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The effects of movement similarity on motor short-term memory.

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THE EFFECTS OF MOVEMENT SIMILARITY ON MOTOR SHORT-TERM MEMORY

A Thesis
Submitted to the Faculty of Graduate Studies
through the Faculty of Physical and Health
Education in Partial Fulfillment of
the Requirements for the Degree of
Master of Physical Education

by

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B.A., University of Western Ontario, 1970

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1971

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Date:

August 14 ______ Adviser

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ABSTRACT

The purpose of this thesis was to determine the effect of similarity of movement on motor short-term memory. There were three independent variables analyzed: retention interval, similiarity and prior movements. The experimental task was a linear slide movement and performance was measured by four dependent variables: absolute and algebraic error for both speed and distance recall. Thirty male, physical education students from the University of Windsor were subjects. The results were analyzed separately for each dependent variable by means of a three factor analysis of variance with repeated measures on the last two factors. Newman-Keuls and simple effects secondary analyses were calculated for the significant main effects and interactions.

It was concluded that recall for speed and distance decreased over time, thus demonstrating proactive interference. This interference was manifest as a negative shift in the response bias as the retention interval increased. As predicted, an increase in movement similarity (defined by speed of movement) caused a decrease in speed recall error but an increase in distance recall error. The response bias shifted in a negative direction for distance recall error and in a positive direction for speed recall error, as similarity of movements increased. No conclusions could be drawn

regarding the effect of the number of prior movements on motor STM.

In summary, it seemed that previous researchers had confounded similarity and range effects when testing the effects of movement similarity on motor STM. In future research, more attention must be focused on the verbal STM studies before proper replication using motor input can be achieved.

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CHAPTER 1

INTRODUCTION

Short-Term Memory

In recent years researchers have become increasingly more interested in man's memory systems. It has been proposed that at least two systems exist; a relatively stable (over time) long-term memory (LTM) system and a very transient short-term memory (STM) system. This thesis was focused on the latter system.

It is self-evident that people tend to forget as time passes, but what causes people to forget is not quite so obvious. Basically, there are two theories which attempt to explain this phenomenon. The trace decay theory states that the stored information spontaneously decays over time and that forgetting is the result of a weakened trace at the time of recall. On the other hand, interference theory proposes that, competing responses learned before the acquisition of the criterion response (proactive interference, PI) or during the retention period (retroactive interference, RI) induce the decrement in recall called forgetting. A third view, acid bath, combines trace decay and interference. It suggests that interfering items interact with the stored trace spontaneously during the retention interval to weaken its strength. This view predicts that the memory trace is destroyed as a function of time, as well as number and similarity of items in storage, but not as a function of the strength of the items. However, the applicability of these theories to motor, as opposed to verbal, STM is unclear since the predictions are based on studies using visual and auditory input only.

At the present stage of knowledge it appears that interference theory best explains visual and auditory phonomena for both LTM and STM. It has long been thought that perceptual motor skills, once learned, are relatively stable over time, but little is known about motor STM because of the lack of study in this area. Since STM is an essential component of skilled movement, physical educators have become interested in this area. Since, as Adams (1967) stated, "one unifying set of laws for all memory is parsimonious and scientifically desirable", it has become the task of physical educators to determine the generalizability of laws derived from verbal studies for motor STM. Thus, the present study was directed towards this end.

Definition of Terms

Short-Term Memory

In 1890, James (Adams, 1967) hypothesized that, "an event in primary memory (STM) has never left consciousness and is part of the psychological present". More recently and more appropriately for this thesis, Fitts and Posner (1967) defined STM "... as a system which loses information rapidly in the absence of sustained attention". Generally, STM involves the first 0 to 120 seconds after presentation of a new stimulus and then the item is either lost or transferred to LTM. In the present study, STM referred to the first 5 to 40 seconds following the completion of the criterion movement.

Kinesthesis

Because of the lack of agreement among researchers as to what kinesthesis actually entails, an operational definition was thought to be appropriate. Kinesthesis was defined as that form of non-visual, non verbal information generated by the subject's linear movement of the slide (the testing device used).

Perceptual Motor Skill

As defined by Wilberg (1969b), this referred to a motor skill initiated by the subject's perception of a stimulus in the environment. Since the movement to be recalled involved visual as well as kinesthetic stimuli and thus was a perceptual motor task, the study was more appropriately called motor STM, as opposed to pure kinesthetic STM.

Undershooting

This was the tendency to be short of the target when recalling the amplitude of the criterion movement or the tendency to be too slow when recalling the speed.

Overshooting

This was the tendency to overestimate the amplitude or to move too quickly when recalling the criterion movement.

Response Bias

Since both magnitude and direction of recall error were deemed important, response bias or set was defined as the tendency of the subjects to undershoot or overshoot (as measured by algebraic error) upon recall, as distinct from the tendency to commit more or less error (as measured by absolute error).

Experimental Variables

Figure 1 represents a sequence of events for a single trial in a motor STM experiment similar to the design used in the present study. Terms are defined from left to right.

Prior Movements. - These included all linear movements along the slide made by the subject before the criterion movement.

Criterion Movement (CM). - The criterion movement, as distinct from the prior movements (this distinction was only made by the experimenter and not by the subjects who treated all movements in a trial similarly), was the last movement made by the subject before the retention interval and the first to be recalled afterwards (recall was in reverse order to presentation). The difference between these two movements was used to measure the amount of forgetting that occurred over the retention interval. The other movements were not recorded by the experimenter although this was not known by the subjects. Proactive interference could not be produced unless the subjects attended to all movements during a given trial.

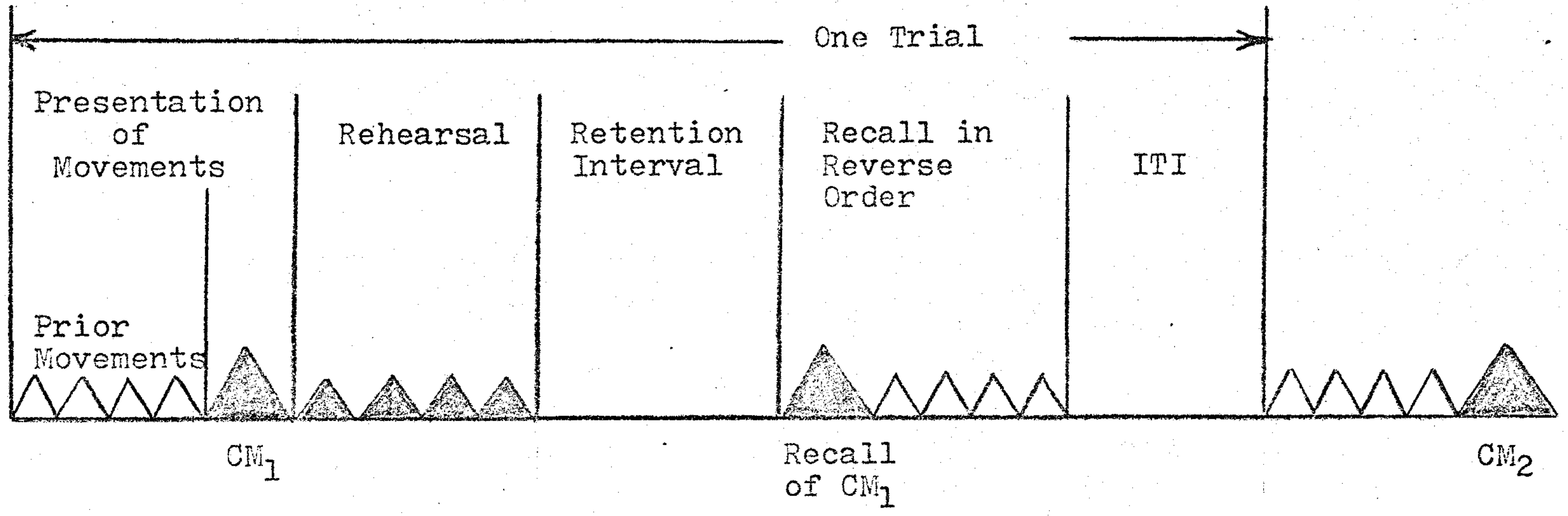

Figure 1.--A schematic representation of a single trial in a STM experiment.

Similarity of Movement. - Similarity in verbal STM is defined acoustically (how a word sounds). An analogy in motor STM would be to define similarity of movements by how they feel, however, because of the lack of knowledge concerning kinesthetic input, this is impossible. Therefore, similarity of movement was operationally defined by the speed of movement along the slide. Prior movements were either the same or a different speed than the CM.

Rehearsal. - Norman (1969) defined rehearsal, relevant to verbal STM, as a type of inner speech by which humans are able to maintain a limited amount of information in memory. More appropriate for motor STM, and used in the present study, Posner (1966) defined rehearsal as a process requiring a portion of a person's central information processing capacity. This definition does not differentiate between overt and covert repetition and thus eliminates the problems involved in distinguishing between mental and physical practice of movement.

Retention Interval. - The retention interval was defined as the time between the completion of the criterion movement and the beginning of the recall period.

Recall. - This was the period during which the subjects reproduced, from memory, the speed and amplitude of all movements made prior to the retention interval. Recall was in reverse order, so that the last movement before the retention interval (CM) was the first movement recalled.

Intertrial Interval (ITI). - The ITI was the time between completion of recall and the beginning of the prior movements in the next trial.

CHAPTER 11

REVIEW OF LITERATURE

Introduction

> That a unitary explanation is desirable (concerning laws of memory) is beyond doubt, but that laws often fail to fulfill our hopes for elegant simplicity is also undeniable. Those interference theorists who believed in one general set of laws for memory, therefore, sought to prove that rapid forgetting was a function of interference (Adams, 1967).

Research began with the hope that the same laws governing forgetting in LTM might also apply to STM. By 1962, (Keppel & Underwood) it seemed apparent that interference theory was applicable for verbal LTM and verbal STM. Because of the similarities as well as the striking differences between motor and verbal STM, it became the task of physical educators to discover if the same laws governing verbal STM might also be appropriate for motor STM.

The review of literature will follow a similar plan; verbal laws concerning the effects of rehearsal, retention interval and proactive interference will be briefly discussed, followed by an extensive review of the motor STM studies in these same areas. The areas reviewed are directly related to the independent variables used in the present thesis.

Rehearsal

One of the most thorough studies dealing with rehearsal of verbal items was completed by Hellyer (1962). Using 1, 2, 4 and 8 repetitions of the criterion item (3 letter consonant syllables), corresponding to the CM in Figure 1, he found that an increase in the number of repetiions increased the resistance to forgetting. Peterson and Peterson (1959) obtained identical results using 1 reinforcement. Similar results had also been reported for covert rehearsal. Thus, it seemed that an increase in rehearsal or repetitions of verbal items decreased forgetting in verbal STM.

One of the first experiments in motor STM was conducted by Adams and Dijkstra (1966) using a linear movement task. A trial consisted of the presentation, repetition and recall of 1 movement and each subject received 7 trials of 7 different distances. This sequence is shown at the top of Figure 2. They found that an increase in the number of repetitions (1, 6 or 15) decreased the amount of forgetting over time, although there was little difference between 6 and 15 repetitions. Although algebraic error was not analyzed, it is evident from Table 3 of their report that the response bias shifted in a positive direction with increasing repetitions. Also using a linear movement along a slide, Montague and Hillix (1968) found that an increase in repetitions (bottom of Figure 2) increased the ability to recall the movement after a retention interval.

Using a paradigm similar to Figure 1, Williams (1970) found that recall of a linear movement was aided by 1, 3 or 10 reinforcements. This was only true of absolute error however,

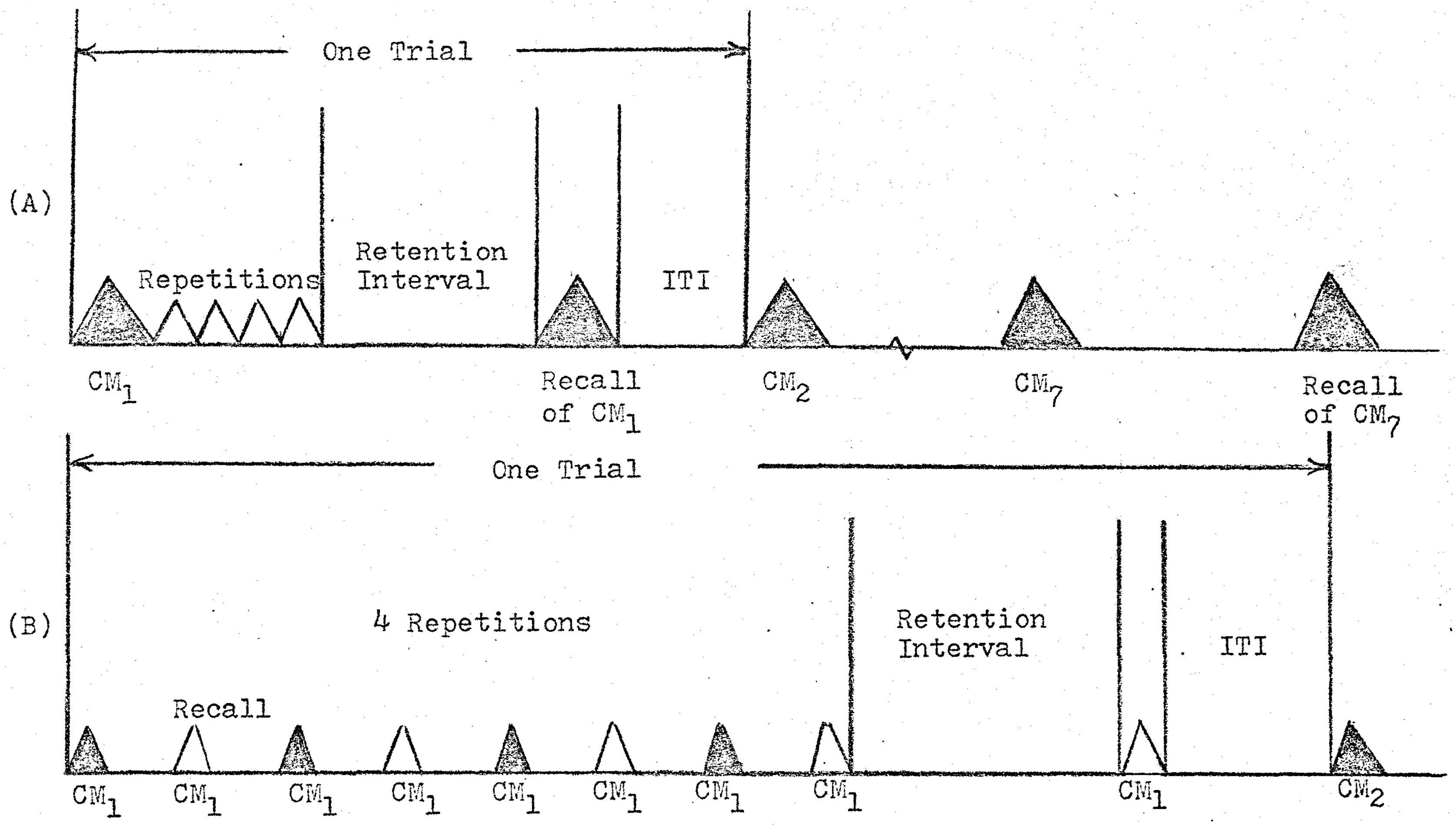

Figure 2.--The model used by (A) Adams and Dijkstra (1966), and the modification of this used by (B) Montague and Hillix (1968).

as neither main effects nor interactions were significant with algebraic error. There was no appreciable decrease in recall over 3 retention intervals (5, 15 and 50 seconds) with 3 or 10 repetitions of the criterion movement, thus it was evident that rehearsal of the CM cancelled any PI effects produced by the prior movements.

