1-1-1979

Cueing and the encoding specificity principle in motor short-term memory.

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CUEING AND THE ENCODING SPECIFICITY PRINCIPLE IN MOTOR SHORT-TERM MEMORY

by

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A Thesis
submitted to the Faculty of Graduate Studies
through the Department of Psychology
in Partial Fulfillment of the
Requirements for the Degree
of Master of Arts at the
University of Windsor

Windsor, Ontario, Canada

1979

ABSTRACT

The present experiment examined motor short-term memory for active and passive movement extents as a function of cueing and as a function of the interaction between encoding and retrieval conditions.

Twenty-four right-handed female subjects were required to retrieve information by reproducing the extent of an encoded criterion movement either in the same mode of execution as the criterion movement (Active-Active; Passive-Passive) or in a different mode of execution (Active-Passive; Passive-Active) in a linear positioning task. The subjects were divided equally into three groups according to the point at which information about the reproduction movement mode of execution was made available (cueing): (a) before the criterion movement, (b) immediately after the criterion movement but before a 15 sec retention interval, and (c) after the retention interval, immediately prior to the reproduction movement.

The results showed that there was no facilitory effect of the point of cueing on retrieval performance. However, when the criterion movement and the reproduction movement modes of execution were the same performance

was better than when the modes of execution were different.

The results of the present experiment were discussed as providing further support for the encoding specificity principle in motor short-term memory. Adopting a recent suggestion that active retrievals reflect recall and that passive retrievals reflect recognition, a theoretical concept for motor recognition failure also was discussed.

ACKNOWLEDGEMENTS

Sincere gratitude is expressed to Dr. T.T. Hirota for his supervision of this manuscript as well as the initial interest he took in me and our subsequent research endeavors.

Special thanks to Dr. J.L. Leavitt for his guidance and for instilling in me the interest to undertake this field of study.

Appreciation is also extended to Dr. A. Kobasigawa for his assistance on this and previous works. A warm thanks to my colleague Sandy Romanow for making the past two years an enjoyable learning experience.

Most important is the sincere gratitude to my wife, Barbara, for her devotion and encouragement and to my parents for their continual support. This manuscript is dedicated to these people.

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CHAPTER I

INTRODUCTION

Extensive research during the past two decades has been directed towards an understanding of the human processing system for movement information. Using a linear arm positioning task Adams and Dijkstra (1966) and Posner (1967) provided initial evidence which suggested that storage of movement information involves a process which is different from the process of storing verbal as well as non-verbal information.

The typical paradigm for examining motor short-term memory involves the encoding of a movement to-be-remembered or criterion movement followed either immediately or after a short delay by the subject's attempt to accurately retrieve the criterion movement, called the reproduction movement. Utilizing this paradigm investigators have separately examined two stimulus cues or attributes which provide movement information. One attribute which may be used to retrieve a criterion movement is the end-location or final stopping point of the movement to-be-remembered. Another attribute is the extent of the movement or the distance travelled. End-location is isolated as an attribute

and examined by varying the starting location of the reproduction movement and instructing the subject to retrieve the final stopping position of the criterion movement, rendering distance unreliable as an effective attribute. Conversely, extent is isolated by varying the starting location of the reproduction movement and instructing the subject to retrieve the distance of the criterion movement, thus end-location becomes an ineffective attribute.

Keele and Ells (1972) and later, Marteniuk and Roy (1972) were the first to isolate and investigate the accuracy of utilizing end-location and extent attributes in movement retrieval. Their results showed that a movement end-location attribute led to a more accurate retrieval of the criterion movement than an extent attribute.

Laabs (1973) examined the retention characteristics of these two movement attributes. The study involved a comparison of retrieving end-location and extent attributes after four retention conditions: immediate, 12 sec rest, 12 sec counting backwards, and 12 sec of spatial reasoning. The results showed that for end-location, retrieval was equally accurate for immediate and 12 sec rest conditions and retrieval was less accurate when rehearsal was prevented (counting backwards or spatial reasoning interpolated). However, while retrieval using an extent attribute was poorer with rest, accuracy did not deteriorate further with interpolated activities. Laabs interpreted these

findings as evidence that an end-location attribute is rehearsable as long as processing capacity is available but that an extent attribute is not rehearsable, spontaneously decaying over time.

In contrast, Marteniuk (1973) found that a movement extent attribute was rehearsable and that a decrement in performance occurred only after 10 sec of interpolated activity. This contradictory finding was explained as a difference in methodology. In the Laabs study the criterion movement was "constrained" (defined by the experimenter) whereas Marteniuk employed a "preselected" criterion movement (defined by the subject). Thus, when a subject was allowed to define his own criterion, retrieval accuracy was improved.

The general finding that preselected movements are more accurately retrieved than constrained movements has been demonstrated in studies where both extent and end-location were reliable attributes for retrieval (Jones, 1974; Marteniuk, 1977), only an end-location attribute was reliable (Stelmach, Kelso, & Wallace, 1975), and where only an extent attribute was available for retrieval (Roy, 1978; Roy & Diewert, 1975, 1978).

Although the superior accuracy in retrieving preselected as opposed to constrained criterion movements has been reliably demonstrated, the nature of this advantage has received many interpretations (for a review

see Kelso, Pruitt, & Goodman, 1979). The present research was concerned only with constrained movement presentations and research discussed henceforth will be limited to results obtained from constrained paradigms.

Active and Passive Movement Conditions

Another issue which has received considerable attention is the role that active and passive movements play in the encoding of a memory trace. In a typical constrained paradigm active movement requires a simple subject-controlled action (of an experimenter defined movement) whereas passive movement involves the guidance of a subject's relaxed arm through the same criterion movement by the experimenter. Following the appropriate retention condition all subjects are required to actively make the reproduction movement.

Marteniuk (1973) was the first researcher to examine the encoding characteristics of actively versus passively generated criterion movements. His results showed that for both extent and end-location attributes, actively producing the criterion movement resulted in superior retrieval accuracy than passive production of the criterion movement. Marteniuk attributed the difference between active and passive movements as encoding to "varying degrees of exactness" (p. 257).

Marteniuk's findings have received only partial support in the literature -- being replicated only under constrained conditions when an extent attribute was available for retrieval. Stelmach, Kelso and Wallace (1975) examined end-location retrieval under active and passive criterion movement conditions and found no differences in retrieval accuracy. Studies which have examined active and passive movements under conditions where both movement end-location and extent were reliable attributes for retrieval (Jones, 1974; Kelso, 1977a; Marteniuk, 1977) have also failed to replicate Marteniuk's (1973) results.

The superiority in accuracy for retrieving active, constrained criterion movements over passive, constrained criterion movements has been successfully replicated for extent as a codable attribute. Roy and Diewert (1978) found that actively presented criterion movements were retrieved more accurately than passively presented criterion movements upon immediate retrieval. Furthermore, Roy (1978) demonstrated that after a 20 sec unfilled retention interval this superiority was maintained. The investigators (Roy & Diewert, 1978) attributed the significance of their findings to an encoding process:

> For a non-preselected movement since active movement during the standard was necessary for accurate memory, it may be that information relevant to the execution of the movement (i.e. efferent or motor command information and/or proprioceptive feedback information) during presentation of the standard is important in memory. (p. 100)

The better retrieval accuracy for actively presented movement information then, has been proposed to reflect some qualitative difference in the encoding of the memory trace -- the memory trace being encoded to a stronger memorial representation under active presentation. Other researchers (Hall & Leavitt, 1977) interpreted the phenomenon within the levels of processing framework (Craik & Lockhart, 1972) and suggested that active movements represent more meaningful information, allowing for more elaboration within a processing level compared to passively presented movements.

