severe proactive effect produced by a single
Fig. 1.--Curves showing mean error over each of the four trials for the experimental and control groups.

--- = Experimental; --------- = Control.
However, the results of this study and verbal studies are not similar over the third and fourth trial. The mean error for trial 3 and trial 4 is not significantly different from trial 1 or trial 2. Figure 2 is taken from the Keppel and Underwood study. We can see from this figure that in verbal studies error continues to increase past trial 2.

Fig. 2.--Retention as a function of the number of prior syllables and length of retention interval.

---


2Ibid.
One possible explanation for this discrepancy could be that not enough subjects were tested, although Wickens, et al. found marked PI with twenty-four subjects each in a total of ten groups.\(^3\) It is, therefore, doubtful that an increase in the number of subjects would drastically change the results.

Another possible explanation would be the relative accuracy of the motor response, causing a reduction in the overall affect of interference. The grand mean for both groups was 2.50 centimeters which is not a great deal of error. The overall mean for the experimental group was 2.65 centimeters.

A novel motor response was utilized so that past experience would not affect the results. Verbal learning studies utilize nonsense syllables. Even though the syllables are meaningless the letters are not, which perhaps could cause more proactive interference. It is reasonable to assume that a motor response similar to others utilized in past experience would increase interference by introducing other competing responses.

The nature of the task to be performed is then increasingly important. This would indicate that a detailed task analysis should be performed prior to exposing a subject to a motor learning experience. Interference could be reduced during short-term memory if competing responses could be kept at a minimum.

If we accept the principle that a motor task is first carried out under conscious control, and that as learning takes place proprioceptive feedback becomes increasingly important, then speed of learning would be dependent upon the speed with which proprioceptive feedback takes control.\textsuperscript{4,5} This theory has been validated by Fitts.\textsuperscript{6} Furthermore, the rate at which motor skill aspects become automatic or under unconscious control, is determined in part by individual capacity for processing information during short-term memory.\textsuperscript{7}

In summary, this study reveals evidence that PI does have an effect on a motor response during short-term memory; also, this effect is limited by the relative accuracy of kinesthetic feedback.

Another factor that complicates the above issue is that a definite order effect occurred in this experiment. It was found that error gradually decreased as the length of the pull increased. As can be seen from Table 6, the subjects who pulled


\textsuperscript{6}\textit{Ibid}.

seventeen centimeters over each trial (B'_1), had a mean difference with the subjects who pulled forty-one centimeters (B'_4) of 1.88 cm., which was significant at the .001 level. The mean for B'_1 was 3.55 cm. and the mean for B'_4 was 1.67 cm. This clearly shows that there was greater error pulling a shorter distance, which is confusing since one would expect the reversal to be true.

This did not affect the trial means since each distance appeared only once for each trial.

The writer believes the reason for these results is that one pull was novel (17 cm.), while the 41 cm. pull caused the subjects to stop at a point which previous kinaesthetic control had been established, thus resulting in decreased error. It is possible that this factor decreased the amount of error and possibly limited the PI effect to some extent.

The results do not indicate that STM follows different rules and principles than long-term storage. PI effects were shown to have occurred after the first trial. These results would then support interference theorists.

There were no results from this study that indicated the process of motor learning is different from verbal learning. There are differences relative to the actual task being performed. The order effect obtained in this study is an example of the unique nature of the motor task employed. More research is needed to give an accurate task analysis of motor skills.
Then past experience could be measured accurately, thus avoiding such "order effects" as occurred in this experiment.
APPENDIX A