Norrie (1969), using a force reproduction task, concluded that 5 and 9 repetitions improved immediate recall but not short term recall (30 sec.). As she noted, this was contrary to the above studies. Since rehearsal of verbal material aids recall at all retention intervals, she reasoned that the above studies may have had a greater verbal component than her study and this could indicate that, "motor performance on a force reproduction task does not follow the same laws as tasks with higher verbal content". This conclusion was partially supported by Pepper (1970), also using force reproduction, who found that increased repetitions of the CM, increased the errors at recall after a 20 second retention interval. This was true for both absolute and algebraic error. Since overshooting of force recall occurred, as was the case in Norrie's (1969) work, Pepper(1970) concluded that repetitions of the criterion force augmented the subject's kinesthetic memory trace causing a positive shift in response bias and therefore the increased error or overshooting to occur. Pepper (1970) hypothesized that, because Adams and Dijkstra's (1966) subjects were characterized by undershooting, the augmented memory trace, resulting from repetition, decreased the error at recall; thus explaining both findings. However, it would be difficult to explain William's (1970) results since repetitions aided recall even though characterized by overshooting.

Montgomery (1970), studying covert rehearsal of a wrist rotation task, found that a 10 second rehearsal period had no effect on forgetting, thus shedding doubt on Pepper's augmented proprioceptive trace explanation of recall. In agreement with Keele (1968), Montgomery (1970) stated, "the possibility that the memory function is dependent upon the nature of the kinesthetic input cannot be easily eliminated".

In conclusion, it seems that overt repetition aids retention of a linear movement but not force reproduction. It also appears that overt and covert rehearsal may differ in effect. The nature of the kinesthetic input and the response set in combination or separate, may be very important in determining rehearsal effects.

Retention Interval

Unlike the information concerning rehearsal of verbal items, there is some dispute concerning the effect of the retention interval on verbal STM. This disagreement is centered around the two conflicting theories of forgetting, interference and decay.

Conrad and Hille (1958), by controlling the presentation and recall rate of digit sequences, concluded that, "the results of this experiment strongly support the view that, in the absence of rehearsal, memory decays very rapidly with time". Using consonant trigrams and retention intervals ranging from 3 to 18 seconds, Peterson and Peterson (1959) found memory to decay over time, when subjects counted backwards (by three's) during the retention interval. However, a replication of the above study by Keppel and Underwood (1962), demonstrated that forgetting did not occur over the retention interval if no prior learn-recall sequences were experienced by the subject.

Posner (1967a) concluded that both theories might have applicability in explaining loss of memory over a retention interval. It is certain, however, if rehearsal, either covert or overt, is not prevented during the retention interval that there is no decrease in recall over time, in verbal STM.

Adams and Dijkstra (1966), using a motor response, found recall accuracy to decrease as the retention interval increased from 5 to 120 seconds accompanied by a negative shift in the response bias. Similar results were obtained by Montague and Hillix (1968) in a replication of the above study. Both studies supported the trace decay theory of forgetting since accuracy of recall decreased significantly over an unfilled retention interval and continued to decrease as the interval increased.

Gentile (1968) examined the retention of simple motor acts (horizontal positioning responses) after retention intervals of 0, 4, 8, 12 and 16 seconds. The subjects were required to count backwards during the retention interval similar to verbal experiments. Again, forgetting increased between 4 and 16 seconds as indicated by increased overshooting of the test position over time. In an attempt to compare visual and kinesthetic memory, Posner (1967a) divided his subjects into four groups: visual distance, visual location, kinesthetic distance, and kinesthetic location. He hypothesized that visual location would not show forgetting over an empty retention interval, but recall accuracy of kinesthetic distance would. Both hypotheses were supported, as in fact, visual retention increased (rehearsal) between a 0 and 20 second retention interval while kinesthetic retention decreased. Gentile (1968) and Posner (1967a) both concluded that trace decay was significant to motor STM.

Following the paradigm shown in Figure 1, Ascoli and Schmidt (1969) and Stelmach (1969b) obtained evidence to support both trace decay and interference in motor STM. With a lever positioning task, it was found that 4 prior movements caused proactive interference, thus decreasing recall, however, the 0 prior movement condition also demonstrated forgetting (decay). Likewise, Stelmach and Wilson (1970), using a 20 second unfilled retention interval and Stelmach and Barber (1970), using an empty 30 second interval, obtained further support for trace decay of kinesthetic information, since forgetting occurred.

However, not all studies have found decreased recall accuracy over an unfilled retention interval. In Experiment 1, Pepper (1970), using a force reproduction task, found no forgetting with 5 empty intervals ranging from 4 to 60 seconds.

In fact, in Experiment 11, there was a significant decrease in recall error over a 30 second retention interval, which Pepper (1970) attributed to a negative shift in the response set from overshooting to less overshooting. The above results compared favourably with those of Norrie (1969), also employing a force reproduction task, under the 1 reinforcement condition. With 5 and 9 reinforcements however, there was a significant difference in recall precision between the 0 and 30 second interval, with accuracy decreasing over time. Besides the apparent differences (different tasks) between the above two studies and the ones previously sited in this section, recall in the former studies were characterized by undershooting at recall while the latter two demonstrated significant overshooting. In a study by Wilberg and Sharp (1970), subjects, recalling movements made with a joystick, experienced no significant decrease in retention over a 15 second interval. It was concluded that the results "do not support the idea of a constant rate of information loss as a function of time in STM". Since the retention interval was only 15 seconds, however, (shorter than other studies) caution in ruling out trace decay must be shown.

It seems obvious from the literature on linear movement, that there is a decrement in recall over an empty retention interval, thus supporting a trace decay interpretation. Considering the latter three studies, it might be hypothesized that a difference in sensory input (different tasks) and response bias (negative or positive) may be significant in determining the effect of an empty interval on retention of a motor skill.

Proactive Interference

Prior Movements

Substantial evidence exists supporting proactive interference in verbal STM. As Adams (1967) stated, "there is little doubt that STM (verbal) is subject to laws of interference" (speaking of proactive interference). In a comprehensive study by Keppel and Underwood (1962), employing 3 consonant trigrams, PI was shown to produce forgetting with 1 and 2 prior learn-recall sequences (prior movements). By means of three similar experiments, they concluded that PI increased, as the number of potentially interfering items, the retention interval and the degree of learning of prior items, increased. Wickens, Born and Allen (1963), demonstrated that PI is a function of the similarity of the prior-learned materials. Digit sets interfered more with recall of digits than with consonant trigrams, and vice versa. Peterson and Gentile (1965) also showed that PI increases as the intertrial interval decreases.

The research on PI in motor STM, however, is quite inconclusive and seems to depend on the experimental design used. With the experimental design shown on the top of Figure 2, Adams and Dijkstra (1966) were unable to prove the existence of PI in motor STM, with as many as 7 trials. In fact, subjects performed better on the last trials, where PI should have been maximum, than on the first trials, where PI should have been minimal. They attributed this to a learning to learn phenomenon as the subjects worked through the trials. Since the ITI in the above experiment had been relatively long (3 minutes), Montague and Hillix (1968) (bottom of Figure 2) reasoned that the memory trace would have been very weak before a new distance was presented, therefore, PI could not have been produced. They also hypothesized, since rehearsal decreases forgetting, that 4 repetitions of the CM were more appropriate than 1, 6 or 15; the former not enough to consolidate the trace and 6 and 15 repetitions too many, thus countering any possible PI effect. However, with 4 repetitions and shorter ITIs (5, 20 and 80 seconds) they were still unable to produce PI effects after 7 trials.

Using a different design (Figure 1) than the above researchers, Ascoli and Schmidt (1969) and Stelmach (1969b) were able to produce PI effects. With 4 prior movements they were able to produce significantly more forgetting than with 0 or 2 prior movements, which had no differential effect on recall. However, since the 0 prior movement condition still produced forgetting, they concluded that both decay and interference theories were needed to explain motor STM. It was also noted by Ascoli and Schmidt (1969) that an increase in the number of prior movements caused a negative shift in the response bias. The average error for 0 and 2 prior movements being about -15 mm and -50 mm for 4 prior movements. Wilberg and Sharp (1970) found that increasing the recall load (number of movements to remember) increased forgetting. Absolute error of recall was greatest with 8 movements, less with 4 and least with 2 movements to remember. As with the other two studies, there was no prior movement X retention interval interaction, as might be expected.

Schmidt and Ascoli (1970a), using Adams' and Dijkstra's (1966) paradigm (Figure 2), were again unable to produce PI with 10 trials and an ITI as short as 10 seconds. From this, they concluded that the apparent PI effects in their previous study were the result of decreased attention to the CM rather than PI, as both would show an increase in forgetting. In a second (1970b) study, they were able to show that counting, during presentation of the CM, had the same detrimental effect as 4 prior movements. It was concluded that the PI effects of their earlier study had been confused with decreased attention. However, Williams (1970) showed that Ascoli and Schmidt (1969) and Stelmach (1969b) were correct in assuming PI to occur in motor STM. If the forgetting was caused by decreased attention, this would be manifest as increased forgetting with immediate recall (5 seconds). If it was due to PI produced by the 4 prior movements, it would be indicated by increased forgetting after a short interval but not with immediate recall. Williams (1970) found significantly more forgetting after 20 and 80 seconds than at immediate recall thus proving his hypothesis. Unlike Ascoli and Schmidt (1969) however, an increase in prior movements caused an increase in both undershooting and overshooting.

In conclusion, like verbal STM, it seems that PI can be produced in motor STM if the proper paradigm is employed, but unlike verbal STM, PI cannot be produced with less than 3 prior responses. Also, there does not appear to be any consistent trend in response bias as the number of prior movements increases. Thus, any conclusions, other than the possible existence of PI in motor STM, seem very hazardous.

Similarity

> At this stage of knowledge it seems reasonable to say that STM is an auditory system distinct from LTM. Both are subject to interference but not the same kind. Acoustic similarity governs interference in STM and semantic similarity determines it in LTM (Adams, 1967).

The initial work in determining the effect of acoustic similarity on the verbal STM system was done by Conrad. In his first study (1962), he determined the acoustic confusability of the letters of the alphabet. After presenting the letters aurally with a background of white noise, he found that most confusions among letters were made with those that sounded alike. For example, when B was spoken, the letters C, P, T or V were often written down as the presented letter. Subsequently (1964), 6 letter sequences drawn from the following 10 letters: BCFMNPSTVX, were presented visually, one letter at a time, at a rate of 0.75 sec/letter. At the end of each sequence (a total of 40 were used) the subject immediately wrote down as much of the sequence as he could remember, in the order it was presented (serial recall). Errors in this experiment were similar to those made in the former study. The letters B C P T V were confused with one another on recall, more than with the other five. Thus, it seemed the STM system was acoustical no matter if the input was visual or auditory. It was recognized that a decrease in recall of sound-alike letters could have been due to errors of perception and not acoustical interference. Thus, using the same 10 letters as before, Conrad (1964) attempted to solve this problem by presenting these letters with and without a white noise background. It was concluded that, although the poor recall of acoustically similar letters could be in part due to unclear perception not all errors could be attributed to this.

> It is tempting to draw three conclusions from Conrad's study: (a) Short-term storage is auditory. (b) Acoustically similar items are represented by similar traces. (c) Partial forgetting of an item is possible, producing intrusion errors that share the unforgotten property common to both the original item and the intrusion (Wickelgren, 1965a).

Wickelgren (1965a) attempted to support these conclusions by investigating intrusions involving all 26 letters and the digits 1 through 9. Here, acoustic similarity referred to the possession of common sounds among letters and digits. It was found that intrusions between letters and between letters and digits occurred with the acoustically similar items, therefore suggesting that the sequence of sounds rather than the sequence of letters were encoded in STM. As expected from the acoustic components or phonemes, there were no intrusion errors among the digits. Wickelgren (1965a) concluded that STM used either an auditory or speech motor code for at least part of the trace and that the results were in total agreement with Conrad's (1962, 1964) earlier work.

In a second study, using consonant-vowel digrams, Wickelgren (1965b) found that the probability of an intrusion appeared to be a monotonic increasing function of the degree of similarity of the presented items. There seemed to be 2 dimensions of similarity: (1) consonant similarity, with 3 values (same consonant in the same position, same consonant in a different position, different consonant), (2) vowel similarity, with only 2 values (same vowel, different vowel). Therefore, the trace for the consonant could be lost in 2 stages and the trace for the vowel in only 1 stage.

Thus, it seems evident from the literature sited that PI affects recall in verbal STM, with as few as 1 prior item interfering with recall of another. It also seems that PI increases (more intrusion errors) as the acoustic similarity of items to be recalled increases. Acoustic similarity is measured by the number of common components or phonemes in the items to be remembered and intrusion errors occur when partial forgetting (or forgetting of some of the acoustic components) occurs and similar items with common phonemes are confused. Concurrent to this is the fact that the verbal STM system seems to use an auditory encoding mechanism no matter if the information (input) is presented aurally or visually.

It is difficult to imagine how the motor STM system could function employing auditory encoding, and it seems that this is unlikely, especially for pure kinesthetic input. It is quite possible, however, that motor similarity could be an important factor affecting recall of movements, although this point is far from clear because of the lack of study in this area.

A study, not concerned with STM per se, but designed to look at the effects of interpolated activity (RI) on acquisition of a simple arc-drawing response (Ra) was conducted by Blick and Bilodeau (1963). The Ra response (a 255° counterclockwise movement) was followed by knowledge of results (KRa) and these together constituted 1 trial of learning. Between trials, predetermined clockwise and counterclockwise movements of 255°, 235°, 205° or 165° (Rb) were made, so that a sequence of 12 trials followed the pattern, Ra - KRa, RB, Ra - KRa, Rb etc.. There was no evidence of retroactive inhibition, as the various interpolated responses did not differentially affect the the acquisition of the arc response. Although there was no formal definition of similarity given, it was evident that direction of movement and degrees of displacement were the criteria used. Both were insignificant in affecting learning of the CM.

Using the design shown on the bottom of Figure 2, Montague and Hillix (1968) were unable to produce PI effects in motor STM of linear responses. Seven trials of seven different response lengths, each differing by 4 cm., were used.

> Interference in verbal tasks is generally thought to be some function of similarity between tasks. Intuitively, motor responses on the same apparatus, differing merely in length, seem very similar. However, if subjects make their responses in terms of spatial position or location, it seems possible that differences of 4 cm. are readily discriminable and, therefore, minimally interfering (Montague & Hillix, 1968).

Two problems in studying motor similarity can be gleaned from this paragraph. First, seemingly similar movements may in fact be perceived as different, since motor components are not learned to the same degree of complexity as verbal phonemes, thus making kinesthetic perception unique to the individual rather than unique to a certain populace, as are the phonemes of a language. Second, different subjects may use different motor cues for purposes of recall, making an operational definition of movement similarity somewhat hazardous.

The first attempt to look specifically at response-similarity and short-term motor retention was conducted by Stelmach (1969a). Using the paradigm shown in Figure 1 (already shown by Stelmach (1969b) and Ascoli and Schmidt (1969) to produce PI), Stelmach (1969a) defined similarity of movement in degrees of displacement of a lever along an arc. Three levels of similarity between the CM and the prior movements were used: $\pm 5^\circ$, $\pm 15^\circ$ and $\pm 25^\circ$. Since only 0, 2 and 4 prior movements were employed the CM was always preceded by 1 longer and 1 shorter movement or 2 longer and 2 shorter movements, unless in the no prior movement condition. Thus, a trial with 4 prior movements under the most similar condition would be: a $+5^\circ$ (as compared to CM) movement, a -5° movement, a $+5^\circ$ movement, a -5° movement and the criterion movement (either 30, 70 or 90 degrees from the starting position) followed by a 5, 15 or 50 second retention interval and recall in reverse order. An ITI of 90 seconds was used to counteract PI effects from trial to trial, as each subject had three trials; 3 target positions and retention intervals but only 1 response similarity condition.