Although the superior retrieval accuracy of active criterion movements has been interpreted as reflecting a better encoding of the memory trace, this conclusion may be based upon a confounded experimental design, since the typical research paradigm employs only active reproduction movements. The procedure requires subjects, having made the criterion movement passively and switched to an active mode during retrieval, being compared to subjects who produced both the criterion and reproduction movements in the same mode of execution. In effect, switching the mode of movement execution at the time of retrieval prevents an appropriate examination of the differences in the encoding of active and passive movements.

Encoding Specificity Principle

Recently, the question of how different conditions at the time of output affect the subsequent retrieval of an encoded item has received considerable attention in the verbal literature. Thomson and Tulving (1970) proposed the encoding specificity hypothesis (presently known as the encoding specificity principle - Tulving & Thomson, 1973) to explain the functional relationship between encoding and retrieval conditions. The encoding specificity principle maintains that the specific encoding operations which are performed on an item determine which conditions at retrieval will facilitate the most accurate access to the memory trace. The more precisely the conditions during output match the episodic memory trace (conditions encoded with the to-be-remembered item) the better the facilitation of retrieval. Widespread support for the theory has been accumulated by numerous investigators (e.g. Fisher & Craik, 1977; Pellegrino & Salzberg, 1975; Tulving & Watkins, 1975) in the area of verbal learning and memory.

The application of the encoding specificity principle to research in the psychomotor area has come under very recent examination. Lee and Hirota (1979) investigated the encoding specificity principle in motor short-term memory under conditions in which subjects were presented the criterion movement either actively or passively and

were required to retrieve the extent of the movement under active or passive conditions. For constrained criterion movements the results showed that when the modes of execution during encoding and retrieval were the same (Active-Active; Passive-Passive) retrieval accuracy for active and passive movements were equivalent. These "same" conditions were significantly better than when the mode of retrieval was different from the mode of presentation (Active-Passive; Passive-Active), which were themselves not significantly different. These findings suggest that when retrieval operations satisfy the conditions under which the criterion movement is encoded, there is no advantage to active as opposed to passively stored memory traces.

Nadeau and Lortie (1978) on the other hand provide evidence that active movements provide for better retrieval of extent information. In their study subjects were informed of the mode of retrieval of passively presented movements before the criterion movement. The results showed that active retrievals were more accurate than passive retrievals.

Cueing

Although the principle of encoding specificity asserts that the degree to which conditions are matched at storage and retrieval is the critical variable some verbal

theorists concede that the operations performed at encoding are affected by the subject's expectations of the conditions to be encountered during retrieval (Flexser & Tulving, 1978; Lockhart, Craik, & Jacoby, 1976). If the subject anticipates that the conditions at retrieval will not match the stored episode, the subject may encode the memory trace in such a manner that will best facilitate retrieval according to the expectations of the conditions to be encountered.

Indeed, evidence from two studies in the psychomotor area suggest that humans are able to process information, varying in accordance with an expectation of the conditions to be encountered at retrieval. Although end-location as a codable movement attribute has been reliably demonstrated to be a more accurate attribute for retrieval than an extent attribute, instructions that alter the expectations about the reproduction movement may reverse the general trend. Hagman and Francis (1975) found that when subjects were told before the criterion movement that extent would be the only reliable attribute for retrieval, extent was significantly better than end-location in retrieving the encoded criterion movement. An experiment by Wilberg and Hall (1976) required subjects to either accurately retrieve the extent of the criterion movement, or to retrieve "just less" or "just more" than the extent of the criterion movement. Their results

indicated that movement extent retrieval was better when the instructions about the reproduction movement were made available before as opposed to after the criterion movement.

The Problem

The superior retrieval accuracy of movements which have been presented actively as opposed to being passively presented have been discussed as reflecting a difference in either the quality or quantity of encoding. While other lines of evidence have shown that superior accuracy with active as opposed to passive reproduction movements suggest that active/passive movement differences are due to conditions available at retrieval, very recent findings concur with the established research in the verbal literature implying that the relationship between conditions available at encoding and retrieval is the critical variable.

The present research is designed to assess the interaction of encoding and retrieval conditions on the memory of movement information. Accuracy of retrieval may be altered through cueing, by manipulating the point at which information about the mode of retrieval is made available to a subject (before presentation; after presentation but before a retention interval; or after the retention interval, before retrieval). The results

will provide an indication of the combined effects of encoding, recoding (information transformation), and retrieval on the processing of movement information.

Hypotheses

1. Cueing. Retrieval will be: (a) most accurate when information of the mode of retrieval is made available prior to the criterion movement, (b) less accurate when the information is given after the criterion but before the retention interval, and (c) least accurate when the information is made available after the retention interval.
2. Encoding. Conditions in which the criterion movement is encoded actively will not differ in retrieval accuracy from passively encoded criterion movements, regardless of the point at which information about the mode of retrieval is made available.
3. Retrieval. Conditions in which the reproduction movement is made actively will not differ in retrieval accuracy from passively retrieved movements, regardless of the point at which information about the mode of retrieval is made available.
4. Encoding Specificity Principle. Retrieval accuracy of conditions in which both the criterion movement and the reproduction movement are made in the same mode of execution (Active-Active; Passive-Passive) will be

more accurate than the performance when retrieving movements in which the reproduction movement is made in a different mode than the criterion movement (Active-Passive; Passive-Active).

5. Cueing and the Encoding Specificity Principle.

(a) Movements in which the mode of criterion movement/reproduction movement execution is the same will show the most marked superiority over the different criterion movement/reproduction movement execution conditions when the information about the mode of retrieval is available after the retention interval. (b) This superiority will be decreased when the information is provided after the criterion movement but before the retention interval. (c) The two conditions will be least different when information about the mode of retrieval is made available prior to the criterion movement.

CHAPTER II

METHODOLOGY

Subjects

Twenty-four right-handed females ($\bar{x}$ age = 22.6 yrs, SD = 5.07 yrs) served as subjects. The subjects were selected from two undergraduate psychology classes at the University of Windsor and received credit towards their mark in the course. All subjects were naive as to the purposes of the experiment.

Apparatus and Materials

The linear slide apparatus consisted of an Ealing Aluminum Optical Bench (cat. # 22-6894), one meter in length. The slide carriage was an Ealing Optical Carrier (cat. # 22-4170) with dimensions of 10 cm across the bench and 9 cm along the bench. A knob attached to a set screw on one side of the carriage served as the subject's handle. On the experimenter's side a meter rule attached to the linear slide provided for measurements to the nearest mm. All measurements were recorded from the leading edge of the carriage. Near noiseless and friction-less movements were made possible by the application of Lubriplate to the contact surfaces of the bench.

The linear slide was placed upon a table approximately 76 cm in height. The slide was secured to the table by the use of two C-clamps. The limits within which the subject was able to move the carriage were defined by the use of wooden blocks, constructed so that the blocks rested on top of the slide and between two Ealing carriers set as stops.