PHOTOGRAPHS SHOWING TESTING INSTRUMENT
AND POSITION OF SUBJECT
### APPENDIX B

**EXPERIMENTAL MODEL WITH SAMPLE OF RAW DATA**

<table>
<thead>
<tr>
<th>Experimental Group</th>
<th>$T_1$</th>
<th>$T_2$</th>
<th>$T_3$</th>
<th>$T_4$</th>
<th>$\sum_{ijkm}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$S_{111}$</td>
<td>2.9</td>
<td>2.7</td>
<td>2.8</td>
<td>3.3</td>
<td>11.7</td>
</tr>
<tr>
<td>$S_{1011}$</td>
<td>2.8</td>
<td>0.8</td>
<td>1.0</td>
<td>3.8</td>
<td>8.4</td>
</tr>
</tbody>
</table>

$\sum_{i_1m} Y_{i_1lm} = 23.5$ \quad 22.3 \quad 20.0 \quad 20.6 \quad \sum_{im} Y_{i_1lm} = 86.4$

| $B_2$              |       |       |       |       |               |
| $S_{112}$          | 4.0   | 2.0   | 6.1   | 3.3   | 15.4          |
| $S_{1012}$         | 0.9   | 6.2   | 0.2   | 5.7   | 13.0          |

$\sum_{i_2m} Y_{i_2lm} = 27.5$ \quad 42.1 \quad 29.8 \quad 37.3 \quad \sum_{im} Y_{i_2lm} = 136.7$

| $B_3$              |       |       |       |       |               |
| $S_{113}$          | 2.0   | 4.4   | 4.2   | 1.2   | 12.1          |
| $S_{1013}$         | 2.0   | 2.5   | 2.5   | 2.6   | 9.6           |

$\sum_{i_3m} Y_{i_3lm} = 22.4$ \quad 35.6 \quad 19.8 \quad 28.1 \quad \sum_{im} Y_{i_3lm} = 105.9$

| $B_4$              |       |       |       |       |               |
| $S_{114}$          | 4.0   | 0.0   | 3.2   | 1.3   | 8.5           |
| $S_{1014}$         | 1.2   | 1.5   | 2.8   | 1.9   | 7.4           |

$\sum_{i_4m} Y_{i_4lm} = 19.0$ \quad 17.5 \quad 33.2 \quad 26.8 \quad \sum_{im} Y_{i_4lm} = 96.5$

$\sum_{ijkm} Y_{ikijkm} = 92.4$ \quad 117.5 \quad 102.8 \quad 112.8 \quad \sum_{ikm} Y_{ikijkm} = 425.5
**EXPERIMENTAL MODEL WITH SAMPLE OF RAW DATA--Continued**

<table>
<thead>
<tr>
<th></th>
<th>$T_1$</th>
<th>$T_2$</th>
<th>$T_3$</th>
<th>$T_4$</th>
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</thead>
<tbody>
<tr>
<td>$S_{121}$</td>
<td>2.0</td>
<td>1.4</td>
<td>2.4</td>
<td>1.7</td>
</tr>
<tr>
<td>$B_1$</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>$S_{1021}$</td>
<td>0.2</td>
<td>5.4</td>
<td>0.1</td>
<td>3.0</td>
</tr>
</tbody>
</table>

$$\sum_{ij} Y_{121m} = 37.5 \quad 34.1 \quad 35.7 \quad 34.7 \quad \sum_{im} Y_{121m} = 142.0$$

<table>
<thead>
<tr>
<th></th>
<th>$T_1$</th>
<th>$T_2$</th>
<th>$T_3$</th>
<th>$T_4$</th>
</tr>
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<tbody>
<tr>
<td>$S_{122}$</td>
<td>1.6</td>
<td>0.2</td>
<td>2.6</td>
<td>1.1</td>
</tr>
<tr>
<td>$B_2$</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>$S_{1022}$</td>
<td>2.2</td>
<td>0.9</td>
<td>1.8</td>
<td>2.0</td>
</tr>
</tbody>
</table>

$$\sum_{ij} Y_{122m} = 19.3 \quad 28.4 \quad 23.4 \quad 13.0 \quad \sum_{im} Y_{122m} = 84.1$$