The analysis using both absolute and algebraic error showed target positions to be insignificant. There was a significant increase in forgetting over the 3 retention intervals with algebraic error. Contrary to verbal STM, Stelmach (1969a) found that a decrease in similarity caused a significant increase in forgetting or a negative shift in the response bias. However, several questions arose from this conclusion. First, Stelmach (1969a) noted that the least similar condition (± 25°) presented a much greater range from which to choose, when recalling the CM, than the most similar condition (± 5°). The possibility of error, therefore, may not have been constant over the 3 levels of similarity. Second, it was noted that the prior movements in the ± 5° condition only varied ± 0.25 in. from the CM. If subjects could not differentiate these movements the prior responses may have been treated as repetitions of the CM and thus adversely affected the results. In verbal STM this type of confusion would increase the number of errors, since the range of possible error remains fairly constant over all similarity conditions. It seems essential that the range of error be controlled in motor STM before a valid comparison can be made between the effects of similarity on verbal and motor STM. In fact, if Stelmach's (1969a) error terms are expressed in relative terms (divided by the range of possible error) the opposite conclusion regarding the effect of similarity might have been drawn.

Third, there is a basic difference between the all or none error term in verbal STM and the degree of correctness associated with the retention measure of motor STM. This latter problem has been inherent in all motor STM studies to date. Thus, Stelmach (1969a) suggested that future studies should consider methods which would allow a more direct comparison with verbal behaviour.

Employing a force reproduction task, Pepper (1970) concluded that forces applied in the same and opposite direction to the CM were equally interfering. Patrick (1971) defined similarity of linear movements in millimeters of displacement and used 3 levels of interpolated task similarity: ± 25 mm, ± 50 mm and ± 100 mm. It was concluded that there was no similarity effect on recall, however, there was a change in response bias. Overall, subjects tended to undershoot the target, but when the interpolated response was longer than the CM, there was a positive shift in the response bias. Therefore, it seemed the sign rather than the absolute value of the deviation of the interpolated response from the CM was critical in shifting the response bias.

> Only when absolute and algebraic error tend to equality will absolute error show interference effects due to the introduction of a biasing factor such as response similarity (Patrick, 1971).

It should be noted that absolute and algebraic error were equal in Stelmach's (1969a) study, but not in Patrick's (1971) research. These conclusions were further supported by Craft and Hinrichs (1971), who found that as the length of the interfering movement paired with the standard movement (one prior movement) increased, response error shifted from a value more negative than, to a value more positive than, the standard reference error level or response bias. Even with the positive shift, however, the response bias remained negative with the longest interpolated distance (64 cm. as compared to the standard of 44 cm.). They also found that interpolated responses were more interfering than prior responses.

In conclusion, it seemed the results in motor STM opposed those of verbal STM concerning the effect of similarity. However, as noted above, there were several problems in the research that prevented any valid conclusions from being drawn.

The importance of response bias was again noted and its value in revealing interference effects demonstrated.

> It is clear that one might reach quite different conclusions about the nature of motor STM depending on whether tasks were characterized by undershooting or overshooting (Pepper, 1970).

Pepper (1970) called this tendency to overestimate or underestimate the CM the "response set", while Patrick (1971) referred to it as "response bias".

> How should interference manifest itself? Should one expect simply an increase in absolute error, variable error or some change in response bias?.....Although a reduction in response bias might be interpreted as an improvement in recall, this is unsatisfactory. Whether an improvement or deterioration is found in the reproduction will depend on the initial response bias (Patrick, 1971).

Patrick (1971) concluded that interference may not be reflected in absolute error scores but may be more sensibly viewed as a change in bias. Thus, both absolute and algebraic error are essential for proper analysis of interference effects.

The Problem

The review of literature indicated that further investigation in the problems involved with PI and similarity effects on motor STM was necessary. Therefore, the purpose of the present thesis was to study the effects of similarity and number of prior movements on the retention of motor information over short intervals of time. Emphasis was placed on attempting to alleviate some of the problems concerned with the effects of movement similarity on motor STM, as measured by absolute and algebraic error. Several acclamations concerning the apparent differences between verbal and motor STM have been made, however, logical conclusions can only be drawn if conditions are similar for both motor and verbal experiments. In some cases this has not been done when it was necessary in order to make a legitimate comparison. It was thought that an attempt in this direction would help clarify the discrepancies between verbal and motor STM concerning the similarity effect.

Hypothesis

The hypotheses were formulated following a review of the relevant literature as presented above. Separate hypotheses were constructed for the two error terms, speed and distance. Because of the unpredictable nature of the response bias and the lack of information in this area, the hypotheses were constructed in relation to absolute error although both absolute and algebraic were analyzed.

Distance

H_1: $A_1 < A_2 < A_3$

H_2: $B_1 > B_2 > B_3$

H_3: $C_1 < C_2 < C_3 < C_4 < C_5$

Speed

H_4: $A_1 < A_2 < A_3$

H_5: $B_1 < B_2 < B_3$

H_6: $C_1 < C_2 < C_3 < C_4 < C_5$

where

A_1 = recall error with a 5 second retention interval,

A_2 = recall error with a 15 second retention interval,

A_3 = recall error with a 40 second retention interval,

B_1 = recall error with all movements @ 20 cm./sec.,

B_2 = recall error with alternate prior movements @ 13 cm./sec. and 27 cm./sec. and the CM @ 20 cm./sec.,

B_3 = recall error with alternate prior movements @ 6 cm./sec. and 34 cm./sec. and the CM @ 20 cm./sec.,

C_1 = error of recall with 0 prior movements,

C_2 = error of recall with 1 prior movement,

C_3 = error of recall with 2 prior movements,

C_4 = error of recall with 3 prior movements,

C_5 = error of recall with 4 prior movements.

The first and fourth hypotheses were formulated from several studies in motor STM (Adams & Dijkstra, 1966, Montague & Hillix, 1968, Williams, 1970), that found the ability to recall linear displacement decreased as the retention interval increased.

Hypothesis two was formulated from the work in verbal and motor STM concerning the effects of similarity (Stelmach, 1969a, Conrad, 1962, 1964). It has been shown that increasing item similarity increases recall error in verbal STM. Since verbal STM is an acoustic system, similarity is defined by means of acoustic components or phonemes. The letters Conrad (1962) found to be most confusing (BCPTV) actually had two components, one similar and one dissimilar. For example, the letter B has the components b and ē to form bē acoustically, similarly C has the components c and ē to form cē, and so on. Therefore, to replicate the verbal STM experiment properly with a motor STM study, the movements must contain at least two distinct components. Distance was used as the first component and speed as the second. It should be noted that the use of two components is unique to the present thesis since no previous research had required the subject to recall more than one component. Since the distances were counterbalanced over the 3 levels of similarity, there was an equal range of possible error under all conditions, which was not the case in Stelmach's (1969a) study. It was hypothesized that an increase in movement similarity (as measured by the speed of movement) would increase the error of distance recall. That is, movements of the same speed but differing only by 2 cm. in displacement, would be much harder to recall than movements of different speeds and different distances (the same 2 cm. difference as in the former condition). It was assumed that subjects would treat the movement in its totality in order for the two component hypothesis to be feasible.[1]

The third and sixth hypotheses were formulated from the studies by Stelmach (1969b) and Ascoli and Schmidt (1969) using the design shown in Figure 1. This was only partially true since they were unable to show PI effects with less than 3 prior movements. The rationale for suggesting that 1 and 2 prior movements might be interfering was obtained from the verbal STM literature (Keppel & Underwood, 1962).

Since the range of possible error for speed recall was different for each of the similarity conditions (the least similar condition had a range from 6 to 34 cm./sec. from which to choose when recalling the speed of CM while the most similar condition only had one speed to recall, 20 cm./sec.), it was hypothesized that an increase in similarity (a decrease in range of possible error) would decrease the speed recall error. That is, the results for speed recall should coincide with Stelmach's (1969a) results, since his similarity conditions demonstrated the same type of range effect. Thus, hypothesis five predicted an opposite effect for movement similarity than hypothesis two because of the confounding range effect.

In summary, it was hypothesized that an increase in the retention interval would increase both speed and distance recall error (H_1 and H_4). Likewise, an increase in both speed

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[1] This concept of totality of movement is elaborated on in the Discussion Section.

and distance recall error should occur as the number of prior movements increases (H_3 and H_6). Finally, it was predicted that an increase in movement similarity would increase the distance recall error (H_2), but decrease the speed recall error (H_5).

CHAPTER 111

METHODOLOGY

Sample

The subjects used in the testing were 30 student volunteers from the four years of physical education at the University of Windsor. Other than the fact that they had to be male and naive, no restrictions were placed on their selection. The average age was 22 years, 1 month with a standard deviation of 1 year, 2 months.

Apparatus

The experimental equipment, as shown in the Appendix, included a Hewlett Packard 8 channel oscilloscope and wave generator, a linear movement apparatus, Belltone earphones and generator, blacked out goggles with a clear, horizontal slit 1/4 inch wide at eye level (when looking straight ahead), a 1/1000 second chronoscope and 3 pairs of electric photo cells connected to the Belltone (1 pair) and chronoscope (2 pairs). A plywood canopy (not shown) was placed over the linear movement apparatus to prevent (along with the goggles) the subject from seeing it during testing.

The linear movement apparatus consisted of a metal slide (a brass bar, 3/4 X 3/4 X 3" bored out to 1/2" in diameter and knob, 1" in height) mounted on a 1/2" steel rod, 4 feet long. This was housed in a birch frame (each side consisted of 3 pieces of 1 X 3 X 4' birch) lined with a 1" arborite strip on each side so the slide was held in an upright position, but could still move easily (against the arborite) along the rod. A pointer was attached to the slide which indicated the length of movement in millimeters, read from a meter stick mounted on one side of the frame. A metal flag was soldered to the bottom of the brass bar so thatit projected downwards from the slide. Appropriate sized holes (5/8" for the large photo cells and 3/8" for the smaller ones) were drilled through the sides of the birch frame, below the level of the steel rod. The first pair of holes (one on each side of frame), 5 cm. from the starting position on the left, housed the pair of photo cells which started the chronoscope when the metal flag broke the circuit. A second pair of holes, 33 cm. from the first pair, housed the photo cells which stopped the chronoscope as the metal flag passed (these 2 pair of photo cells were never moved). The last pair of photo cells could be moved to any of the remaining holes depending on where the experimenter wished to stop the subject's movement. When this circuit was broken, the buzzer sounded in the earphones. Since the holes for the photo cells controlling the buzzer were only 2 cm. apart, coloured letters were painted on the frame above them, so the experimenter could readily distinguish them during the testing.

The wave generator was attached to the oscilloscope so that a dot could be made to travel from left to right across the screen at any of the 5 predetermined speeds.

Task

Following the commands, "ready", "produce" for each movement (1 to 5 movements were required in any one trial), the subject was required to move the slide from left to right along the rod. The velocity of movement was determined by the speed of the dot moving across the oscilloscope and the amplitude of movement by the buzzer sounding in the earphones, signalling the subject to stop as quickly as possible. After each movement, the subject returned the slide to the starting position with his left hand. After a predetermined number of movements, a short retention interval followed, during which, the subject sat quietly, looking straight ahead, grasping the slide with his right hand. On the commands, "ready", "recall", the subject recalled the distance and speed of each movement, in reverse order to the presentation. This procedure constituted 1 trial and each subject had 15 trials which took approximately 45 minutes to complete.

Independent Variables

Three factors were chosen as the independent variables: retention interval, similarity of movement and prior movements.

Retention Interval

Three intervals were employed, representing an intermediate range of delay in relation to the sited literature:

1. Immediate recall - a 5 second interval.
2. Short delay - a 15 second interval.
3. Long delay - a 40 second interval.

Similarity

Three levels or 5 movement speeds were used:

1. High similarity - all prior movements and the CM at the same speed (20 cm./sec.).

2. Intermediate similarity - prior movements systematically alternated between 13 cm./sec. and 27 cm./sec. and the CM at 20 cm./sec..

3. Low Similarity - prior movements systematically alternated between 6 cm./sec. and 34 cm./sec. and the CM at 20 cm./sec..

Prior Movements

A maximum of 5 movements (4 prior movements and the CM) and a minimum of 1 movement (0 prior movements and the CM) had to be recalled on any given trial:

1. 0 prior movements - one movement (CM) produced and recalled.

2. 1 prior movement - two movements (1 prior movement plus CM).

3. 2 prior movements - three movements (2 prior movements plus CM).

4. 3 prior movements - four movements (3 prior movements plus CM).

5. 4 prior movements - five movements (4 prior movements plus CM).

Dependent Variables

Four dependent variables were used: absolute and algebraic error for speed (cm./sec.) and distance (mm.) recall.

Speed

Absolute and algebraic error terms were calculated by subtracting the speed of the last movement produced (CM) from the first movement recalled (CM). A positive error indicated that recall of the CM was too fast and a negative term, too slow. It should be noted that speed was only calculated for 33 cm. of each movement (speed of movement = 33 cm. ÷ time). As indicated in the Section on the Apparatus, the first 2 pair of photo cells, 33 cm. apart, were never moved during the experiment and the time (sec.) to move between these two points was the time used to calculate speed. This procedure was necessary since the exact point at which the subject stopped on any given movement was not known until he actually stopped. The results of a pilot study showed movement speed to be fairly consistent for all intervals up to 60 cm. if the apparatus was nearly frictionless.

Distance

Absolute and algebraic error terms were calculated by subtracting the amplitude of the CM produced from the CM recalled. A positive error indicated overshooting and a negative value, undershooting.

Experimental Design

The independent variables, described above, were combined to produce 45 experimental conditions. Each subject was tested under all similarity and prior movement conditions but only 1 retention interval. Thus, the experiment could be described as a 3 (fixed) factor model with repeated measures on the last 2 factors (similarity and prior movements).

A systematic counterbalancing procedure was necessary for the retention intervals, distances of prior movements and the CM, order of the number of prior movements and order of the movement similarity conditions.

Retention Interval

The subjects were systematically rotated through the 3 intervals in the order which they arrived for testing. For example, the first and fourth subjects were tested with a 40 second interval, the second and fifth with a 15 second interval and the third and sixth with immediate recall (5 seconds).

Distances

Since there were 5 distances (48, 50, 52, 54, 56 cm.) and 15 trials, each distance was used three times (once under each similarity condition) as the CM, for each subject. The prior movement and CM distances were counterbalanced to prevent a distance from occurring twice in any trial and to ensure all distances were used an equal number of times for each subject.

Prior Movements

The 5 conditions were randomized differently for each similarity condition and differently for each set of three subjects, as described above.

Movement Similarity

The 3 levels of similarity (high, intermediate and low) were counterbalanced using a randomized, standard Latin square, so that each level was used equally for the first, second and third block of 5 trials, over all subjects. That is, levels of similarity were not mixed throughout the 15 trials for each subject.

Instructions to Subjects

The following instructions were read to each subject.

Your job in this experiment will be to recall movements from memory. It is essential that you remember both the speed and distance of movement and therefore concentration is important.

Wearing these goggles and earphones, left hand in your lap and sitting upright in the chair, grasp the slide with the first three fingers of your right hand, like so.

The procedure will be as follows:

1. On the command "ready" focus your attention on the left side of the oscilloscope.

2. On the command "produce" follow the dot on the scope with the slide, always moving from left to right. Do not try to catch the dot if you are late starting, just move the slide at the same speed. The speed you move will be the speed you must remember.

3. Continue moving the slide until a buzzer sounds in the earphones and then stop as quickly as possible. The distance to be remembered is where the slide stopped, not where the buzzer sounded.

4. This procedure may be followed for 1 to 5 movements.

5. After a short interval the "ready" command will be given again.

6. On the command "recall" all movements, that is, distance and speed, will be recalled in reverse order. For example, if 3 movements had been produced, the commands would have been:

(a) "ready", "produce" (you would produce some movement A),

(b) "ready", "produce" (some movement B),

(c) "ready", "produce" (some movement C),

(d) short interval,

(e) "ready", "recall" (recall C),

(f) "ready", "recall" (B),

(g) "ready", "recall" (A).

7. After each movement, either "produce" or "recall", hold the final position for 1 second, then return the slide to the starting position here with the left hand and then regrasp the slide with the right hand.

8. This procedure constitutes one trial and there will be a 90 second rest between trials.

The experimenter then asked the subject if there were any questions regarding the above procedure. When these were answered, the subject was given a few practice trials until he was sure of the testing procedures to be followed.