Vision was blocked by a visual shield, constructed so as to allow free arm movements while preventing visual feedback. The shield consisted of a vertical panel 79 cm in height joined perpendicular at the bottom to a 56 cm deep horizontal shelf. The horizontal shelf was 21 cm above the surface of the table and provided space for unrestricted lateral arm movement. Attached to the shelf, directly in front of the subject and placed horizontally, was a 2.54 cm diameter Plexiglas rod mounted on two vertical metal rods and served as an adjustable head and chin rest. The entire shield was painted flat black.

An adjustable swivel stool served as the subject's seat. The experimenter was seated on the opposite side of the table. A Hunter decade timer was used to time retention intervals.

Experimental Design

The design of the present study was a 3x2x2 factorial with repeated measures on the last two factors. The between

subjects variable consisted of three points where information about the mode of the reproduction movement was made available to the subject (CUEING). The two within subject variables were the mode in which the criterion movement was executed (CRITERION MOVEMENT MODE of EXECUTION) and the mode in which the reproduction movement was made (REPRODUCTION MOVEMENT MODE of EXECUTION).

There were three CUEING groups of eight subjects each. One group received information about the mode of the reproduction movement prior to producing the criterion movement (PRE-CM CUEING). A second group received information immediately following the criterion movement but prior to a 15 sec unfilled retention interval (PRE-RI CUEING). The final group received the information immediately following the 15 sec retention interval, just prior to the reproduction movement (PRE-RM CUEING).

There were two levels of each of the two within subject variables. The CRITERION MOVEMENT MODE of EXECUTION was made either actively by the subject (ACT) or was guided through the movement passively by the experimenter (PASS). The REPRODUCTION MOVEMENT MODE of EXECUTION was also made either actively or passively. Each subject was tested on eight trials under each of the four criterion movement/reproduction movement combinations (ACT-ACT; ACT-PASS; PASS-ACT; PASS-PASS), for a total of 32 trials.

Procedure

The experimental session began (in a room near the test room) with a brief explanation of the task requirements (see Appendix B for detailed instructions). The experimenter and the subject then went to the test room where the subject was seated with the saggital plane of the body opposite the chin rest and the midpoint on the linear slide. The height of the subject's chair was adjusted so that the extended arm was at approximately right angles to the body's coronal plane.

The experimental session consisted of two phases: a pretest and a test phase. During the pretest the subject was given ten 50 cm passive movements during which the subject was prompted to totally relax her arm. Then there were 10 active movements during which the subject was prompted to move at the same velocity as the passive movements. The pretest concluded with four practice trials at each of the criterion movement/reproduction movement conditions.

During the test phase each trial (for all subjects) consisted of a criterion movement, a 15 sec retention interval and a reproduction movement. The criterion movement was 30 cm in length. Upon contacting the stop defining the end-location of the criterion movement, the subject was instructed to release the handle and place her hand on her lap. Following the retention interval the subject

was then required to regrasp the handle and retrieve the extent of the criterion movement. All movements were made from right to left.

The only difference in instructions between the three CUEING groups was the point at which the information about the mode of retrieval was presented to the subject. Each subject was handed a copy of the instructions and asked to follow as the experimenter read the instructions aloud.

Movement end-location as a codable attribute was made unreliable for retrieval by varying the starting location of the reproduction movement ± 5 cm and ± 10 cm from the starting location of the criterion movement. Each of the four reproduction movement starting locations occurred randomly eight times during the experimental session. Each of the four criterion movement/reproduction movement combinations also occurred randomly eight times.

Data Analysis

In accordance with a recent suggestion by Roy (1976) and current practice in the literature, three dependent measures were used: absolute error (AE), constant error (CE), and variable error (VE). Adopting the interpretation of these measures by Ho & Shea (1978), AE was considered the measure of retrieval accuracy. CE was interpreted as an indication of subjective response biasing and VE was

considered a measure of consistency or the variability of each subject's performance. The CE and VE measures provided for a clearer interpretation of the results for retrieval accuracy.

Each dependent measure was analyzed using a three-way analysis of variance (ANOVA) with repeated measures on the last two factors (Winer, 1971, case 1, p. 539). Post-hoc comparisons were performed using the Duncan's New Multiple Range procedure.

CHAPTER III

RESULTS

Three measures of reproduction performance are reported in the present experiment: absolute error, constant error, and variable error.

Absolute Error (AE)

Analysis of variance for AE is summarized in Table 1. Main effects of cueing were significant, $F(2,21) = 4.11$, $p < .05$. Main effects of criterion movement mode of execution, $F(1,21) = 2.33$, $p > .05$, and reproduction movement mode of execution, $F(1,21) = 0.00$, $p > .05$, were not significant. An interaction between criterion movement mode of execution and reproduction movement mode of execution was significant, $F(1,21) = 21.01$, $p < .001$. All other interactions failed to reach significance levels.

Post-hoc analysis using the Duncan's New Multiple Range procedure on the main effect of cueing showed that the PRE-RI group (mean of 4.27 cm) was significantly less accurate than the PRE-CM and PRE-RM groups (means of 3.41 cm and 3.54 cm, respectively), which were not significantly different themselves. (see Figure 1)

Duncan's analysis on the criterion movement mode of

Table 1

Analysis of Variance Summary Table for Absolute Error Data

Source	SS	df	MS	F
Between Subjects	48.59	23		
A (Cueing)	13.65	2	6.83	4.11 *
Subjects within groups	34.94	21	1.66	
Within Subjects	104.00	72		
B (Criterion mode of execution)	1.82	1	1.82	2.33
AB	0.18	2	0.09	0.12
B x subj. w. groups	16.37	21	0.78	
C (Reproduction mode of execution)	0.00	1	0.00	0.00
AC	3.06	2	1.53	0.94
C x subj. w. groups	34.29	21	1.63	
BC	23.74	1	23.74	21.01 **
ABC	0.91	2	0.46	0.41
BC x subj. w. groups	23.63	21	1.13	