**Control Group ($A_2$)**

<table>
<thead>
<tr>
<th></th>
<th>$T_1$</th>
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<th>$T_3$</th>
<th>$T_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{123}$</td>
<td>3.1</td>
<td>2.5</td>
<td>4.3</td>
<td>0.9</td>
</tr>
<tr>
<td>$B_3$</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>$S_{1023}$</td>
<td>0.8</td>
<td>1.1</td>
<td>0.1</td>
<td>0.8</td>
</tr>
</tbody>
</table>

$$\sum_{ij} Y_{123m} = 28.3 \quad 24.7 \quad 18.7 \quad 10.4 \quad \sum_{im} Y_{123m} = 82.1$$

<table>
<thead>
<tr>
<th></th>
<th>$T_1$</th>
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<th>$T_3$</th>
<th>$T_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{124}$</td>
<td>1.0</td>
<td>0.6</td>
<td>2.0</td>
<td>0.9</td>
</tr>
<tr>
<td>$B_4$</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>$S_{1024}$</td>
<td>2.3</td>
<td>1.5</td>
<td>0.6</td>
<td>1.0</td>
</tr>
</tbody>
</table>

$$\sum_{ij} Y_{124m} = 18.6 \quad 19.7 \quad 17.1 \quad 11.5 \quad \sum_{im} Y_{124m} = 66.9$$

$$Y_{ik} i2km = 103.7 \quad 106.9 \quad 94.9 \quad 69.6 \quad Y_{ikm} i2km = 375.1$$

$$\sum_{ijk} Y_{ijkm} = 196.1 \quad 224.4 \quad 197.7 \quad 182.2 \quad \sum_{ijkm} Y_{ijkm} = 800.6$$
### SUB-TOTALS FOR B-T CELLS

<table>
<thead>
<tr>
<th></th>
<th>$T_1$</th>
<th>$T_2$</th>
<th>$T_3$</th>
<th>$T_4$</th>
<th>$\sum Y_{ijm}$</th>
<th>$\sum Y_{ijkm}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_1 + B_1'$</td>
<td>61.0</td>
<td>56.4</td>
<td>55.7</td>
<td>55.3</td>
<td>228.4</td>
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<td>$B_2 + B_2'$</td>
<td>46.8</td>
<td>70.5</td>
<td>53.2</td>
<td>50.3</td>
<td>220.8</td>
<td></td>
</tr>
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<td>60.3</td>
<td>38.5</td>
<td>38.5</td>
<td>188.0</td>
<td></td>
</tr>
<tr>
<td>$B_4 + B_4'$</td>
<td>37.6</td>
<td>37.2</td>
<td>50.3</td>
<td>38.0</td>
<td>163.4</td>
<td></td>
</tr>
</tbody>
</table>

$\sum Y_{ijk} = 196.1$  $224.4$  $197.7$  $182.4$
NOTES:

\[ A_1 = \text{Experimental Group} \]
\[ A_2 = \text{Control Group} \]
\[ T_1 \ldots T_4 = \text{Trials one to four} \]
\[ B_1 = \text{Exp. treatment level pulling 17 cm., 25 cm., 33 cm., and 41 cm. in that order from trial 1 to trial 4 respectively.} \]

In a similar manner:

\[ B_2 = \text{Exp. group pulling 33 cm., 17 cm., 41 cm., and 25 cm.} \]
\[ B_3 = \text{Exp. group pulling 25 cm., 41 cm., 17 cm., and 33 cm.} \]
\[ B_4 = \text{Exp. group pulling 41 cm., 33 cm., 25 cm., and 17 cm.} \]
\[ B_1' = \text{Control group pulling 17 cm., over each of four trials.} \]

In a similar manner:

\[ B_2' = \text{Control group pulling 25 cm.} \]
\[ B_3' = \text{Control group pulling 33 cm.} \]
\[ B_4' = \text{Control group pulling 41 cm.} \]
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