Testing Procedure

1. The photo cells controlling the buzzer were placed in the appropriate holes. Since the distance to stop the slide was different for each speed, because of the momentum built up during movement, it was necessary to run a pilot study to determine the average stopping distance for each speed. Therefore, different holes were used for different speeds for each specific distance (48, 50, 52, 54, 56 cm.).

2. Following the commands given by the experimenter, the subject completed the required number of movements for the trial (the experimenter had to move the photo cells for the buzzer after each movement).

3. Only the time and distance of the CM were recorded (this was not known by the subject).

4. As soon as the subject stopped the slide on the CM, the experimenter started the stopwatch to time the retention interval.

5. Either immediately after the subject returned the slide to the starting position after the CM or after 15 or 40 seconds, the commands for recall were given.

6. Again, only the time and distance for the CM were recorded.

7. Following the completion of recall of the last movement in the trial, the experimenter started the stopwatch

to time the 90 second rest given between trials (ITI).

8. This procedure was followed for 15 trials.

Treatment of Results

1. The 45 treatment conditions were analyzed using Winer's Case 1 (pp. 319) a three factor analysis of variance with repeated measures on the last two factors.

2. Newman-Keuls and simple effects secondary analyses were applied to significant F values.

3. A graph of errors by trial was plotted in order to check for possible learning or fatigue effects.

4. Pearson product-moment correlations were calculated, post hoc, between the error terms for speed and distance for each treatment condition.

5. Percentage error was calculated for speed and distance using absolute error ($\bar{x}$ error/$\bar{x}$ distance of CT movement X 100). This was also done throughout the literature where possible.

6. The $\alpha = .05$ level of confidence was accepted for all hypotheses.

CHAPTER lV

RESULTS

Since there were four dependent variables (absolute and algebraic error for speed and distance recall) and an analysis of variance computed for each, the results were presented separately for each variable. A post hoc calculation of the power of several of the F ratios at the $\alpha = .05$ level of confidence (recorded in Tables l, ll, Vll and lX) revealed that they had a range of .20 to .85.[1] Because of this and because of the uniqueness of the present study for motor STM (as pointed out in the Hypothesis Section) all levels of confidence up to and including $\alpha = .10$ were reported, instead of the original $\alpha = .05$ level.

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[1] In inferential statistics, as used by the behavioral scientist, there are generally two types of decision errors that can be committed. A type 1 error occurs if the experimenter rejects the Null Hypothesis when, in fact, it is true. The probability of making this type of error is designated by alpha (α). Conversely, the experimenter may fail to reject the Null Hypothesis when it is false and thus commits a type 2 error. The probability of this occurring is designated by beta (β).

The probability of committing a type 1 error is established by the experimenter, before the testing, by setting α at the desired level of confidence (conventionally .01 or .05). If the Null Hypothesis is true, the probability of the experimenter making the correct decision, with his particular statistical test, is $1 - \alpha$. On the other hand, if the alternate hypothesis is true, the probability of making the correct decision is $1 - \beta$. This latter probability is the sensitivity or power of the test of significance. In words, power is the probability that the decision rule rejects the Null Hypothesis when a specified alternate hypothesis is true (Winer, 1962).

Unlike alpha, which is set by the experimenter, beta is dependent upon: (1) the α level chosen, (2) the sample size, (3) the treatment effect and (4) the particular statistical test employed. An increase in the numerical size of α (or decrease in the confidence of rejecting H_0) will decrease the potential of a beta error. Similarly, an increase in the sample size and/or treatment effect will also decrease β and thus increase the power. These two are most often used to set the power of the test since the α level is arbitrarily set prior to the testing and the test of significance used is dictated by other factors. Increasing the sample size is a potent means of increasing power but is not always feasible since large samples are costly in time and effort. The power is usually established by determining the maximum percentage of the total variance which is acceptable as error variance, while still rejecting H_0. Since the total variance consists of treatment variance and error variance, any decrease in error variance will increase the power of the test. Similar to setting the alpha level before the testing, the experimenter may determine (a priori) what portion of variance may be due to intra-variability and experimental error variance (other things being equal) and thus set the power of the test. However, in cases such as the present thesis, where the porportion of error variance to accept cannot be gauged from previous research, power can be determined from the actual error variance (post hoc) as opposed to the conventional a priori approach, without changing the interpretation of power. For example, a power of .25 for the F ratio of the similarity main effect for algebraic error of distance recall (Table 11) means that there were only 25 chances in 100 of rejecting a false Null Hypothesis or claiming a significant treatment effect at the $\alpha = .05$ level of confidence. The two types of error were greatly out of proportion since both were deemed equally important; that is, there were only 5 chances in 100 ($\alpha = .05$) of rejecting the Null Hypothesis if it was true, but 75 chances in 100 of not rejecting it if it was false ($\beta = .75$).

Conventionally the $\alpha = .05$ or .01 level has been used, based on the notion that type 1 error is undesirable and should be avoided. However, in the behavioral sciences "both types of errors may be equally important, particularly in exploratory work" (Winer, 1962). For example, concluding that an experimental effect is not significant may result in an experimenter discontinuing a promising line of research whereas a type 1 error would mean further exploration into a blind alley. The problem then arises as to which course to follow. Usually, this has been solved by falling back on accepted conventions ($\alpha = .05$ or .01), instead of using decision rules which best fit the purposes of the study. Calculation of the power of the F ratios for main effects may reveal that the .05 and .01 levels of confidence are inappropriate, and thus, a more liberal α level might be chosen.

Distance Recall

Absolute Error

All main effects (retention interval, movement similarity and prior movements) and their interactions failed to reach significance at the required level of confidence (Table 1).

Algebraic Error

The analysis of variance (Table 11) indicated that the main effects of retention interval and prior movements were significant (α = .01). The retention interval X similarity and retention interval X prior movements interactions were also significant (α = .10).

As the retention interval increased, the response bias for distance recall shifted in a negative direction from a mean of + 18 mm. at 5 seconds to a mean of - 23 mm. at 40 seconds (Figure 3). A Newman-Keuls analysis (Table 111) confirmed this as error for the 5 second interval was significantly different from the 40 second interval. A negative shift in the response bias also occurred as the number of prior movements increased as 0 prior movements had a mean error of + 12 mm. which changed to - 38 mm. for 3 prior movements (Figure 4). This trend did not occur for the 4 prior movements, however, since the Newman-Keuls (Table 1V) indicated that 0 prior movements was significantly different from 3 prior movements but not 4 prior movements. Inspection of the graph in Figure 5 indicated that there was greater undershooting of the CM, after the 40 second interval, under the high and

TABLE 1

ANALYSIS OF VARIANCE OF MAIN EFFECTS AND INTERACTIONS FOR ABSOLUTE ERROR OF DISTANCE RECALL

Source	SS	df	MS	F	Power
Between S's					
Retention Int. (I)	19001.61	2	9500.81	2.28	.25
error	112472.84	27	4165.66		
Within S's					
Similarity (S)	2150.17	2	1075.09	1.92	.20
I X S	1853.78	4	463.45	0.83	
error	30267.78	54	560.51		
Prior Movements (P)	830.77	4	207.69	0.32	
I X P	4007.37	8	500.92	0.78	
error	69698.39	108	645.36		
S X P	2886.21	8	360.78	0.48	
I X S X P	10175.37	16	635.96	0.84	
error	163778.69	216	758.23		

TABLE 11

ANALYSIS OF VARIANCE OF MAIN EFFECTS AND INTERACTIONS FOR ALGEBRAIC ERROR OF DISTANCE RECALL

Source	SS	df	MS	F	Power
Between S's					
Retention Int. (I)	143190.41	2	71595.21	5.41***	.65
error	357039.82	27	13223.70		
Within S's					
Similarity (S)	6736.81	2	3368.41	2.30	.25
I X S	13562.42	4	3390.61	2.32*	
error	78962.64	54	1462.27		
Prior Movements (P)	17229.76	4	4307.44	3.94***	.75
I X P	15759.23	8	1969.90	1.80*	
error	118181.95	108	1094.28		
S X P	14770.90	8	1846.36	1.37	
I X S X P	19201.67	16	1200.10	0.89	
error	291906.89	216	1351.42		

*** Significant at the .01 level of confidence
* Significant at the .10 level of confidence

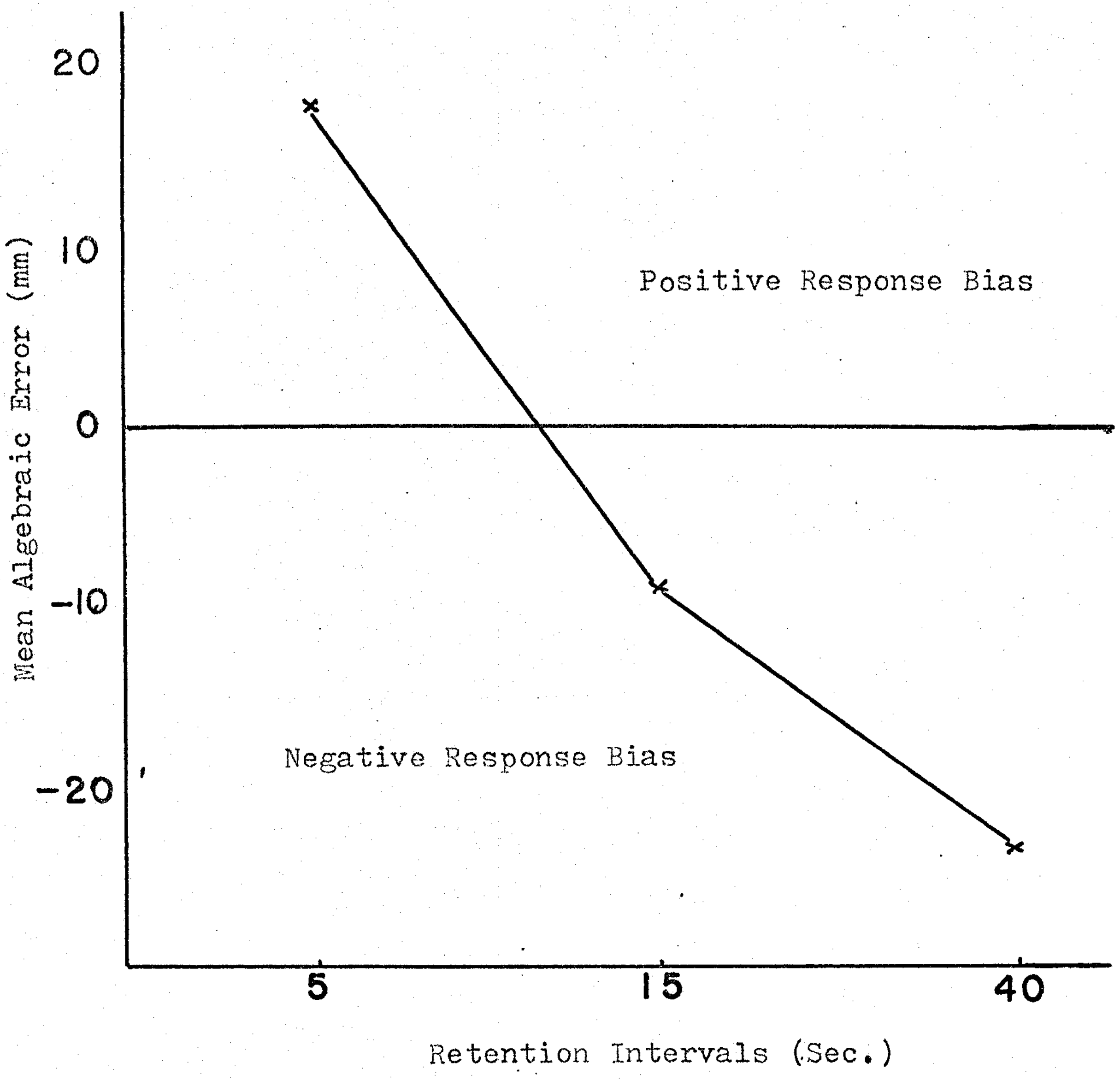


Figure 3.--Mean Algebraic Error vs. Retention Interval Main Effect for Distance.

TABLE 111

DIFFERENCES BETWEEN MEAN ALGEBRAIC DISTANCE ERROR AT THE THREE RETENTION INTERVALS (NEWMAN-KEULS PROCEDURE)

Means (mm)	A_3 -23	A_2 -9	A_1 18
-23		14	41***
-9			27

*** Significant at the .01 level of confidence

TABLE 1V

DIFFERENCES BETWEEN MEAN ALGEBRAIC DISTANCE ERROR FOR THE FIVE PRIOR MOVEMENT CONDITIONS (NEWMAN-KEULS PROCEDURE)

Means (mm)	c_4 -38	c_3 -30	c_5 -21	c_2 -4	c_1 12
-38		8	17	34	50***
-30			9	26	42
-21				17	33
-4					16

*** Significant at the .01 level of confidence.

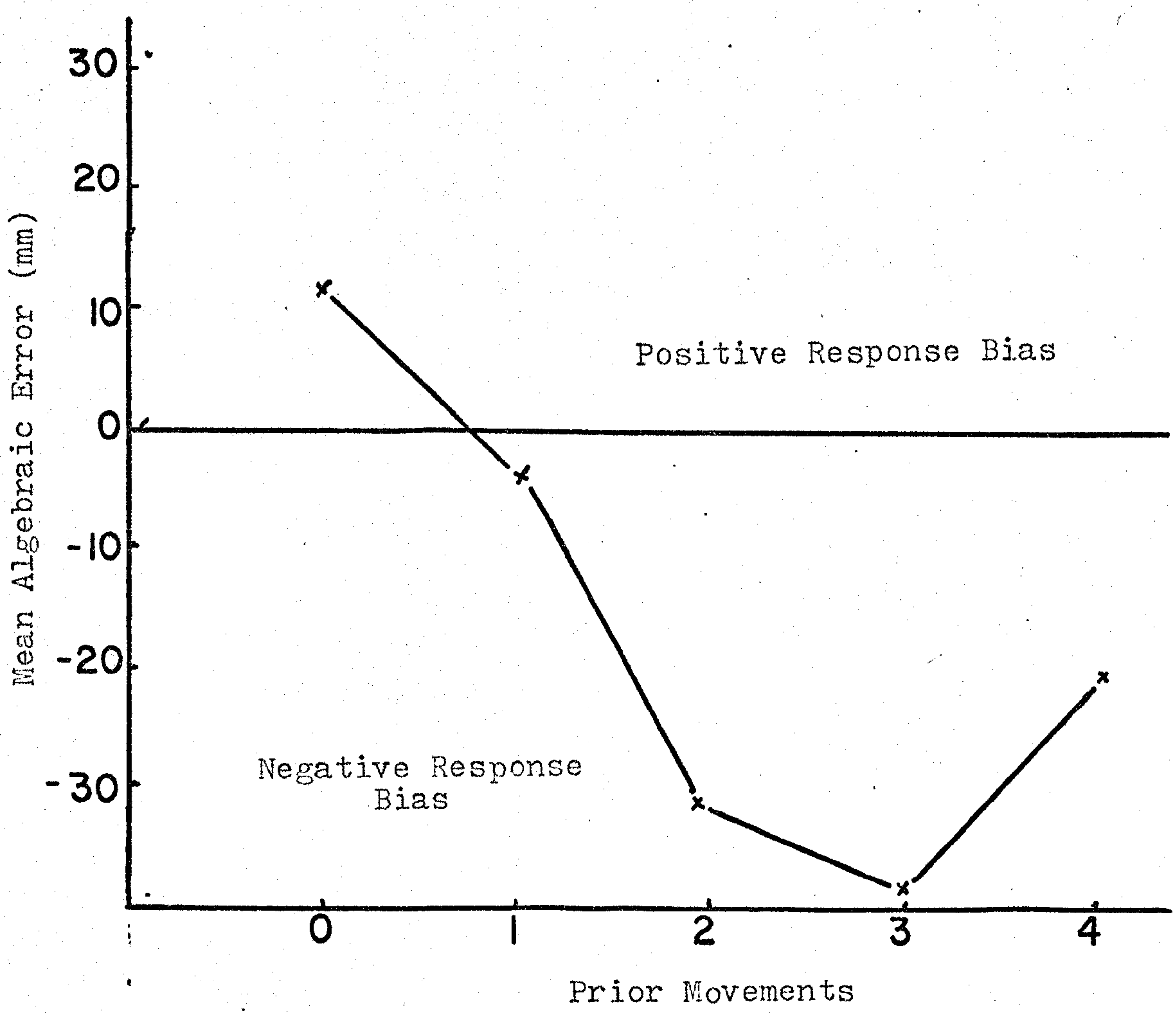


Figure 4.--Mean Algebraic Error vs. Prior Movements Main Effect for Distance.