* $p < .05$

** $p < .001$

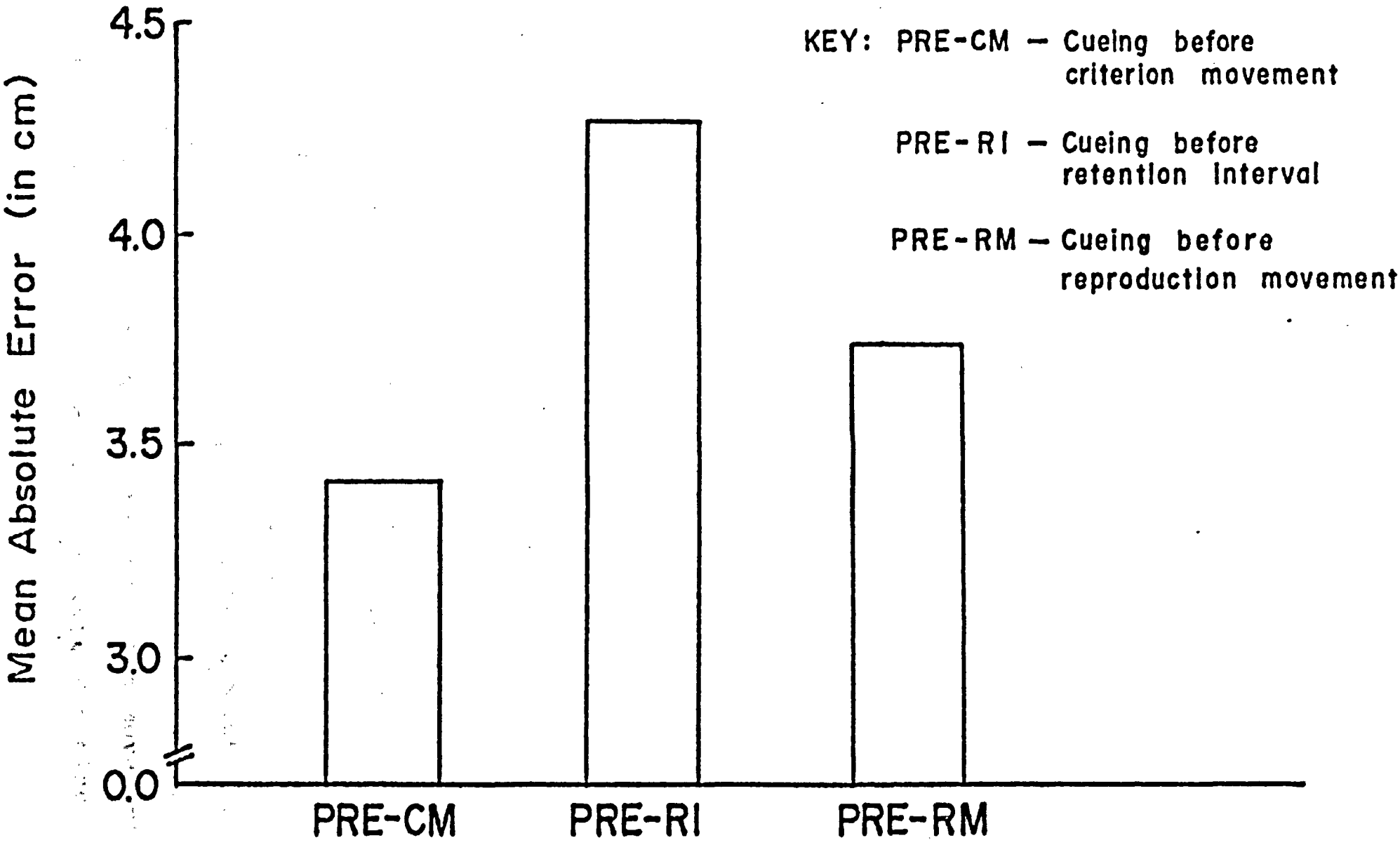


Figure 1. Mean absolute error as a function of the point at which information about the reproduction movement mode of execution is given.

execution by reproduction movement mode of execution interaction revealed that when the criterion movement was active, active retrieval was more accurate than passive retrieval. However, when the criterion movement was passive, active retrieval was less accurate than passive retrieval. Each of the paired interactions in which the modes of execution were the same (Active-Active; Passive-Passive) had significantly less mean absolute error (3.39 cm and 3.10 cm, respectively) than each of the different modes of execution pairs (Active-Passive, mean of 4.37 cm; Passive-Active, mean of 4.10 cm). The Active-Active and the Passive-Passive conditions were not significantly different. The difference between the Active-Passive and the Passive-Active conditions also failed to reach significance levels. (The interaction effects may be seen in Figure 2).

Constant Error (CE)

Analysis of variance for CE is summarized in Table 2. Main effects of criterion movement mode of execution, $F(1,21) = 38.51$, $p < .001$, and reproduction movement mode of execution, $F(1,21) = 26.74$, $p < .001$, were significant. The main effect of cueing $F(2,21) = 1.00$, $p > .05$ was not significant. An interaction between cueing, criterion movement mode of execution, and reproduction movement mode of execution, $F(2,21) = 5.49$, $p < .05$, was also

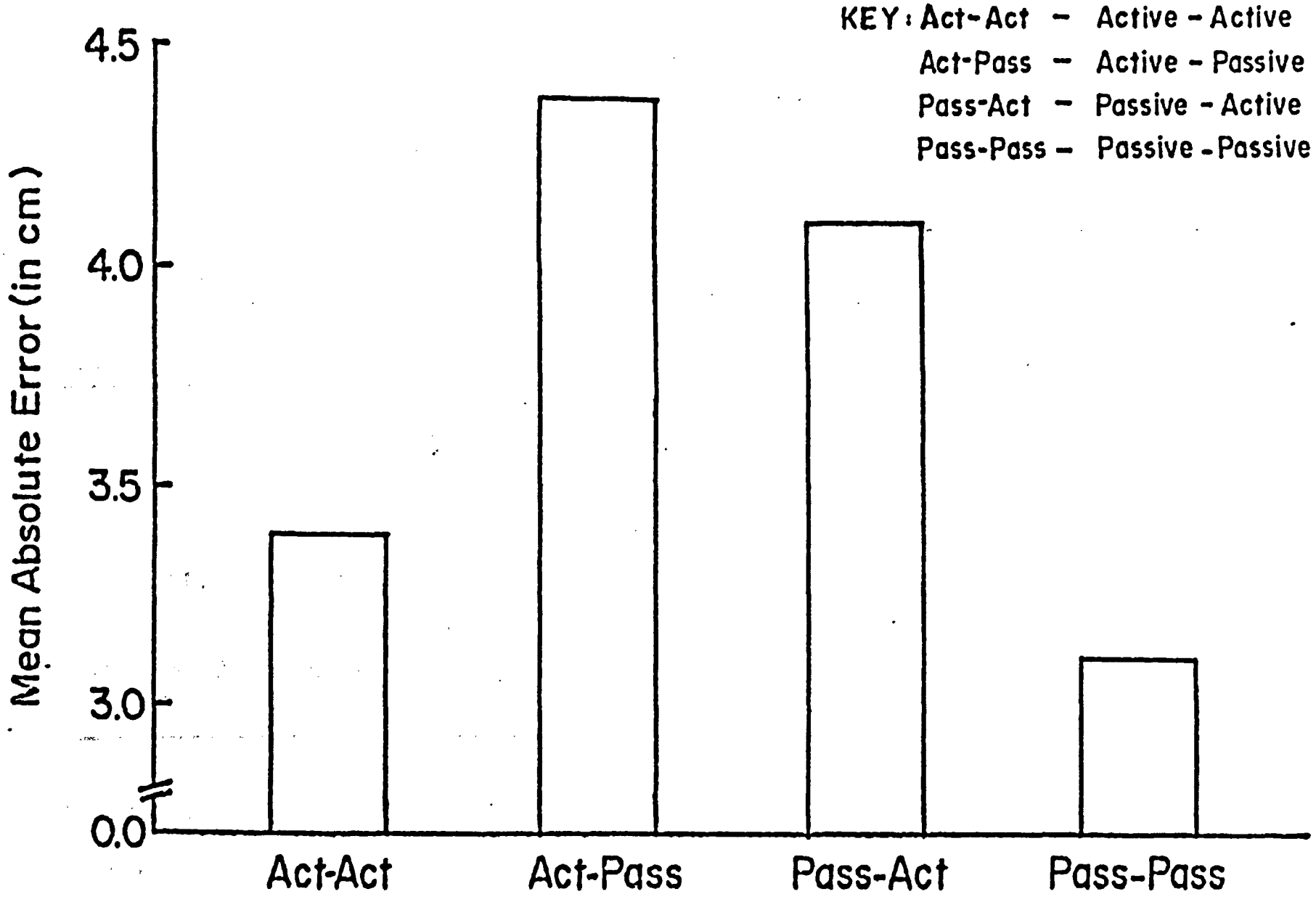


Figure 2. Mean absolute error for interaction of criterion movement and reproduction movement modes of execution.

