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RECALL AND RECOGNITION OF MOVEMENT ATTRIBUTES FROM MOTOR SHORT TERM MEMORY

by

© GERALDINE HAMILTON TANNIS

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled RECALL AND RECOGNITION OF MOVEMENT ATTRIBUTES FROM MOTOR SHORT TERM MEMORY submitted by Geraldine Hamilton Tannis in partial fulfilment of the requirements for the degree of Doctor of Philosophy

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ABSTRACT

The purpose of the present research was to investigate within the constraints of a recall and a speeded recognition paradigm the functional nature of the encoded information in a movement stimulus. The two attributes of concern in the movement were location and distance. In Experiment I, the S was required to produce a linear movement stimulus consisting of a start location, a distance and an end location. The S was then presented with a probe set consisting of one two or three of these attributes and was to respond as to whether the probe attributes were the same or different from the stimulus attributes. The subjects received a directive pre or post stimulus input cue regarding the to-be-remembered items. Recognition of location information resulted in shorter reaction times and lower error scores than those produced in recognition of distance. Recognition of distance information when location also appeared in the probe set showed reduced RT's and increased accuracy as opposed to the condition wherein distance was recognized in isolation.

In Experiment II, a recall paradigm was used with the same multiple attribute input (location and distance) and cue techniques as Experiment I. For all three independant variables (constant, absolute and variable error) location recall resulted in lower error scores than those for distance recall. Distance recall improved only when a

location attribute was one of the to-be-recalled set. Location information, both start point and end point, emerges as reliable attributes for both recall and recognition. The indication is that location information is available to a deeper level of encoding than distance information. It is probable that location is an integral part of the functional stimulus for a linear movement task. Distance information because of its primary encoded form appears to be integrated with location information for storage and has little effect on the functional form of the movement stimulus.

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INTRODUCTION

Fitts (1953) has stated that the problem of optimum coding is central to any study of the information transmission capacity of a system. However, due to a dearth of studies dealing directly with coding of information from a motor task, relatively little can be said about the nature of coded motor information. Consequently little is known regarding the relevant attributes of a movement stimulus which could facilitate learning and/or retrieval.

The coding process (Appendix A) as described by coding theory is not necessarily an inherent process in the human performer. However it is a feature of an information processing system which requires an interface between the environment and the system. This interface requires a mapping of the external stimulus on to an internal representation and hence a transformation or coding process. The assumption of the coding process must then be accepted if research is to be pursued on the nature of the internal representation of kinesthetic information (K) within an information processing model.

The coding process itself may be viewed as a transfer of information from a short term sensory store (STSS) to a short term store (STS) and a long term store (LTS) during which there are selected information processing transforms, (Atkinson and Shiffrin, 1968) the nature of which is indicated by:

(a) the nature of the input

(b) the constraints and demands of the memory operation (STM or LTM), and

(c) the output demands of the task.

Recently, several studies have attempted to use the coding concept to investigate motor short-term memory (Nacson, Jaeger and Gentile, 1972; Colby, 1974; Diewart, 1975; Hall and Leavitt, 1977). These studies have tackled the question of whether or not information from motor tasks is processed centrally.[1] The implication is that if K is centrally processed it will demand time and space in the processing sequence. Also it implies that the code used to form the stored internal representation of the information is handled by the central processing mechanisms (CNS) and not by a peripheral mechanism. However delineating the locus of the coding process does not define the nature of a motor code.

Until recently the major theoretical position regarding K is that this type of information is not represented centrally since K showed forgetting over an unfilled interval. Therefore K was not considered as viable information for motor recall, (Adams and Dijkstra, 1966; Posner and Konick, 1966; Wilberg, 1969; Keele, 1973). To

[1]The term "central processing" is used extensively in the MSTM literature (Marteniuk, 1973; Diewart, 1975) and implies a cognitive involvement in the handling of input information.

elaborate, Posner and Konick, (1966) and Posner, (1967a), suggested that K was not stored by an active process, such as verbal rehearsal, (hence no verbal code used) but was stored in some non-rehearsable form such as an image. This notion of an image in Sperling's (1963) terms is used to refer to an extremely brief and complete representation of the stimulus. Posner (1967a) suggested similarly that the coded information for K would contain all information not in the form of verbal labels. However, Posner further stated that it is a code containing information available in the task and not necessarily what the subject is subjectively experiencing or attending to. This implies that all the information available in the K array is not necessarily used by the subject. The nature of the nominal form of K information and the coded functional form as an internal representation may be radically different. Laabs (1971, 1973) found differential recall effects dependent on the type of movement attribute investigated. Specifically, he showed that distance information was spontaneously forgotten and that end location information was retained over an unfilled retention interval. Laabs (1975) suggested that these two types of movement information be treated separatel[illegible] [illegible] hey appeared to have different encoding and retention characteristics.

As a r[illegible]lt of these various findings there are several general hypotheses that could be made regarding the internal representation (code form) and processing of K information.