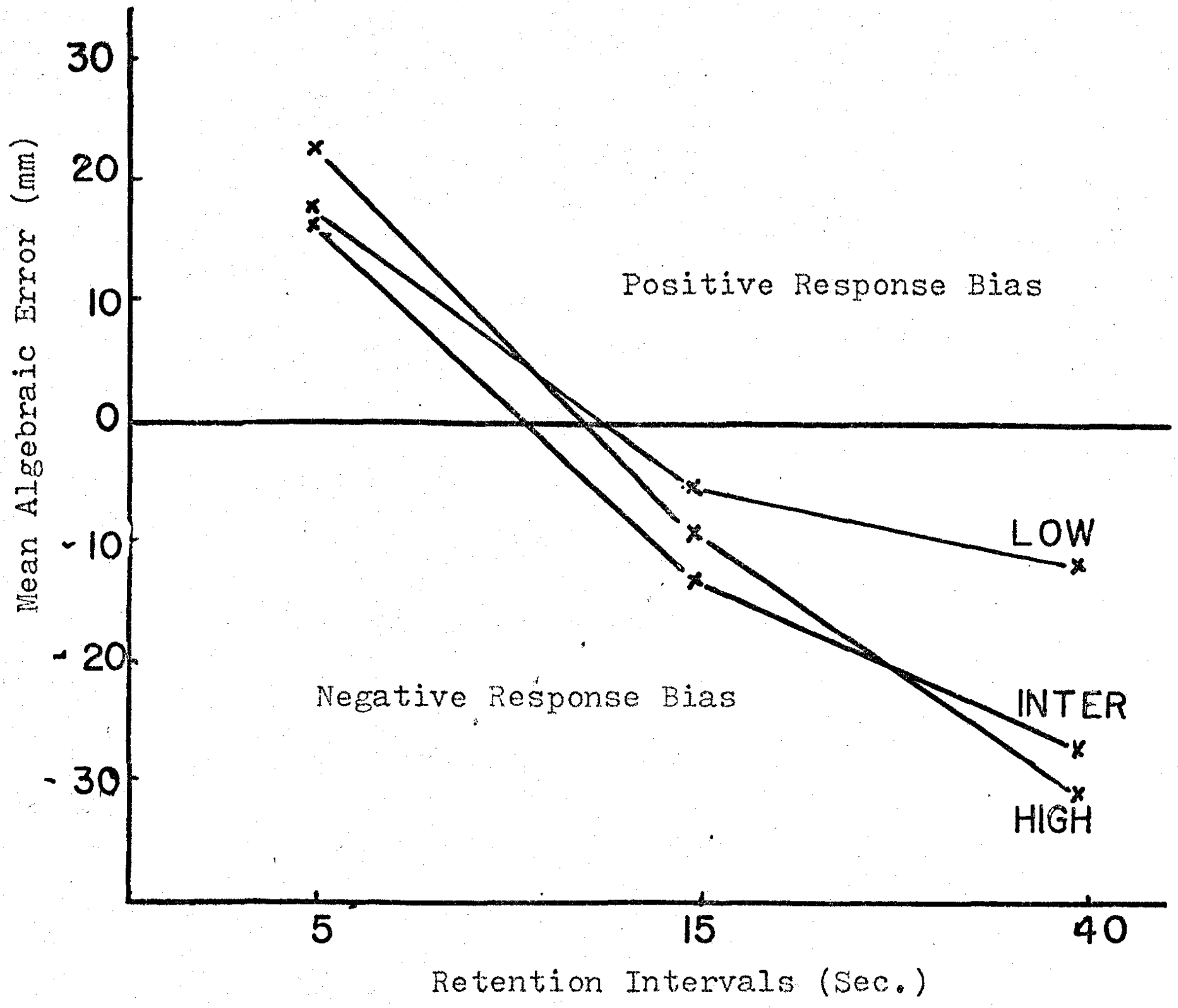


Figure 5.--Mean Algebraic Error vs. Retention Interval X Similarity Interaction for Distance.

intermediate similarity conditions than under the low similarity condition. Analysis of simple effects (and Newman-Keuls) of the retention interval X similarity interaction (Table V) showed that the high similarity condition was significantly different from the low similarity condition at 40 seconds. Subjects demonstrated (Figure 6) greater overshooting of the CM, at immediate recall, with 0 prior movements than with 4 prior movements (30 mm. vs. 3 mm.) but this consistent trend did not continue at the 40 second interval. This was confirmed, as the analysis of simple effects and subsequent Newman-Keuls of the retention interval X prior movements interaction (Table V1) indicated that 4 prior movements were different from 0 prior movements at immediate recall but 3 prior movements were different from 4 prior movements at 40 seconds.

Speed Recall

Absolute Error

Analysis of variance (Table V11) indicated that the movement similarity ($\alpha = .10$) and prior movement ($\alpha = .01$) main effects reached significance. As movement similarity decreased, speed recall error increased from a mean of 5.5 cm./sec. for the high similarity condition to 6.9 cm./sec. for the low similarity condition (Figure 7). A Newman-Keuls analysis (Table V111) verified this, as the high similarity condition was significantly different from the low similarity condition. Although there was a significant prior movement main effect, inspection of the graph in Figure 8 revealed a

TABLE V

THE RETENTION INTERVAL X SIMILARITY INTERACTION FOR ALGEBRAIC ERROR OF DISTANCE RECALL (ANALYSIS OF SIMPLE EFFECTS)

Source	SS	df	MS	F ratio
b @ a_1	837.29	2	418.65	0.29
b @ a_2	1214.45	2	607.23	0.42
b @ a_3	18247.48	2	9123.74	6.24***
error (b)	78962.64	54	1462.27	
a @ b_1	86755.48	2	43377.74	8.05***
a @ b_2	48682.09	2	24341.05	4.52**
a @ b_3	21315.25	2	10657.63	1.98
error (a)	436002.46	81	5382.75	

*** Significant at the .01 level of confidence
** Significant at the .10 level of confidence

DIFFERENCES BETWEEN THE THREE SIMILARITY CONDITIONS AT THE FORTY SECOND RETENTION INTERVAL (NEWMAN-KEULS PROCEDURE)

Means (mm)	b_1 -32	b_2 -27	b_3 -11
-32		5	21***
-27			16

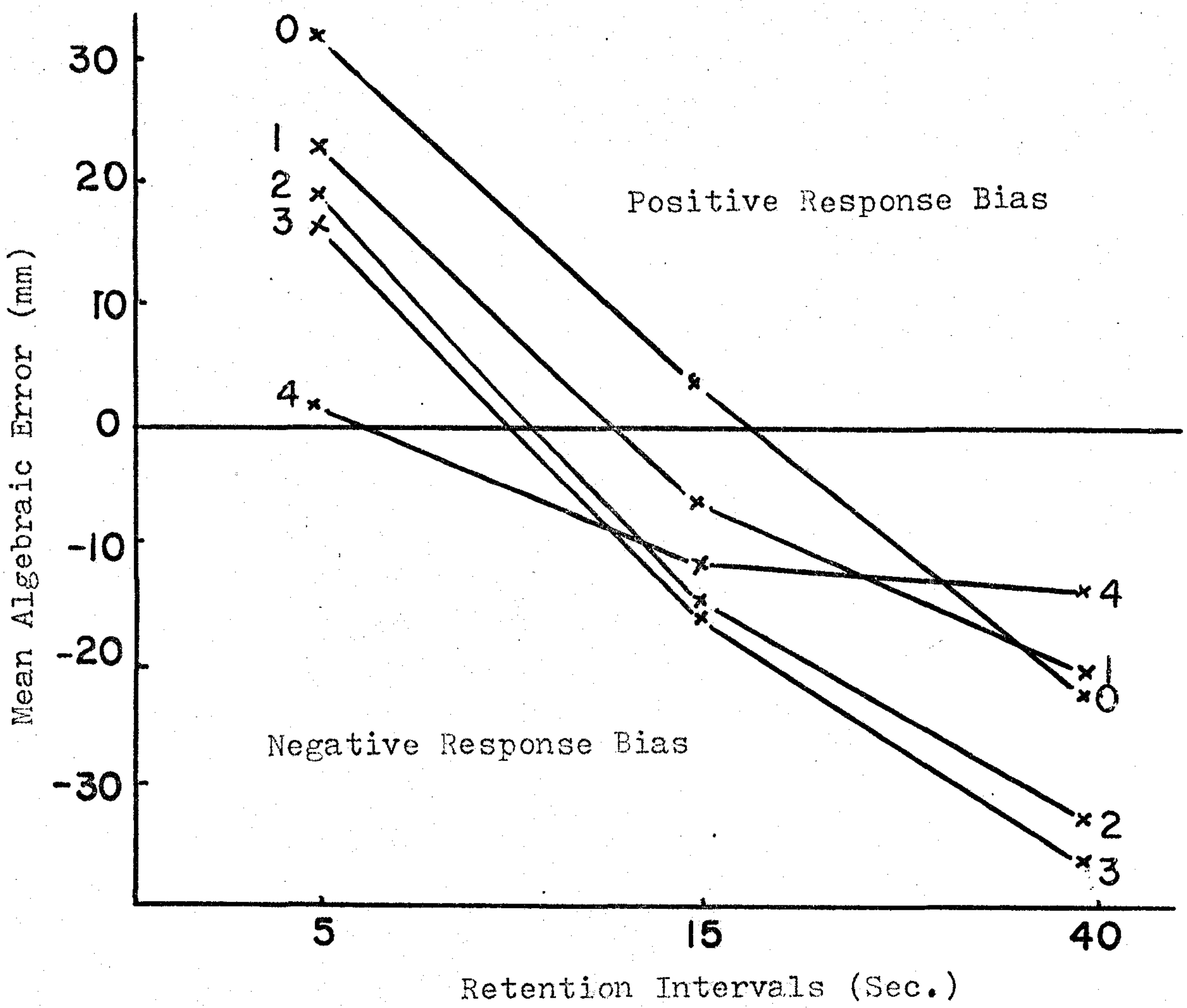


Figure 6.--Mean Algebraic Error for Distance Recall vs. Retention Interval X Prior Movements Interaction.

TABLE V1

THE RETENTION INTERVAL X PRIOR MOVEMENT INTERACTION FOR ALGEBRAIC ERROR OF DISTANCE RECALL (ANALYSIS OF SIMPLE EFFECTS)

Source	SS	df	MS	F ratio
c @ a_1	13425.03	4	3356.26	3.07**
c @ a_2	7511.13	4	1877.78	1.72
c @ a_3	12052.83	4	3013.21	2.75**
error (c)	118181.95	108	1094.28	
a @ c_1	43244.69	2	21622.35	6.14***
a @ c_2	29414.87	2	14707.44	4.17**
a @ c_3	40923.76	2	20461.88	5.81***
a @ c_4	40940.43	2	20470.24	5.82***
a @ c_5	4425.87	2	2212.94	0.63
error (a)	475221.77	135	3520.16	

*** Significant at the .01 level of confidence
** Significant at the .05 level of confidence

DIFFERENCES BETWEEN THE FIVE PRIOR MOVEMENT CONDITIONS AT THE FIVE SECOND RETENTION INTERVAL (NEWMAN-KEULS PROCEDURE)

Means (mm)	c_5 3	c_4 15	c_3 18	c_2 23	c_1 31
3		12	15	20	28**
15			3	8	16
18				5	13
23					8

TABLE V11

ANALYSIS OF VARIANCE OF MAIN EFFECTS AND INTERACTIONS FOR ABSOLUTE ERROR OF SPEED RECALL

Source	SS	df	MS	F	Power
Between S's					
Retention Int. (I)	17321204.40	2	8660602.20	0.05	
error	4580082971.66	27	169632702.65		
Within S's					
Similarity (S)	159910557.41	2	79955278.71	2.45*	.32
I X S	51368741.99	4	12842185.50	0.39	
error	1762054558.60	54	32630639.97		
Prior Movements (P)	617349969.84	4	154337492.46	4.51***	.85
I X P	358517380.85	8	44814672.61	1.31	
error	3698853276.44	108	34248641.45		
S X P	103092078.91	8	12886509.86	0.48	
I X S X P	288492338.16	16	18030771.14	0.66	
error	5859477883.60	216	27127212.42		

*** Significant at the .01 level of confidence
* Significant at the .10 level of confidence

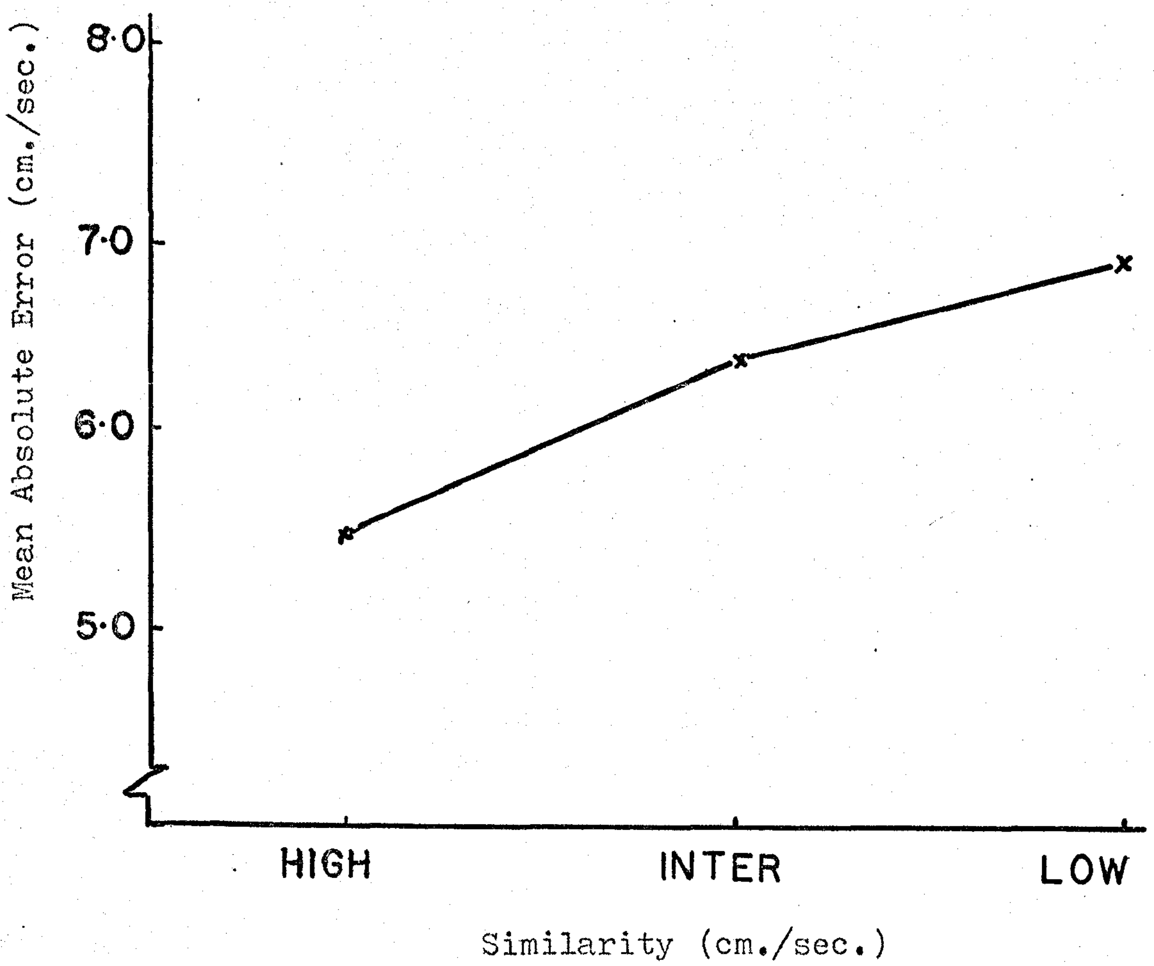


Figure 7.--Mean Absolute Error for Speed Recall vs. Similarity Main Effect.