Table 2

Analysis of Variance Summary Table for Constant Error Data

Source	SS	df	MS	F
Between Subjects	375.11	23		
A (Cueing)	32.67	2	16.34	1.00
Subjects within groups	342.44	21	16.31	
Within Subjects	432.01	72		
B (Criterion mode of execution)	86.26	1	86.26	38.51 **
AB	7.00	2	3.50	1.56
B x subj. w. groups	46.95	21	2.24	
C (Reproduction mode of execution)	129.97	1	129.97	26.74 **
AC	13.01	2	6.51	1.34
C x subj. w. groups	102.12	21	4.86	
BC	0.42	1	0.42	0.29
ABC	15.92	2	7.96	5.49 *
BC x subj. w. groups	30.36	21	1.45	

* $p < .01$

** $p < .001$

significant.

A Duncan's analysis revealed that for the main effect of criterion movement mode of execution, active presentations were overshot (mean of 0.97 cm) while passive presentations were undershot (mean of -0.93 cm). Concerning the reproduction movement mode of execution, active retrievals were undershot (mean of -1.14 cm) and passive retrievals were overshot (mean of 1.19 cm). Post-hoc analysis of the triple interaction between cueing, criterion movement mode of execution, and reproduction movement mode of execution is presented in Appendix D.

Variable Error (VE)

Analysis of variance for VE is summarized in Table 3. Main effects of cueing, $F(2,21) = 0.50$, $p > .05$, criterion movement mode of execution, $F(1,21) = 1.52$, $p > .05$, and reproduction movement mode of execution, $F(1,21) = 0.03$, $p > .05$, were not significant. An interaction between criterion movement mode of execution and reproduction movement mode of execution was significant, $F(1,21) = 9.44$, $p < .01$. All other interactions failed to reach significance levels.

A Duncan's post-hoc analysis was performed on the interaction between criterion movement mode of execution and reproduction movement mode of execution. As illustrated in Figure 3, the Passive-Passive condition (mean of 3.18

Table 3

Analysis of Variance Summary Table for Variable Error Data

Source	SS	df	MS	F
Between Subjects	44.91	23		
A (Cueing)	2.05	2	1.03	0.50
Subjects within groups	42.86	21	2.04	
Within Subjects	75.38	72		
B (Criterion mode of execution)	1.32	1	1.32	1.52
AB	3.22	2	1.61	1.85
B x subj. w. groups	18.31	21	0.87	
C (Reproduction mode of execution)	0.03	1	0.03	0.03
AC	1.45	2	0.73	0.80
C x subj. w. groups	19.12	21	0.91	
BC	9.72	1	9.72	9.44 *
ABC	0.58	2	0.29	0.28
BC x subj. w. groups	21.63	21	1.03	

* $p < .01$

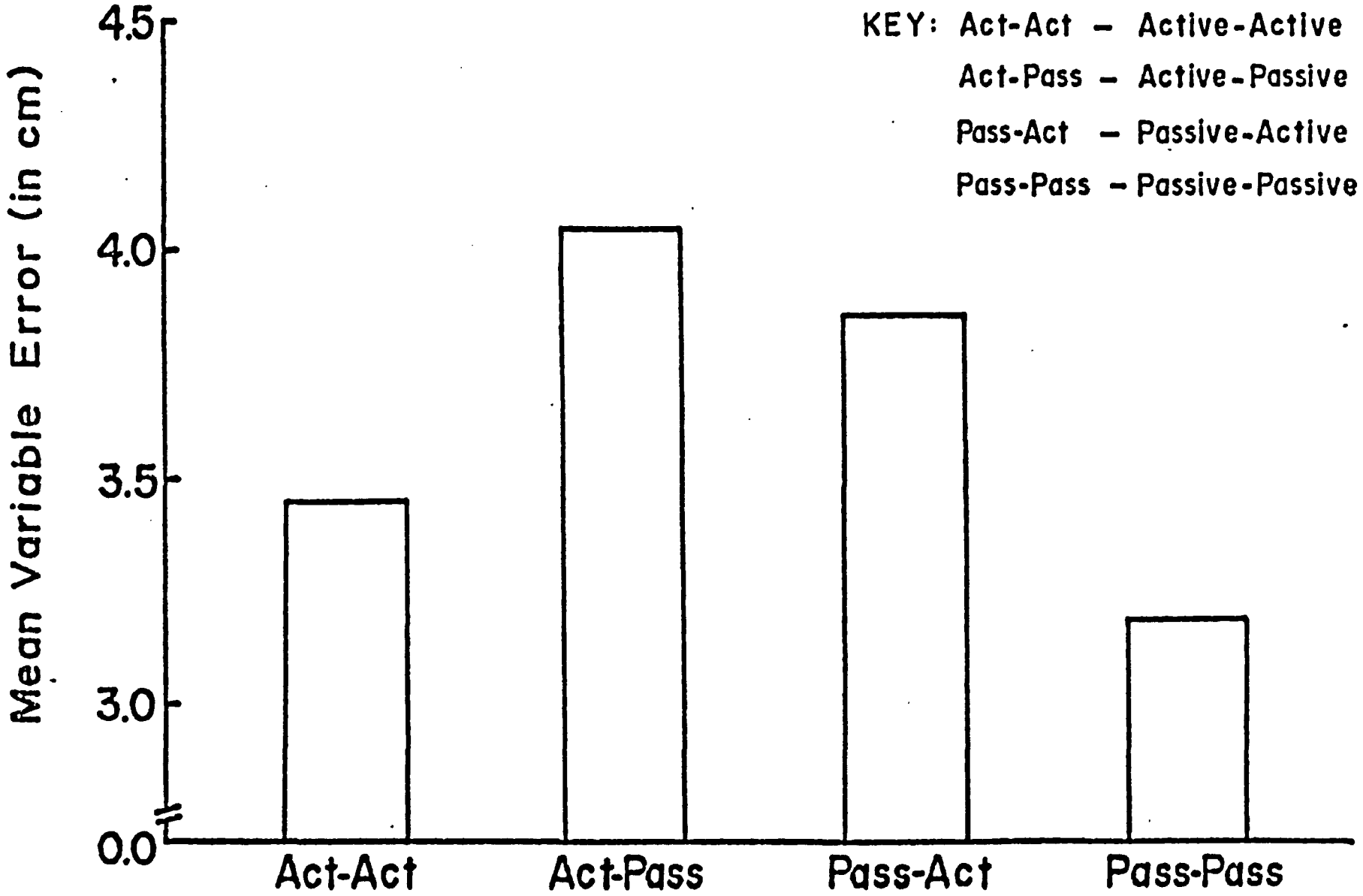


Figure 3. Mean variable error for interaction of criterion movement and reproduction movement modes of execution.

cm) was performed with significantly less variability than the Passive-Active condition (mean of 3.85 cm) and the Active-Passive condition (mean Of 4.05 cm). Consistency in responding during the Active-Active condition (mean of 3.45 cm) was not significantly different from any of the other conditions. The Active-Passive and Passive-Active conditions also were not significantly different.