(a) K is not available for central processing because there is no short-term storage system for that type of information. Keele (1973) supports this view. He suggests that information that was first thought to be stored in STS, is in fact stored in a sensory register in what he calls a precategorial form. Further, the information is available for recall for a period of approximately 20 seconds. Keele (1973) rejects the notion of a motor short term memory process. This in fact negates the possibility of central encoding of movement information. The use of the sensory register as the only storage mechanism does not demand time and space in the central processing unit (CPU). This further implies that the code form for K is primary or perceptual in nature (Appendix A).

(b) The encoding process for K entails conservation of all information. This implies that a direct representation is formed for storage in STM. This view suggested by Posner (1967a) postulates a direct representation for the STM process analogous to a direct visual representation stored in a short-term sensory storage system (Sperling 1963; 1967). The nature of the coded information would be based on the physical characteristics of the movement and the encoding process would entail application of a physical code. Posner (1967a) terms this representation "a kinesthetic image... which might include spatial position and other detailed information which would not appear in a verbal description of the stimulus." (p.268). Therefore he negates the possibility of a semantic and/or conceptual code hich in turn limits the depth of processing available to the information.

(c) K information derived from a movement may be represented along several dimensions characterized by the attributes of distance, location, endpoint, direction, etc. Each of these attributes may have different encoding and retention characteristics. Some attributes may be available to deeper levels of encoding such as a conceptual or semantic encoding as opposed to a more superficial physical encoding (Appendix A). The quality of the encoded information may change dependent upon the attributes available for the subject to encode and the combination in which they appear. Laabs, (1971) and Marteniuk and Roy, (1972) found that certain cues, specifically location, were more reliable (i.e. better retained in STM) which may indicate a more optimal encoding process can be carried out on this type of material.

When considering these three hypotheses it should be noted that there is a range of strategies available to the S under the various experimental conditions. As Craik (1971) has noted, the best encoding processes are highly flexible ones and that the advantage of one encoding procedure over another may depend on the task demands and the salient features of the stimulus-as-presented. In other words, there is a distinct possibility that different types of coded information can be developed for the same stimulus event, with the assumption that a given encoding operation is optimal for the specific condition.

The Relationship Between Storage and Output

Examining the number of errors as a quantitative measure of recall performance in the STM process fails to provide any insight into the qualitative nature of the system malfunction (Schurr, 1973). Errors in recall from memory may be attributed to inaccurate perception, interference and/or loss while in storage as well as retrieval failure (Conrad, 1964; Wickelgren, 1965a). Examination of the types of input which result in an errorful performance in a STM task may provide some indication of the effects of mode and character of the memory system and retrieval.

It is assumed that in STM operations, encoding strategies or the use of an encoding process optimal for the task demands are employed. This assumption is supported by the results of Buschke's (1966, 1967) studies which suggest that recall demands influence the manner in which information is encoded for the STM operation. If his remarks are interpreted within the Atkinson and Shiffrin (1968) memory model, it would appear that the material stored in STS during rehearsal for short-term memory retention relates the input to the readout and response. Also the nature of the information to-be-stored appears to be partially dependent on the response demands of the task. Buschke (1968) further states that when output demands are not available to the performer, the encoding process adopted will be an optimizing one in which maximum information would be encoded to ensure effective retrieval and readout.

The assumption is that the STM operation is a rehearsal operation wherein there is a matching of information in the STS with information or stored abstractions in LTS (Craik and Lockhart, 1972). The matching results in elaboration of the information in STS which could possibly aid retention (Warren, 1972). This is in fact a type of elaborative encoding (Tulving and Madigan, 1970) and the extent of its use would most likely be affected by output demands. The effectiveness of such an encoding process would also be influenced by the type and amount of elaborative information available in LTS. The fidelity or degree of errorless reproduction of the input should reflect the robustness of the encoded information and subsequently the depth of processing that the information has undergone. Depth of encoding used in this sense implies a greater degree of semantic or cognitive analysis or encoding (Craik and Lockhart, 1972).

However, in this study, experimental variables which control depth of encoding with verbal stimuli are not used. Therefore conclusions about the depth of encoding of a movement attribute, based on this assumption, are tentative. Craik and Lockhart (1972) state that memory trace persistence is a function of the depth of encoding or analysis in that stronger more elaborate traces are associated with deeper levels of encoding. As Tulving (1970) has pointed out, higher order encodings should be available to the subjects after repeated presentations. This assumes that the nature of the information allows for a deeper level of processing. Presumably if no semantic or conceptual counterpart can be found for the information, the robustness of the encoded information will be depressed. An alternate strategy would be to create an analogous representation of the abstracted information. However the information takes on the embellishments of that analogy and may be manifested in retrieval by a less-than-perfect output representation of the output.