TABLE V111

DIFFERENCES BETWEEN MEAN ABSOLUTE SPEED ERROR FOR THE THREE SIMILARITY CONDITIONS (NEWMAN-KEULS PROCEDURE)

Means (cm./sec.)	B_1 5.5	B_2 6.4	B_3 6.9
5.5		0.9	1.4*
6.4			0.5

* Significant at the .10 level of confidence

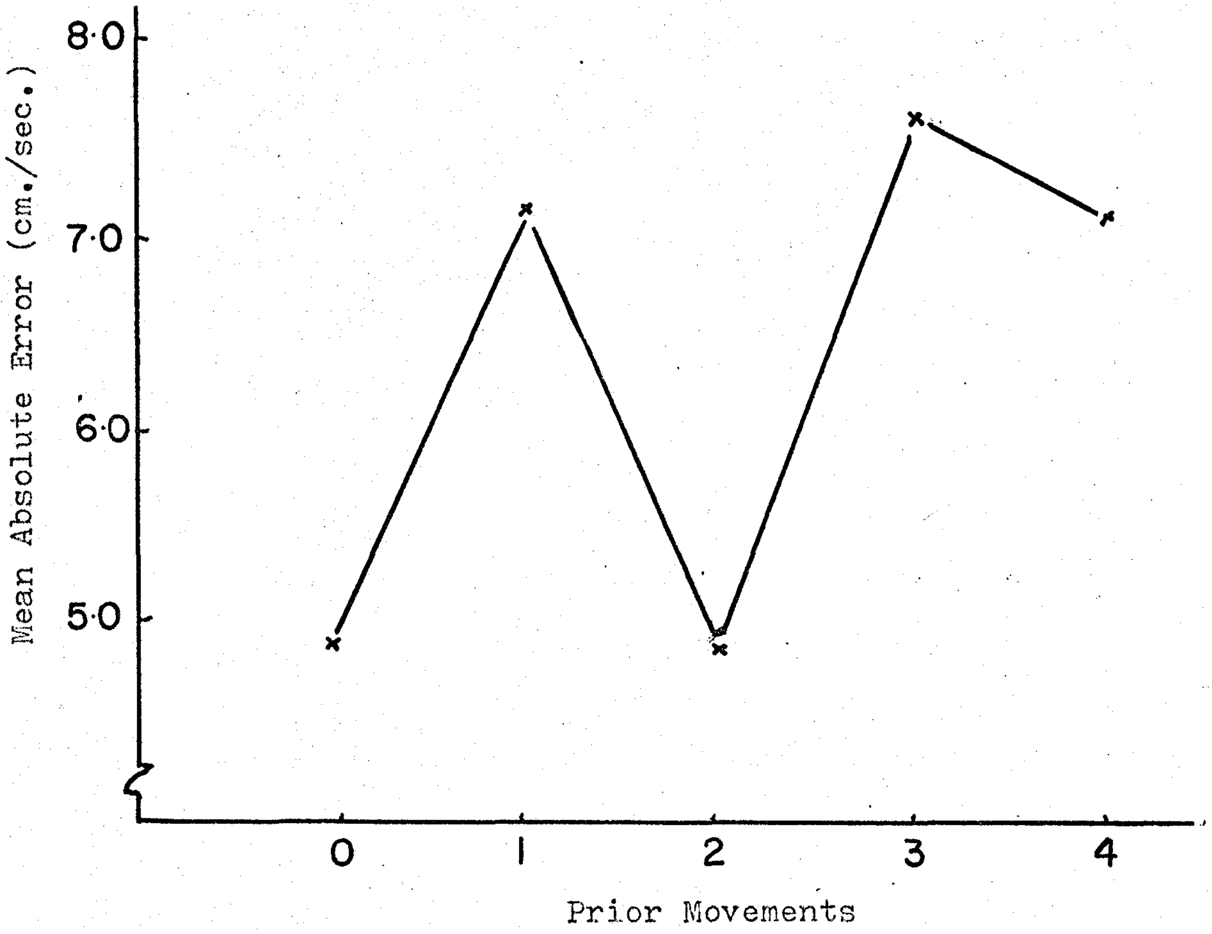


Figure 8.--Mean Absolute Error for Speed Recall vs. Prior Movements Main Effect.

lack of any consistent trend.

Algebraic Error

Analysis of variance (Table 1X) showed that the retention interval main effect (α = .10) and retention interval X similarity (α = .05) and retention interval X prior movements (α = .10) interactions were significant. As the retention interval increased, the response bias for speed recall shifted in a negative direction; mean error at immediate recall was + 3.3 cm./sec. while it was - 1.6 cm./sec. at 40 seconds (figure 9). A Newman-Keuls analysis confirmed this, as immediate recall was different from the 40 second interval (Table X). The plot of the retention interval X movement similarity interaction (Figure 10) revealed that subjects under the low similarity condition demonstrated greater undershooting (-2.9 cm./sec.) than under the other two similarity conditions (-0.7 and - 1.0 cm./sec.), at the 40 second retention interval. Analysis of simple effects and Newman-Keuls (Table X1) verified this. Although there was a significant retention interval X prior movements interaction, no consistent trend was demonstrated (Figure 11).

Totality of Movement

The plot of mean albsolute error for distance by trials (Figure 12) indicated that there were no unwanted learning or fatigue effects, as most trials had a mean error of approximately 40 mm.. The intercorrelations between absolute error of distance and speed recall for the 45 treatment conditions (Table X11) did not demonstrate a consistent relationship between the two.

TABLE IX

ANALYSIS OF VARIANCE OF MAIN EFFECTS AND INTERACTIONS FOR ALGEBRAIC ERROR OF SPEED RECALL

Source	SS	df	MS	F	Power
Between S's					
Retention Int. (I)	1780312025.55	2	890156012.78	2.81*	.40
error	8562013717.18	27	317111619.15		
Within S's					
Similarity (S)	20402508.35	2	10201254.18	0.37	
I X S	301516333.77	4	75379083.44	2.75**	
error	1479323066.28	54	27394871.60		
Prior Movements (P)	118609738.85	4	29652434.71	0.56	
I X P	743767176.10	8	92970897.01	1.75*	
error	5727959650.92	108	53036663.43		
S X P	673995419.43	8	84249427.43	1.26	
I X S X P	1001396707.98	16	62587294.25	0.93	
error	14480195505.52	216	67037942.16		

** Significant at the .05 level of confidence
* Significant at the .10 level of confidence

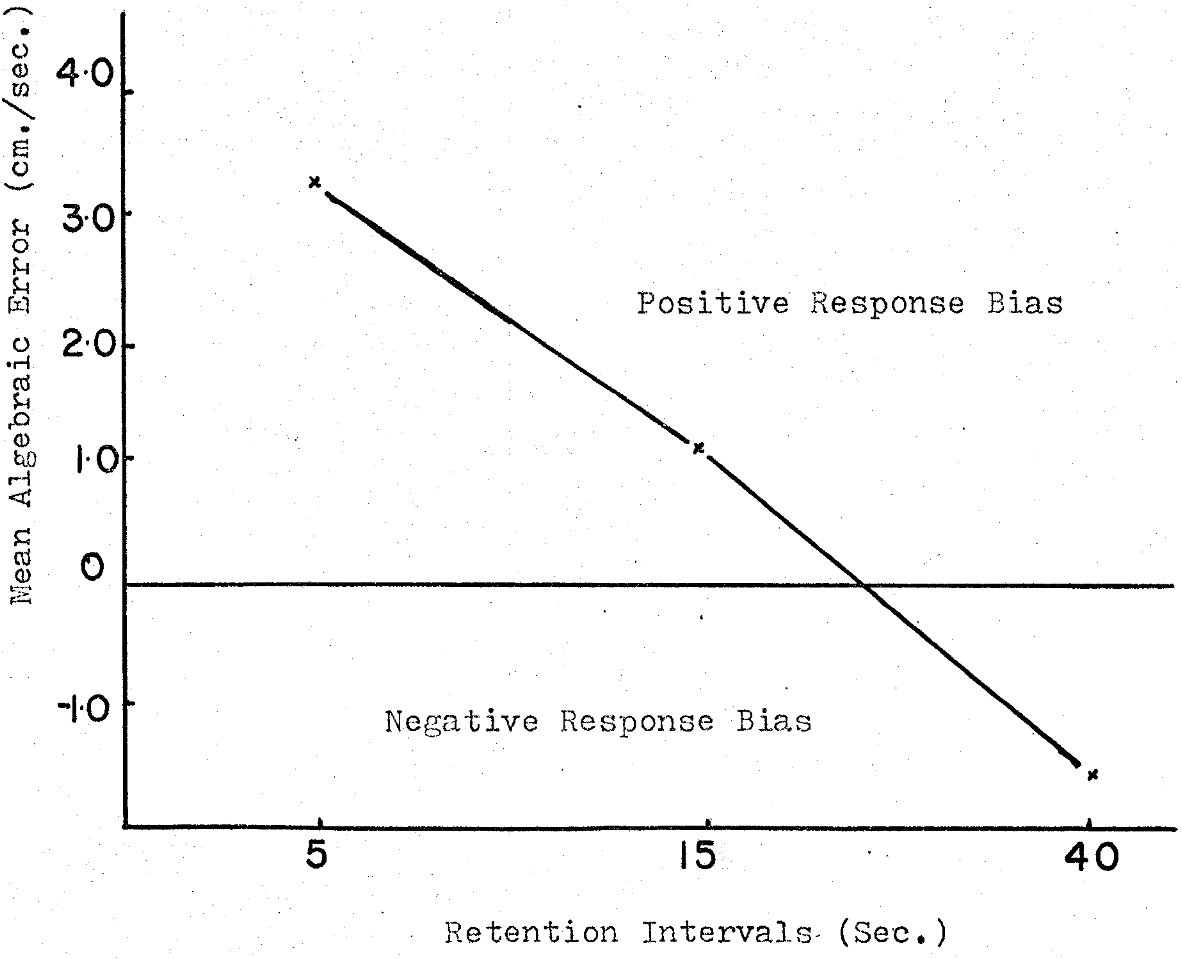


Figure 9.--Mean Algebraic Error for Speed Recall vs. Retention Interval Main Effect.

TABLE X

DIFFERENCES BETWEEN MEAN ALGEBRAIC SPEED ERROR AT THE THREE RETENTION INTERVALS (NEWMAN-KEULS PROCEDURE)

Means (cm./sec.)	A_3 -1.6	A_2 1.1	A_1 3.3
-1.6		2.7	4.9*
1.1			2.2

* Significant at the .10 level of confidence

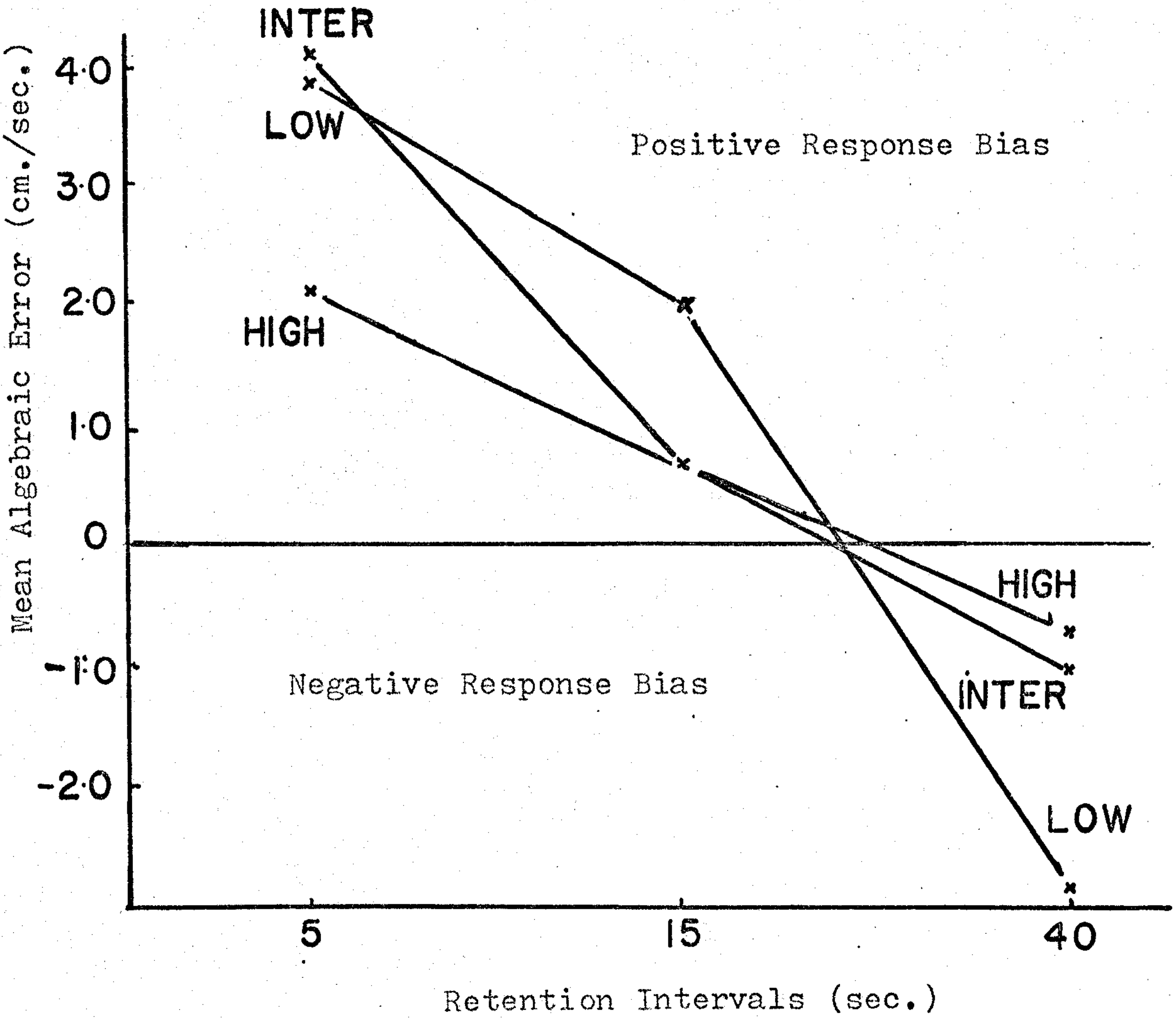


Figure 10.--Mean Algebraic Error for Speed Recall vs. Retention Interval X Similarity Interaction.