CHAPTER IV
DISCUSSION

Many theories and paradigms commonly reported in the verbal literature have been utilized by researchers in the psychomotor area (e.g. Hall, 1978; Ho & Shea, 1978; Leavitt, Lee, & Romanow, 1979; Magill & Dowell, 1977). The present study adopted another concept from verbal learning, the encoding specificity principle, to base predictions about relationships between encoding and retrieval operations in memory for movement information. Previous research concerning the role of active and passive movements have emphasized the importance of encoding on memory without regard for the possible importance of the effects of retrieval conditions. Indeed, the encoding specificity principle would suggest that investigation of the congruency between encoding and retrieval operations would yield a more accurate account of the overall view of memory and the processing of movement information.

Providing information about retrieval conditions might be expected also to alter the way in which humans encode or process encoded information. The functional relationship between encoding and retrieval may be understood then, as a consequence of task expectations.

The results of the present study confirmed the hypothesis based upon the encoding specificity principle for retrieval accuracy (i.e. AE) and partially confirmed the prediction (only the Passive-Passive condition was better than the "different" conditions) for performance consistency (i.e. VE). The expected findings for the effects of cueing were not obtained. Furthermore, the predicted interaction between cueing and the encoding specificity principle also was not supported.

The main effect for criterion movement mode of execution (encoding hypothesis) and the main effect for reproduction movement mode of execution (retrieval hypothesis) observed for performance bias (i.e. CE) in the present study was not expected. Indeed, previous findings for performance biasing effects of active and passive movements are highly inconsistent (c.f. Marteniuk, 1973; Nadeau & Lortie, 1978; Roy, 1978). The main effects as well as the triple interaction observed for performance bias have no clear theoretical basis and provide for no meaningful comparisons at this time.

Cueing

The hypothesized effects of the point of cueing that were expected in the present study were not obtained. The failure of subjects to retrieve stored information based upon the sensory consequences that were expected

at retrieval is, however not without theoretical importance.

Hall and Leavitt (1977) suggested that within a certain level of processing there is elaboration of the sensory consequences of a movement. If active and passive movements are subject to elaboration then the facilitory effects of cueing should have allowed the subject to elaborate the encoded material to varying degrees depending upon the expected mode of movement execution at retrieval and the point at which the cue was presented. The results of the present study provide no evidence to indicate that the point of cueing differentially affects directive and/or effective elaboration of active and passive movements.

An experiment (published after the completion of the present study) by Newell, Shapiro, and Carlton (1979) provided subjects with cues about the mode of retrieval in an experiment where visual and kinesthetic modalities were manipulated at input and output. Similar to the present study, Newell et al. provided information either before the criterion movement presentation, after presentation but before a 10 sec retention interval, and after the retention interval. The results of the present study were congruent with the Newell et al. findings: there was no facilitory effect of the point of cueing. Contrary to findings along other lines of motor research

(c.f. Hagman & Francis, 1975; Wilberg & Hall, 1976) these results imply that prior knowledge of the conditions under which the to-be-remembered movement will be retrieved does not provide for any improvement in retrieval accuracy.

The most surprising result of the present study was the poor retrieval accuracy of the group which received information about the mode of retrieval immediately after the criterion movement but before the retention interval. Intuitively, it seems unlikely that the information provided by the cue produced this finding. A more plausible expanation would be that the verbal cue from the experimenter served to divert attention from the information provided by the movement. Considering that the cue was presented to the subject immediately upon contact of the stop defining the end of the criterion movement it is possible that the presentation of the cue disrupted the normal encoding and/or storage processes. The poor retrieval accuracy of the group receiving the cue after the criterion movement but before the retention interval must be considered tentative however, with regards to the Newell et al. (1979) study which showed that all three cueing groups were equal in retrieval accuracy.

Encoding Specificity Principle

The results of the present study both support and extend previous findings concerning the encoding speci-

ficity principle for active and passive movements. Lee and Hirota (1979) found that retrieval accuracy of actively and passively constrained movement presentations followed the predictions based upon the encoding specificity principle (Tulving & Thomson, 1973). The present study not only replicated these findings but also provided partial support for the encoding specificity principle for performance consistency as well. In addition, the superiority of movement retrieval in the same mode of execution as the criterion movement was maintained regardless of the point at which information of the retrieval mode was made available.

The applicability of the encoding specificity principle may also be extended to research in other aspects of psychomotor behavior. Investigation of the modality effects of movement information typically employs a research paradigm in which presentation of movement information is in one modality (e.g. visual or kinesthetic) and then retrieval is either in the same modality (intramodal transfer) or the other modality (intermodal transfer). The consistent finding in the literature is that intramodal transfer of movement information is retrieved more accurately than intermodal transfer (Diewert & Stelmach, 1977; Kelso & Frekany, 1978; Newell, Shapiro, & Carlton, 1979). Even though visual input dominates attention when presented simultaneously with

other modalities (see Posner, Nissen, & Klein, 1976 for a review), researchers have concluded that "if vision is to be useful it must be available for both presentation and reproduction movements" (Kelso & Frekany, 1978, p. 154). Restated, these findings show that the conditions at encoding (i.e. the modality of presentation) must be available at retrieval for optimal performance accuracy.

Wallace (1977) examined motor short-term memory under conditions where the direction of movement retrieval and the limb used to retrieve the criterion movement were manipulated. Once again, the results showed that if the encoded conditions were present at retrieval (i.e. same limb or same direction) performance accuracy was better than when the conditions at encoding were different during retrieval.

Recognition and Recall

Support for the encoding specificity principle was accumulated by Tulving and his associates on the basis of experimental evidence involving two types of retrieval operations for verbal material, recognition and recall. Evidence prior to Tulving's discoveries concerning the differences between recognition and recall was best expressed in terms of the dual-process hypothesis (Anderson & Bower, 1972; Kintsch, 1970). In summary, the dual-process hypothesis:

> assumes that recall includes recognition as a subprocess. You should remember that our previously described theory of recall includes the process of search (following pathways in LTM and finding items), and decision (deciding whether or not those items are appropriate to report). The dual-process model accepts this sequence of events as a model for recall, and further suggests that recognition corresponds to the decision process. That is, it suggests that recall includes search and recognition. The decision stage of recall is assumed to involve the same processes as are involved in recognition, the processes described by signal detection theory. Thus, we see that recognition is essentially recall with the search processes removed. (Klatsky, 1975, pp. 216-217)

The underlying assumption of the dual-process theory is that recognition is necessarily equal or superior to recall in proportion of presented items retrieved. Support for the encoding specificity principle was obtained with the discovery of recognition failure -- the failure to recognize items that had previously been recalled (Tulving & Thomson, 1973).