TABLE X1

THE RETENTION INTERVAL X SIMILARITY INTERACTION FOR ALGEBRAIC ERROR OF SPEED RECALL (ANALYSIS OF SIMPLE EFFECTS)

Source	SS	df	MS	F ratio
b @ a	109654568.37	2	54827284.19	2.00
b @ a	58701184.89	2	29350592.45	1.07
b @ a	153563088.85	2	76781544.43	2.80*
error (b)	1479323066.28	54	27394871.60	
a @ b_1	193330701.45	2	96665350.73	.78
a @ b_2	667081558.89	2	333540779.45	2.70*
a @ b_3	1221416098.97	2	610708049.49	4.98***
error (a)	10041336783.46	81	123967120.78	

*** Significant at the .01 level of confidence
* Significant at the .10 level of confidence

DIFFERENCES BETWEEN THE THREE SIMILARITY CONDITIONS AT THE FORTY SECOND RETENTION INTERVAL (NEWMAN-KEULS PROCEDURE)

Means (cm./sec.)	b_3 -2.952	b_2 -1.005	b_1 -.650
-2.952		1.947*	2.302*
-1.005			.355

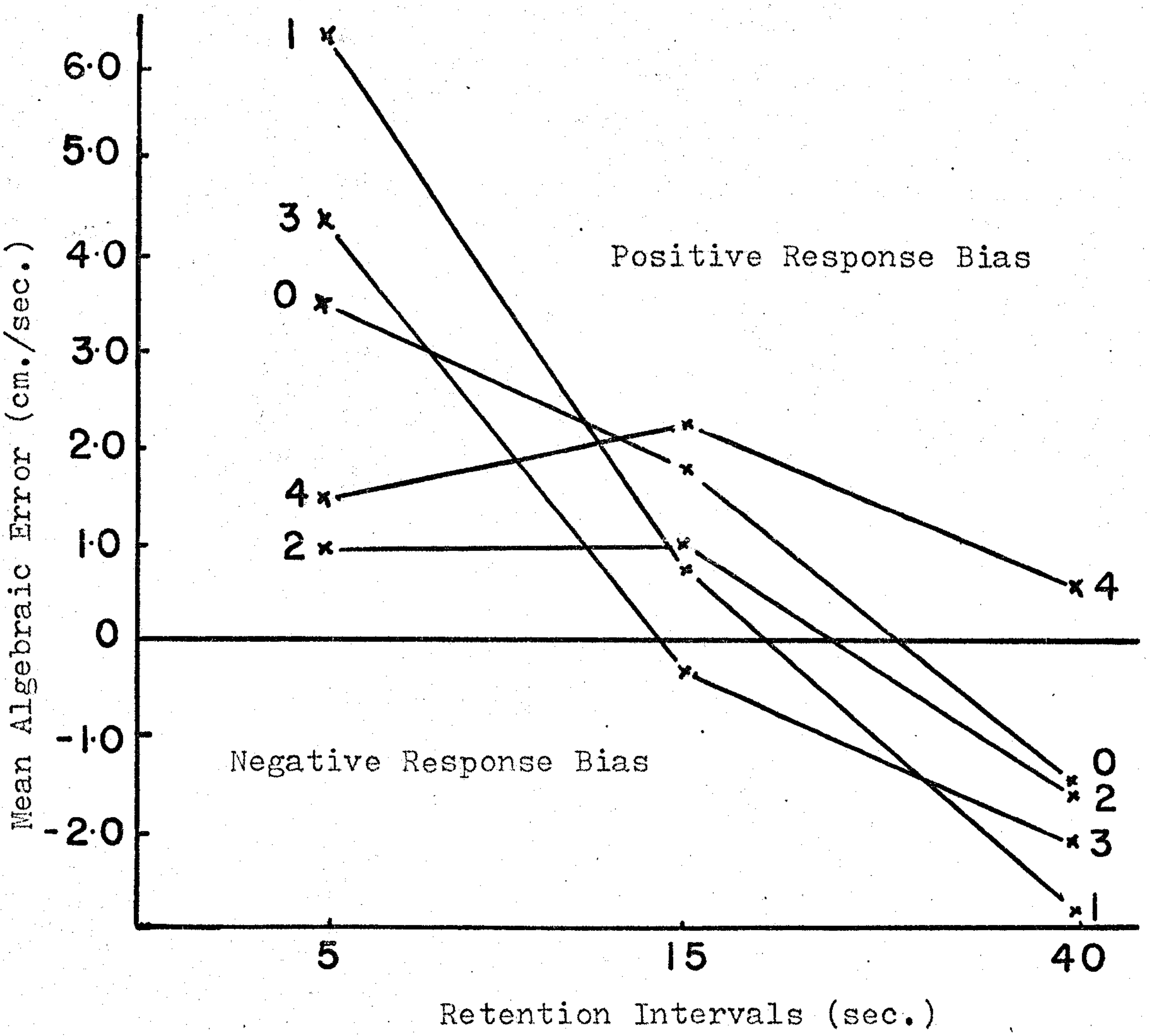


Figure 11.--Mean Algebraic Error for Speed Recall vs. Retention Interval X Prior Movements Interaction.

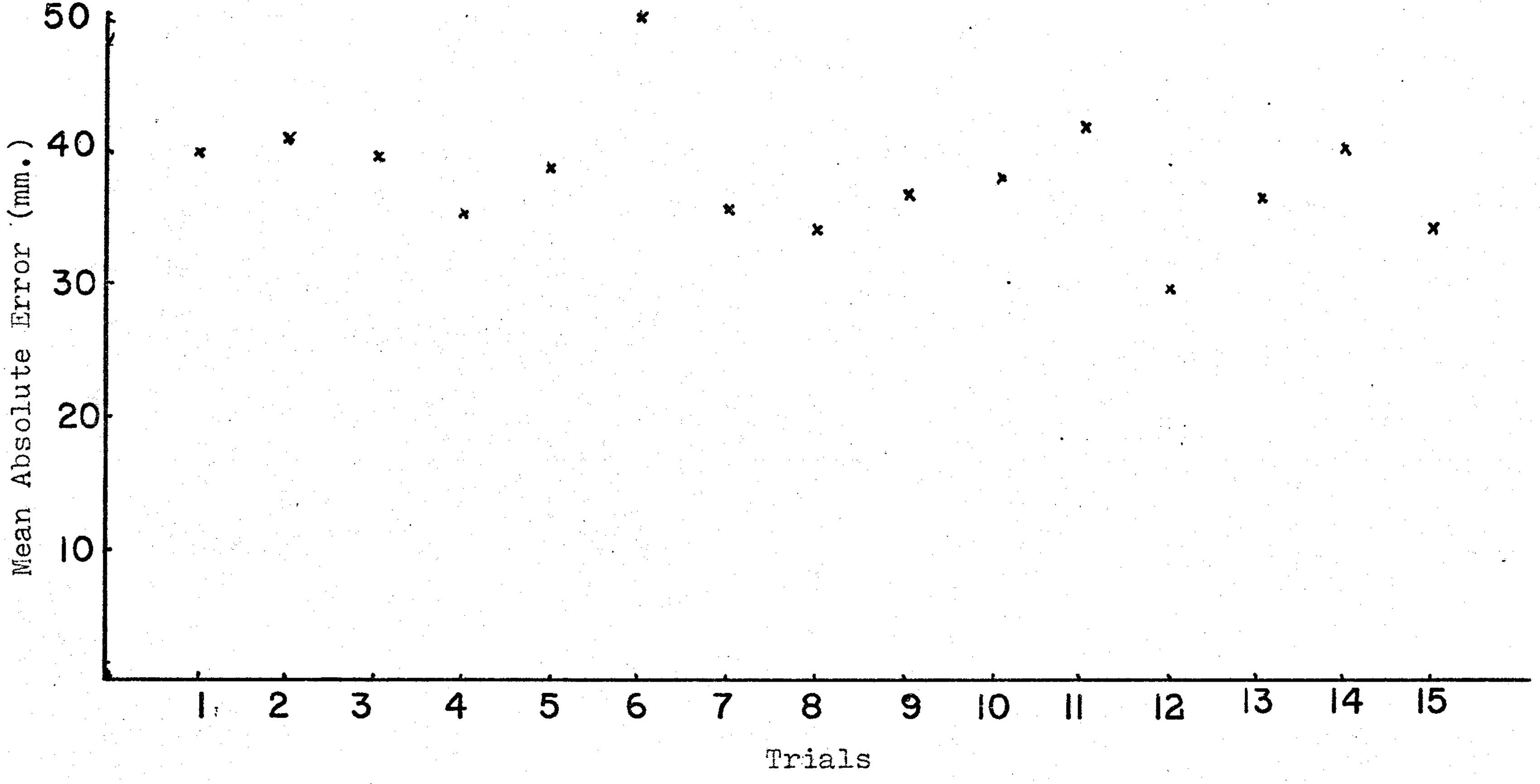


Figure 12.--Mean Absolute Error for Distance vs. Trials.

TABLE X11

THE RELATIONSHIP BETWEEN ABSOLUTE SPEED AND DISTANCE RECALL ERROR

Retention Interval	High Similarity				
	Prior Movements				
	0	1	2	3	4
5 sec.	.15	.35	-.25	-.26	-.04
15 sec.	.05	-.25	.19	-.10	.06
40 sec.	-.68	-.02	-.15	-.30	-.39

Retention Interval	Intermediate Similarity				
	Prior Movements				
	0	1	2	3	4
5 sec.	.39	-.42	.31	-.25	.05
15 sec.	-.38	-.10	-.09	-.04	.28
40 sec.	.29	.17	-.06	-.25	-.19

Retention Interval	Low Similarity				
	Prior Movements				
	0	1	2	3	4
5 sec.	-.15	-.31	-.49	.21	-.03
15 sec.	.13	.64	-.09	-.38	-.41
40 sec.	-.01	-.38	.13	-.59	-.64

At the $\alpha = .05$ level of confidence an $r = .60$ was required for significance.

CHAPTER V

DISCUSSION

Totality of the Movement

For the treatment effects to be valid, it was assumed that the subjects treated each movement (speed and distance) in its totality. Therefore, it was necessary to determine if this was, in fact true. The similarity effect would be impossible to determine if subjects attended to one of the components and not the other. If subjects concentrated on amplitude alone, neither of the similarity conditions would be expected to be significant, since both speed and distance similarity effects depended on attention to speed. If subjects focused solely on speed of movement, one would expect a similarity effect for speed but not distance.

Since there was no strong similarity effect on distance, for either algebraic or absolute error and because the relative error terms demonstrated distance recall (7% error) to be 3 times as accurate as speed recall (20% error), there was a possibility the above assumption was unfounded. As the error terms indicated, it did not appear that subjects were attending to both components equally. It was reasoned that this would be manifest in high negative correlations between speed and distance recall error, since attention to one component and not the other would result in accurate scores (small error) for the attended to component and non accurate (large error) scores for the other component. This was not the case, however, since none of the correlations (computed separately for each of the 45 experimental conditions) were significantly different from zero (Table X11). It was not known if 20% relative speed error was comparable to the 7% distance error (which did compare to the literature, although slightly higher - 7% vs. 4%) since there had been no research reported with speed as a component in motor STM. Since the measuring devices for speed and distance were different (meter stick vs. chronoscope), it was possible that the great differences between speed and distance recall accuracy were due to greater measurement error for speed. However, this seemed improbable, since instrument error would be less than 1%. The greater error in distance recall, as compared to the literature, was possibly the result of the subjects recalling what they thought was presented rather than their actual movement, although the instructions were explicit in this matter. This could have affected speed recall in a similar manner.

Studying active kinesthesis, Marteniuk (1971) concluded that subjects could combine information from more than 1 stimulus continuum for complex discriminations. Since the above conclusion strengthened the plausibility of the assumption and because the similarity effects did not follow the direction indicated by the relative error terms, it was believed that the subjects did treat the movement in its totality.

Retention Interval

Although neither distance nor speed demonstrated a significant trend with absolute error, both showed a change in response bias (algebraic error) over time. Hypotheses 1 and 4 predicted an increase in error as the retention interval increased. It can be seen (Figure 3) that subjects demonstrated a very strong positive response bias at immediate recall, for distance. After the 15 second interval, this bias had become negative in sign and subsequently increased in that direction over the 40 second retention interval. A similar shift (Figure 9) occurred for speed reproduction, although a negative response bias did not occur until the 40 second interval. This negative shift in response set for speed and distance coincided with the literature sited (Adams & Dijkstra, 1966, Stelmach, 1969, Ascoli & Schmidt, 1969). However, most of these studies were marked by a negative response bias for all recall conditions, thus, an increase in algebraic error (negative shift) would also increase absolute error. In the present study, however, a negative shift from immediate recall would tend to cancel the magnitude of error. This, in fact, was the case and resulted in the 15 second retention interval having the least error (Figure 3 and 9). This, in itself, however, is not a sufficient reason for the lack of significance with the absolute data, since Williams (1970) found error to increase over time with absolute error and a similar positive bias. The fact that speed was presented visually (oscilloscope) may have resulted in a visual memory component. Since visual STM does not decrease over an empty retention interval, this may have decreased the retention interval effect. In fact, Pepper (1970), using an oscilloscope to present various response pressures, found no forgetting over time with either absolute or algebraic error, although a negative trend was apparent in the response bias. Since the subjects in this study were expected to treat the movement in its totality (speed and distance), the visual component could have affected both speed and distance recall.

It was evident, that although absolute recall error did not increase as the retention interval increased (Hypotheses 1 and 4) there was a definite change in the memory trace, as indicated by the negative shift in the response bias.

Similarity

Hypothesis 5 predicted a similarity of movement effect parallel to the sited literature (Stelmach, 1969a), that is, recall error for speed should have increased as similarity decreased. This was shown to be true for both absolute and algebraic error (Figures 7 and 10). As the range of possible error increased (similarity decreased), subjects committed greater (magnitude) error. This effect, however, was not manifest with algebraic error until the 40 second retention interval (Figure 10). At the 40 second retention interval, the low similarity condition showed significantly more undershooting of the criterion speed than did either of the other two conditions. There was no significant difference between the intermediate and high similarity conditions, however, it was possible that the subjects had difficulty in distinguishing the 3 speeds (13, 20 and 27 cm./sec.) and as a result, decreased the proposed effect. In fact, many of the subjects thought there were only 3 speeds in the experiment, as was indicated by their questions after the testing. Montgomery (1970) found, that on occasions of doubt, subjects would move (circular movement task) to some point near the middle of the range of movement. If this type of effect occurred for speed recall of the two similarity conditions above (high and intermediate), recall error would be greatly decreased since the middle speed was (20 cm./sec.) always required in recall of the CM. Thus, decreased ability to distinguish between these 2 levels of similarity would decrease the error without actually increasing recall. Exactly this type of effect may have occurred in Stelmach's (1969a) study on movement similarity (as he admits), since there was only a 1/4 inch difference between his CM and the movements under the most similar condition ($\pm 5^{\circ}$).

Opposite to Hypothesis 5, the second hypothesis (distance recall) predicted greater error under the high similarity instead of the low similarity condition. This was not demonstrated by the absolute (Table 1) nor algebraic (Table 11) error terms for distance recall, since the similarity main effect failed significance. This may be partially explained by the greater relative error for speed recall, as this would decrease the similarity effect for distance recall. However, this cannot be a total explanation since there was a significant similarity effect for speed recall and because it was believed, as shown above, that the subjects treated the movement in its totality. Also, the graph in Figure 12 shows that this effect was not diminished by unwanted fatigue or learning.

An analysis of the simple main effects of the retention interval X similarity interaction for algebraic error of distance recall led to the explanation. There was significantly more undershooting in the intermediate and high similarity conditions than in the low similarity condition (Figure 5), at the 40 second retention interval. The lack of differentiation between the 2 most similar conditions and the interval effect were similar to that noted for algebraic error of speed recall. The former effect was probably due to the inability of most subjects to distinguish among the 3 speeds. The latter effect suggested that Posner's (1966) acid bath view was appropriate in explaining the results. This predicts that forgetting is produced when competing, similar items in STM intermingle during the retention interval and destroy the information contained in the trace. Interference depends on the similarity of items and the time they have to interfere. Thus, PI effects were not manifest under the present conditions until sometime between the 15 and 40 second retention interval. This was different from the literature sited (Stelmach, 1969b, Ascoli & Schmidt, 1969, Williams, 1970) in that PI effects were maximum after 15 seconds. The reason for this was not immediately apparent, although Montgomery (1970) concluded that the memory function may be dependent upon the nature of the kinesthetic input. All previous work had been done with simple linear movement tasks, thus the kinesthetic input in the present study might have been different, causing the observed delay in PI effects.