Motor Recognition and Recall

Retrieval of information involving the processes of recognition and recall has also been examined for motor behavior (e.g. Newell & Chew, 1974; Schmidt, Christenson, & Rogers, 1975; Williams, 1978). A recent study by Kelso (1978) provided evidence suggesting that passive movements in retrieval of movement information involves a recognition component whereas active movements in retrieval reflect recall. Kelso found that the removal of performance feedback (KR withdrawl) following response acquisition

in a linear positioning task resulted in a rapid decline in retrieval accuracy of the active response mode group in contrast to the relatively stable maintenance of performance of the passive response mode group. The superiority of the passive (recognition) over the active (recall) group was discussed as being congruent with the dual-process hypothesis of verbal learning.

Adopting Kelso's (1978) suggestion (passive retrieval reflecting recognition; active retrieval reflecting recall) the present findings concur with reports in the verbal literature (e.g. Bartling & Thompson, 1977; Rabinowitz, Mandler, & Barsalou, 1977; Tulving & Watkins, 1977; Watkins & Tulving, 1975; Wiseman & Tulving, 1976) concerning the cases where recognition is poorer than recall (i.e. recognition failure). In the present experiment appropriate examination of recognition failure would be a comparison of the Active-Active condition (i.e. recall of actively presented movements) and the Active-Passive condition (i.e. recognition of actively presented movements). The superior retrieval accuracy of recall (i.e. in the Active-Active condition) over recognition (i.e. in the Active-Passive condition) observed in the present study may thus be considered evidence for motor recognition failure. Caution concerning motor recognition failure is advised however until

further evidence is accumulated in regards to active and passive retrievals reflecting recall and recognition, respectively.

CHAPTER V

CONCLUSIONS

The study of human memory in previous years has typically focused upon (among other processes) the independent effects of encoding and retrieval operations. Recently, Tulving (1979) criticized this approach and suggested three central ideas which should be considered when conducting research on human memory:

> (a) the necessity of stipulating both encoding and retrieval conditions when describing data or making theoretical inferences from them; (b) the futility of trying to understand processes of remembering, either in general or in any specific situation, in terms of only the encoding or storage processes or only in terms of retrieval processes; and (c) the pivotal role played by phenomenon demonstrating interactions between encoding and retrieval conditions in shaping theoretical ideas about memory (pp. 408-409)

The results of the present experiment and of a previous study (Lee & Hirota, 1979) support Tulving's suggestions and should be given careful consideration by researchers in the area of motor memory. It is further suggested that an appropriate examination of the relationship between encoding and retrieval conditions involves the manipulation of variables that alter this relationship. The present experiment found no evidence to suggest that cueing affects the interaction between encoding and retrieval

in memory for movement extent. Future research may be focused upon such variables as attention, proactive and retroactive interference, range effects, repetition effects, organization, and developmental differences on the encoding/retrieval relationship in motor memory.

APPENDIX A

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS

START*	GROUP		
	PRE-CM	PRE-RI	PRE-RM
Subject 1	Pass-Pass	Act-Act	Act-Act
	Act-Act	Pass-Pass	Pass-Pass
	Pass-Act	Act-Act	Pass-Pass
	Act-Pass	Act-Pass	Act-Act
Subject 2	Act-Act	Act-Pass	Act-Act
	Pass-Pass	Act-Pass	Pass-Pass
	Pass-Act	Pass-Act	Pass-Pass
	Pass-Act	Pass-Act	Pass-Act
Subject 3	Act-Act	Act-Act	Pass-Pass
	Pass-Pass	Act-Pass	Act-Act
	Act-Act	Pass-Pass	Pass-Act
	Act-Act	Act-Pass	Act-Pass
Subject 4	Act-Pass	Act-Act	Pass-Pass
	Pass-Pass	Pass-Act	Act-Act
	Pass-Act	Act-Act	Act-Act
	Act-Pass	Pass-Act	Pass-Pass
Subject 5	Act-Pass	Pass-Act	Pass-Act
	Pass-Pass	Pass-Act	Act-Act
	Act-Act	Pass-Pass	Act-Pass
	Act-Pass	Act-Act	Act-Pass
Subject 6	Pass-Pass	Act-Pass	Pass-Pass
	Act-Pass	Pass-Act	Act-Act
	Pass-Pass	Pass-Pass	Act-Pass
	Act-Act	Pass-Pass	Act-Pass
Subject 7	Pass-Act	Pass-Act	Act-Pass
	Act-Pass	Act-Act	Pass-Act
	Act-Act	Act-Pass	Pass-Act
	Pass-Act	Pass-Pass	Pass-Act
Subject 8	Act-Pass	Act-Act	Pass-Act
	Pass-Act	Pass-Pass	Pass-Act
	Pass-Act	Act-Pass	Act-Pass
	Pass-Pass	Pass-Pass	Act-Pass

* Trial at which subjects in each group began the presentation order of experimental conditions.

APPENDIX B

INSTRUCTIONS TO SUBJECTS

The present experiment will examine how well you remember non-visual, movement information. The task involves movement along a linear slide between two stops. The experiment is divided into two phases. During the pretest you will be acquainted with the apparatus and the experimental conditions. In one condition you will grasp the carriage handle with the thumb and index finger of your right hand and actively move the apparatus from right to left. This will be called active movement. In the other condition you will lightly place two fingertips on the handle, totally relaxing your arm and hand, and the carriage will be moved for you. This will be called passive movement.

In the test phase one trial will consist of two movements. The first move, called the criterion movement will require an active or a passive movement starting on your right and moving left until a stop is contacted. Following the criterion movement there will be a short delay during which you are required to mentally rehearse the criterion movement. Following the delay you will attempt to reproduce the same distance as the criterion movement. The reproduction movement will be made either actively or passively. If the reproduction movement is passive, you will lightly place two fingertips on the handle, the carriage will be moved by me, and you must say stop when you think your hand has travelled through the same distance as the

criterion movement. Do not attempt to stop the slide yourself during passive reproduction. Merely say stop.

** Special Instructions **

PRE-CM Group: On each trial, before the criterion movement is made I will tell you the conditions under which you will make the criterion movement (i.e. active criterion or passive criterion) and the conditions under which you will make the reproduction movement (i.e. active reproduction or passive reproduction). Are there any questions?

PRE-RI Group: On each trial, before the criterion movement is made I will tell you the conditions under which you will make the criterion movement (i.e. active criterion or passive criterion). Immediately following the execution of the criterion movement but before the delay period I will tell you the condition under which you will make the reproduction movement (i.e. active reproduction or passive reproduction). Are there any questions?

PRE-RM Group: On each trial, before the criterion movement is made I will tell you the condition under which you will make the criterion movement (i.e. active criterion or passive criterion). Immediately following the delay period I will tell you the condition under which you will make the reproduction movement (i.e. active reproduction or passive reproduction). Are there any questions?