Since the similarity effects for speed recall mirrored the findings of Stelmach (1969a) and others (Patrick, 1971, Craft & Hinrichs, 1971) and since the distance recall results were opposite to those above, it would seem that the research on movement similarity to this point, had confused similarity and range effects. To properly test the effect of movement similarity on motor STM, it is essential that the possible range of error be equal for all similarity conditions. This is impossible if similarity and the error term measuring the similarity effect are defined by the same "component" [for example, Stelmach's (1969a) similarity was measured in degrees of displacement along an arc, as was his error term], unless a relative error term is used, as was indicated in the Review of Literature. Although very difficult or often impossible, experimentation in motor STM must replicate, as closely as possible, the research in verbal STM, if its aim is to determine the generality of verbal laws for motor STM. Unless this is accomplished, legitimate conclusions cannot be made.

Prior Movements

Hypotheses 3 and 6 predicted an increase in PI as the number of prior movements increased. However, this was not the case for absolute error of distance recall, as the proposed effect failed significance (Table 1). The prior movement main effect for algebraic error for distance recall was significant but 3 rather than 4 prior movements were more interfering than 0 prior movements. Figure 6 revealed that 4 prior movement had a much smaller positive response bias than 0 prior movements at immediate recall, however, this uniform trend did not continue for the 15 and 40 second retention intervals. The trend at immediate recall was similar to that noted by Ascoli and Schmidt (1969) for all retention intervals, as the response bias became more negative as the number of prior movements increased. Observation of the absolute and algebraic error of speed recall (Figures 8 and 11) indicated a similar lack of direction.

Before Stelmach (1969) and Ascoli and Schmidt (1969) used the paradigm in Figure 1 to produce PI in motor STM, there had been little success using the paradigms in Figure 2. In fact, the latter researchers have since discounted their results, although Williams (1970) has verified them by showing the existence of PI effects separate from a decreased input (attention) as Ascoli and Schmidt (1969) concluded. Inspection of Figures 6 and 11 clearly showed a decreased input (attention) at immediate recall, since there should be no difference among prior movements at this point because of the negligible time available for traces to interfere and thus cause forgetting. This decrease in input was also indicated by the larger percentage error (7%) in this study, as compared to the literature ($\bar{x}$ = 4%). Since PI effects appear to be very transient, depending greatly on the design used, this decreased input may have been enough to leave the trace somewhat ineffective. However, as the acid bath view proposes, increased forgetting does not depend on the magnitude of the traces but on their similarity.

Another possibility, is the fact that the memory function seems to depend greatly on the type of kinesthetic input. It was quite possible that the more complex task used in the present study produced a different input than in the other studies. In the previous three studies demonstrating PI effects (Ascoli & Schmidt, 1969, Stelmach, 1969b, Williams, 1970), there was a constant interval of 10 seconds between prior movements. This was not the case here because of the difference in tasks, although an interval very similar to this was achieved (8 to 12 seconds).

Thus, no specific reason to explain the above results was immediately available.

CHAPTER V1

SUMMARY AND CONCLUSIONS

Summary

This study was proposed to investigate the effects of similarity of movement on motor STM. Algebraic and absolute error terms were used to measure performance on speed and distance recall. The independent variables were retention interval, similarity and prior movement. Each subject was tested under all levels of the latter 2 variables but only under 1 retention interval. The subjects were 30 male students from the four years of physical education at the University of Windsor.

Subsequent to a review of the pertinent literature, the following 6 hypotheses were formulated:

1. The longer the retention interval, the greater the recall error for distance.

2. As similarity of movement increases, the recall error for distance will increase also.

3. The recall error for distance will increase as the number of prior movements increases.

4. The longer the retention interval, the greater the recall error for speed.

5. As the similarity of movement increases, the recall

error for speed will decrease.

6. An increase in the number of prior movements will increase the error of speed recall.

The raw data was collected and analyzed using Winer's (1962) Case 1, a three factor analysis of variance with repeated measures on the last two factors. Significant F ratios were further analyzed using Newman-Keuls and simple main effects procedures.

Conclusions

1. Although there was no marked increase in the magnitude of error as the retention interval increased, the response bias shifted in a negative direction from overshooting to undershooting, for both speed and distance recall.

2. Increased similarity of movement caused an increase in recall error for distance and a decrease in recall error for speed at the 40 second retention interval. The correct error term for determining the true effect of movement similarity was the former.

3. Increased similarity caused a negative shift in response bias for distance recall and a positive shift for speed recall.

4. No significant trend was produced by increasing the number of prior movements although PI was produced as noted in the similarity condition.

Further Direction

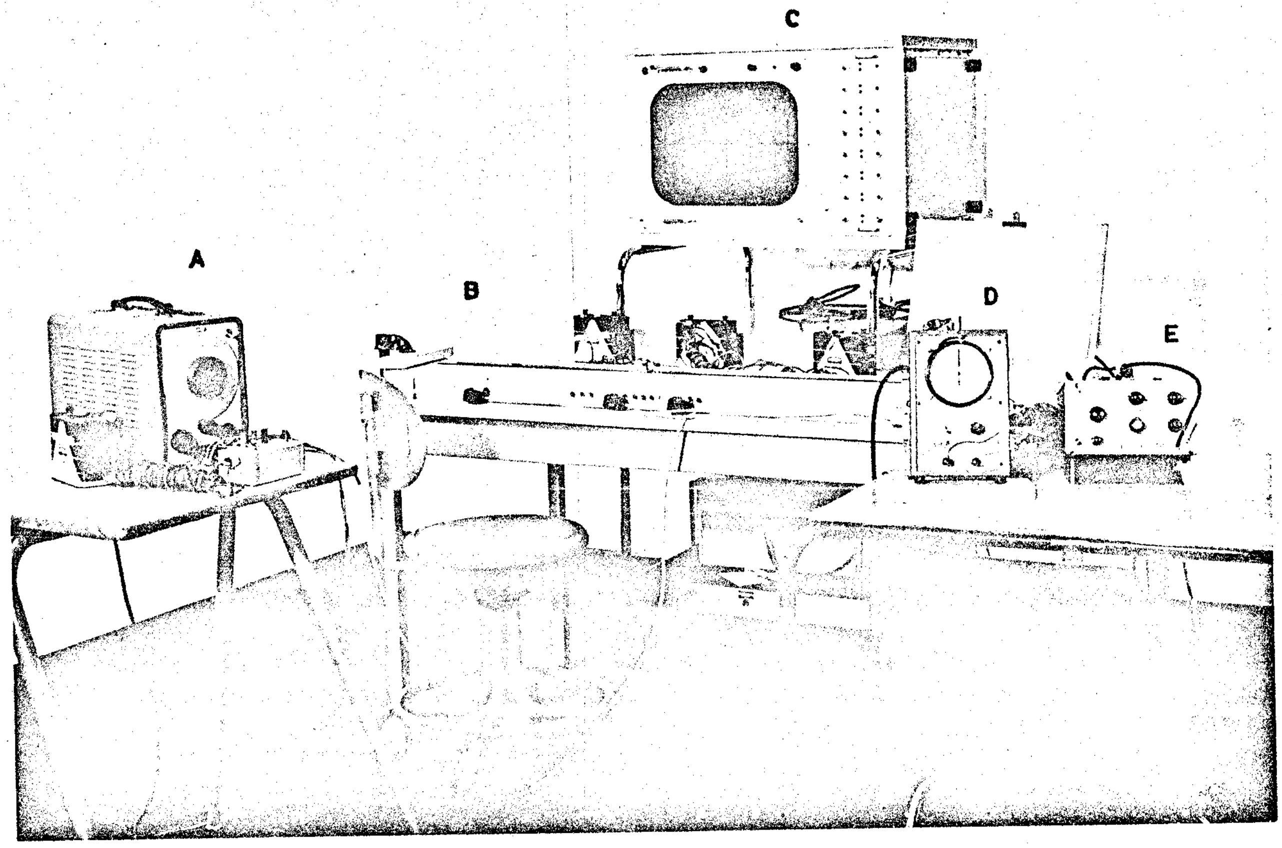
It was evident from the results of this study that attempts to test the generality of verbal STM laws, using kinesthetic input, should only be made after careful consideration of the verbal law and the experimentation leading up to it. If this is not done, scientifically sound conclusions cannot be drawn from the research. This is not to say, however, that research in motor STM should be done solely to determine the generality of verbal laws.

During the testing, it was obvious that further research is needed to clarify what kinesthetic cues (input) are actually used for recall. For example, how or is speed a usable kinesthetic input for STM recall? If it is, is it possible to store information from 2 continua (speed and displacement) in STM simultaneously? What effect does this have on storage capacity? Questions such as these must be answered before generalizations involving kinesthetic input can be tested. If 2 similar motor STM experiments are conducted, but unknowingly the input differs, generalizations, after studying the results from both, may be very haphazard if not impossible.

The testing and analysis of results also pointed out the importance of the error term used or the significance of directional biasing. The general response set of the subjects under the various conditions was shown to be very important in affecting the results. Since many things can affect this bias (length of retention interval, similarity, length of movement, position of subject relative to the equipment etc.), it is necessary that experimental procedures are standardized both within and between experiments. This can only be achieved through distinct and concise reporting.

APPENDIX

APPARATUS



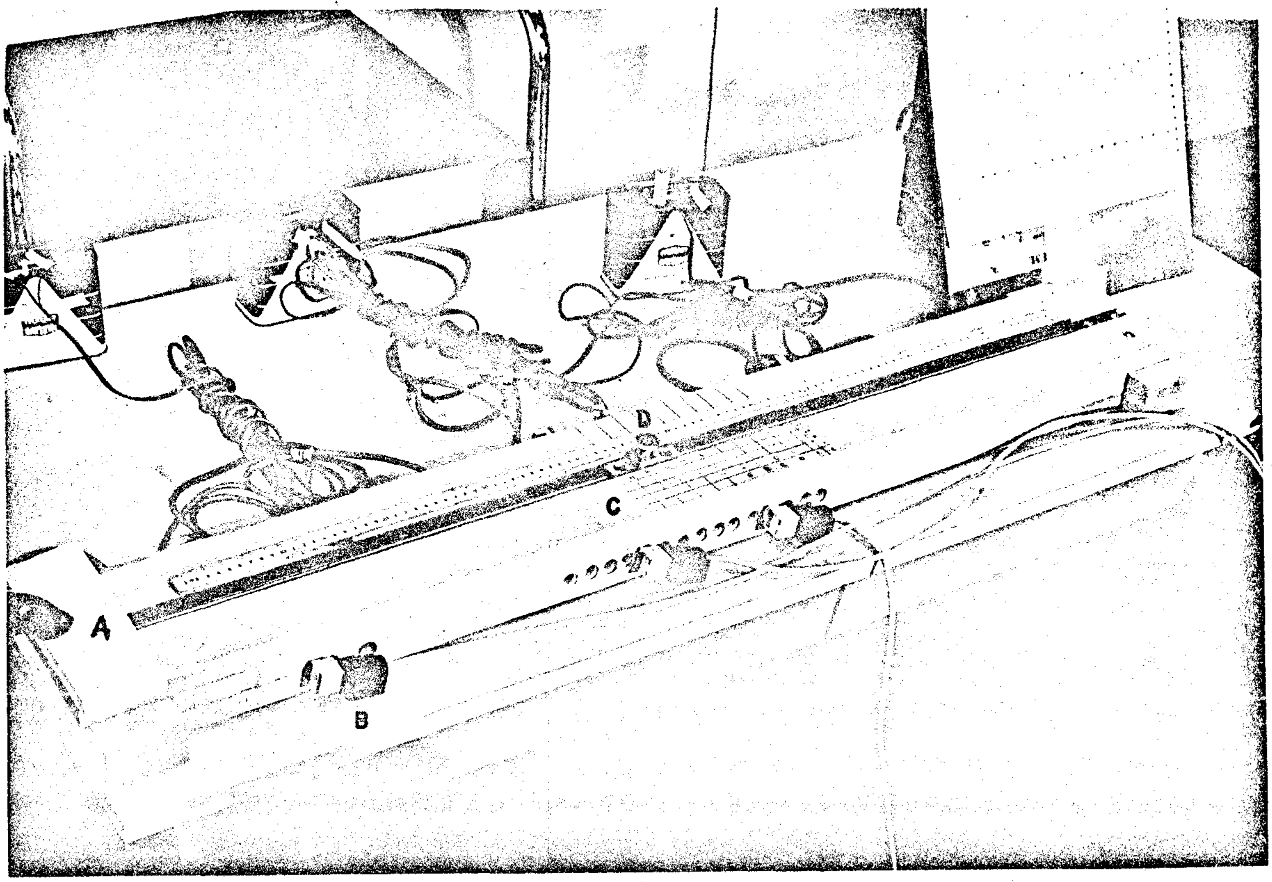
A - Belltone earphones and generator.

B - Linear movement apparatus.

C - Oscilloscope.

D - Chronoscope.

E - Wave generator.

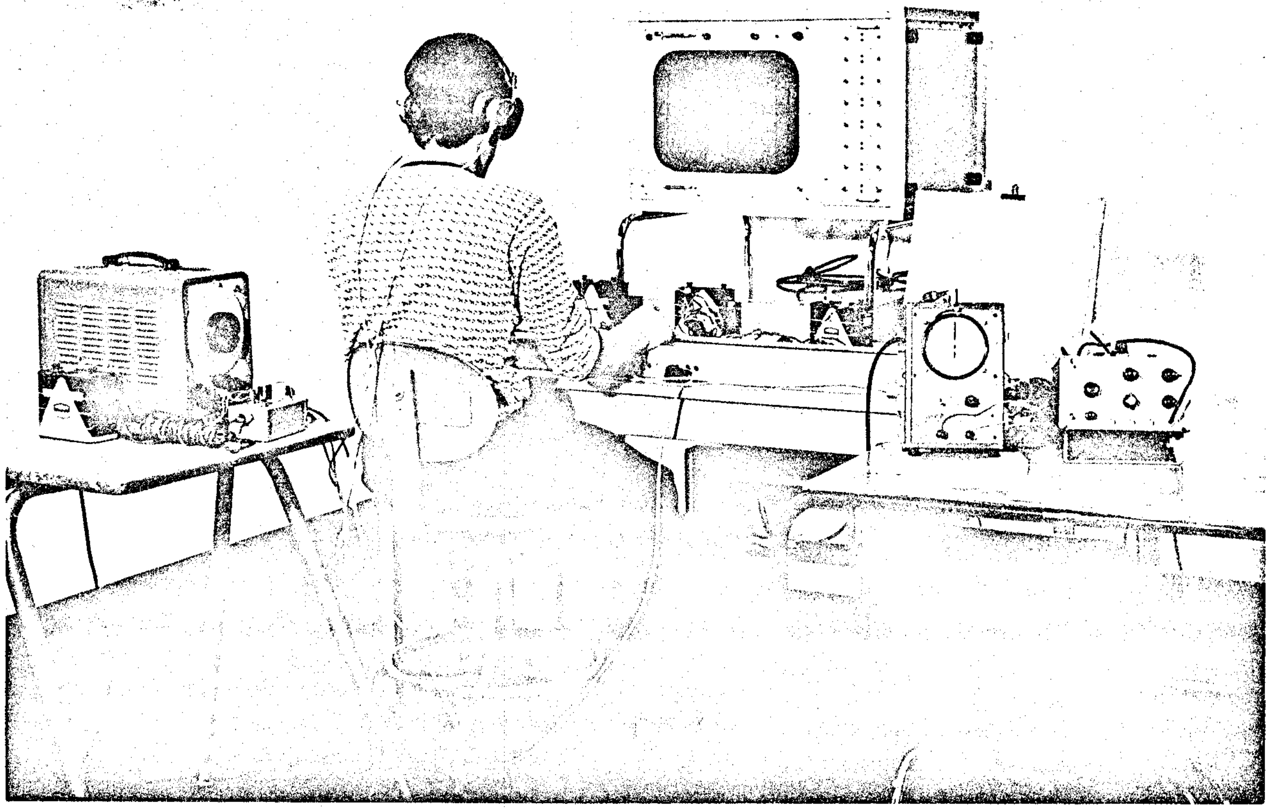


A - Linear movement apparatus.

B - Photo cell.

C - Colour letter code for holes.

D - Metal slide.



Subject sitting at experimental equipment.

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