APPENDIX C

MEAN ERROR SCORES FOR EACH SUBJECT UNDER CRITERION MOVEMENT AND REPRODUCTION MOVEMENT INTERACTIONS

Table 4

Mean Absolute Error under Criterion Movement and Reproduction Movement Interactions

	ABSOLUTE ERROR			
CUE	ACT-ACT	ACT-PASS	PASS-PASS	PASS-ACT
PRE-CM	2.89	3.75	2.65	4.79
	3.81	3.93	2.55	4.80
	3.90	4.84	3.16	4.65
	3.36	3.70	1.65	2.95
	2.54	2.69	2.50	1.63
	2.28	3.96	3.56	2.51
	2.54	5.84	4.13	4.34
	3.16	3.24	3.23	3.74
PRE-RI	4.25	4.04	2.81	4.28
	3.74	8.26	4.56	2.89
	4.28	5.00	4.20	6.30
	3.66	5.29	2.89	4.58
	4.21	3.96	6.16	3.84
	3.01	4.29	3.20	4.31
	4.41	2.70	2.10	4.94
	3.21	7.19	4.64	3.43
PRE-RM	2.48	3.35	2.13	4.59
	3.24	3.65	2.33	2.71
	3.15	3.78	2.14	1.75
	3.05	3.15	2.06	5.94
	3.33	7.45	2.34	6.35
	4.29	2.89	2.31	3.31
	4.05	4.74	3.08	5.84
	2.40	3.26	4.09	4.03

Table 5

Mean Constant Error under Criterion Movement and Reproduction Movement Interactions

	CONSTANT ERROR			
CUE	ACT-ACT	ACT-PASS	PASS-PASS	PASS-ACT
PRE-CM	-0.94	3.58	2.23	-3.24
	3.64	2.40	1.90	0.80
	3.85	3.54	1.66	0.18
	-2.69	-1.78	-0.18	-2.95
	1.59	2.69	1.58	-0.65
	2.23	3.29	3.56	1.11
	-0.56	-1.71	0.80	-1.61
	0.74	-0.79	-1.60	-3.11
PRE-RI	-2.95	-3.29	-2.29	-4.28
	1.01	7.59	2.34	-2.89
	-3.83	2.20	-4.15	-6.30
	-1.96	5.29	0.59	-4.33
	-4.06	-3.89	-6.16	-2.46
	-1.89	2.84	-0.85	-2.91
	-0.96	2.03	0.25	-3.74
	1.89	7.19	3.76	1.48
PRE-RM	-0.63	2.73	0.30	-3.16
	1.09	2.68	-1.15	1.19
	1.30	1.15	2.09	0.78
	-2.55	1.23	-0.99	-5.94
	0.15	7.45	-0.51	0.00
	3.44	2.89	-0.09	-0.04
	-4.03	2.84	-0.48	-5.21
	-0.13	0.74	1.49	-1.28

Table 6

Mean Variable Error under Criterion Movement and Reproduction Movement Interactions

	VARIABLE ERROR			
CUE	ACT-ACT	ACT-PASS	PASS-PASS	PASS-ACT
PRE-CM	3.38	2.01	3.71	3.82
	2.43	3.91	2.71	5.59
	3.34	4.15	4.01	5.81
	3.63	3.86	2.41	2.35
	3.16	0.99	2.64	2.12
	2.59	2.59	2.75	3.01
	3.65	7.00	4.46	5.84
	3.71	4.49	3.54	3.56
PRE-RI	3.85	4.58	2.54	2.10
	4.29	6.20	5.30	2.76
	3.35	5.82	3.87	3.92
	3.89	2.88	3.33	3.58
	3.19	3.29	2.97	4.10
	3.30	5.66	3.38	3.90
	5.06	3.60	2.25	4.26
	3.26	4.62	3.59	4.08
PRE-RM	2.83	2.84	2.46	4.29
	3.97	3.26	2.62	2.87
	4.09	4.78	2.00	1.86
	2.78	3.92	2.13	2.80
	3.80	4.81	2.96	7.35
	3.24	2.31	2.93	3.81
	2.71	5.28	3.45	4.23
	3.21	4.32	4.26	4.35

APPENDIX D

POST-HOC COMPARISONS OF SIGNIFICANT MAIN AND INTERACTION EFFECTS FOR CUEING, CRITERION MOVEMENT AND REPRODUCTION MOVEMENT CONDITIONS USING DUNCAN'S PROCEDURE

Table 7

Duncan's Analysis of the Main Effect of Cueing for Absolute Error

	PRE-CM	PRE-RM	PRE-RI
PRE-CM ($\bar{x}$=3.41cm)	----	Q=0.57	Q=3.74*
PRE-RM ($\bar{x}$=3.54cm)	----	----	Q=3.17*
PRE-RI ($\bar{x}$=4.27cm)	----	----	----

critical Q(21 df), k=2 = 2.95
k=3 = 3.10

* $p < .05$

Table 8

Duncan's Analysis of Interaction Effect between Criterion Movement and Reproduction Movement Modes of Execution for Absolute Error

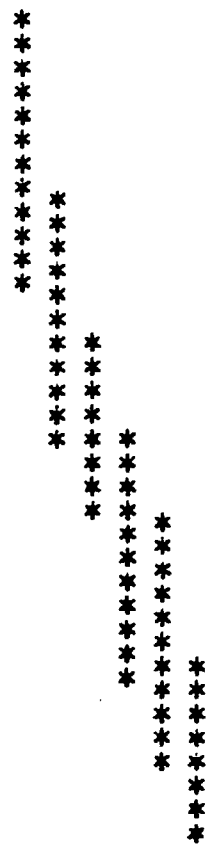
	Pass-Pass	Act-Act	Pass-Act	Act-Pass
Pass-Pass ($\bar{x}$=3.10cm)	-----	Q=1.32	Q=4.55*	Q=5.77*
Act-Act ($\bar{x}$=3.39cm)	-----	-----	Q=3.23*	Q=4.45*
Pass-Act ($\bar{x}$=4.10cm)	-----	-----	-----	Q=1.23
Act-Pass ($\bar{x}$=4.37cm)	-----	-----	-----	-----

critical Q(21 df), k=2 = 2.95
k=3 = 3.10
k=4 = 3.25

* $p < .05$

Table 9

Duncan's Analysis of the Interaction Effect between Cueing, Criterion Movement and Reproduction Movement Modes of Execution for Constant Error



	Mean CE
PRE-RI/Pass-Act	-3.18 cm
PRE-RM/Pass-Act	-1.71 cm
PRE-RI/Act-Act	-1.59 cm
PRE-CM/Pass-Act	-1.18 cm
PRE-RI/Pass-Pass	-0.81 cm
PRE-RM/Act-Act	-0.17 cm
PRE-RM/Pass-Pass	0.08 cm
PRE-CM/Act-Act	0.98 cm
PRE-CM/Pass-Pass	1.24 cm
PRE-CM/Act-Pass	1.40 cm
PRE-RI/Act-Pass	2.50 cm
PRE-RM/Act-Pass	2.70 cm

- ANOVA $MS_e = 1.45$
- all pairwise interactions not connected by a vertical line are significant at $p < .05$

Table 10

Duncan's Analysis of Interaction Effect between Criterion Movement and Reproduction Movement Modes of Execution, for Variable Error

	Pass-Pass	Act-Act	Pass-Act	Act-Pass
Pass-Pass ($\bar{x}$=3.18cm)	-----	Q=1.29	Q=3.19*	Q=4.14*
Act-Act ($\bar{x}$=3.45cm)	-----	-----	Q=1.90	Q=2.86
Pass-Act ($\bar{x}$=3.85cm)	-----	-----	-----	Q=0.95
Act-Pass ($\bar{x}$=4.05cm)	-----	-----	-----	-----

critical Q(21 df), k=2 = 2.95
k=3 = 3.10
k=4 = 3.18

*p .05

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