(A) Response Methods: Recall Versus Recognition

The dependent variables found in the motor memory literature are for the most part derived by a method of recall in which reproduction of the input (totally or in part) is required. In the recognition method the S must decide whether or not a given item or probe is a match with the the previously presented stimulus. As Underwood (1972) suggests, in the recall response instance, the S asks "What was the word?" whereas in recognition the question is "Is this that word?". Functionally the difference between the two methods is that recall necessitates operation of a retrieval mechanism. It is assumed that recognition eliminates the retrieval problem because the stimulus does not have to be accessed (Murdock, 1968). Underwood (1969) further states that attributes utilized in a recognition task may not correspond to those in a recall task. He distinguishes between discriminative attributes, responsible for recognition decisions, and retrieval attributes, functional during recall.

(i) Recognition

Few studies have been conducted investigating movement recognition (Marshall, 1972; Kantowitz, 1974; Newell and Chew, 1974; Newell and Boucher, 1974; Newell, 1975). None of these have collected recognition latency data but have reported on percentage errors, same-different judgements, (Kantowitz, 1974) and on an index of recognition (Newell and Chew, 1974). This index is difference between S's estimate of his movement performance and his actual movement performance. The purpose of these studies was to examine the motor [illegible]cognition process and to draw functional simil[illegible] [illegible] differences between the motor recognition proces[illegible] a[illegible] motor recall process. No attempt has been made to [illegible] [illegible]e techniques of a speeded-recognition paradig[illegible] to [illegible]gat[illegible] the [illegible]ture of stored K information.

In a speeded recognition paradigm (Sternberg, 1966) the subject must classify a probe stimulus into either a positive or negative category based on whether the probe stimulus is the same as the previously presented stimulus or is a member of a previously presented array. The subject is encouraged to make his response as fast and as accurately as possible. The purpose of this paradigm is to produce an almost error free performance under speeded response conditions such that conclusions can be drawn on the time needed to respond rather than the failure to respond correctly (Sternberg, 1975).

The major assumptions of the method are:

1. reaction time (RT) or the elapsed time between the offset of the stimulus and the onset of the response is occupied by a series of successive stages whose additive durations determine the length of RT.
2. the stages are stochastically independent.

If the stages are independent and if a factor is used experimentally which affects only one stage of the multi-stage model then the effect on RT will be independent and additive since the stages are independent and additive.

The four stages which Sternberg (1969a) proposed are:

1) encoding stage: transformation of the stimulus into an internal representation of its identity. Factors primarily affecting this stage would be quality, detectabilty and intensity of the stimulus-

as-presented.

2) comparison stage: the probe item is alternatively compared against each item in the previously presented stimulus array. Assuming as Sternberg does that this stage is exhaustive, the major factor would be the size of the stimulus set.

3) Binary decision stage: the decision making stage (negative or positive) based on the results of the comparison stage.

4) Translation and response organization stage: the response is selected from the transmitted information into a motor output. The major factors influencing this stage would be the S-R compatibility and the proportion of positive/negative responses (i.e. if the probability of one were greater than the other, a response bias may be set up and by response expectancy reduce the duration of this stage).

The major concern in the present study is with the encoding stage and what the dependent variable (RT) may reveal about the nature of the encoding process. In the serial-exhaustive scan model[2], derived from speeded-recognition paradigm, Sternberg predicts no serial position difference for positive responses since the memory scan is exhaustive. In addition, comparison times on sameness and difference should be equal. However Forrin and Morin (1969) and Burrows and Okada (1971) both have shown that the RT for a positive response is shorter for an item appearing in the earlier part of the list. Also, Posner et al. (1969) and Nickerson (1973) found a comparison with a matched test item faster than a no-match comparison.

These discrepancies in the Sternberg model have led other researchers to propose modifications (Burrows and Okada, (1971); Theios, (1973); Juola, Taylor and Young, (1974)), which relate mainly to the encoding stage. Burrows and Okada (1971) in an attempt to account for the serial position effect proposed a "two-state model of accessibility". The state of accessibility, would determine whether the search in memory would be self-terminating or exhaustive. A low state of accessibility for an item could conceivably be a result of a lack of elaborative or associated information in LTS. There would then be a li..ted amount of information on which to make the decision. If ..e item had high accessibility value there should be adequate elaborative information upon which to make a judgement and the search would be self-terminating.

Atkinson and Juola (1973), Juola, Taylor and Young (1974), Mohs and Atkinson (1974) have proposed a model

[2]serial; because plotting RT against target set size, RT increased linearly and exhaustive; since the slopes of the RT functions were the same for both target and distractors (Sternberg, 1969a).

similar to the previous one. They assume the search is optimal with the subject employing a strategy similar to speed-accuracy tradeoff. Juola et al. (1974) suggest an encoding stage that includes an analysis of the test stimulus and construction of a functional stimulus which is unique to the form and modality of the input. They term this the perceptual code which is mapped in LTS in the appropriate location generating a conceptual code. This in turn generates a familiarity index for the item based on a generalized activation level which could be interpreted as the number of associations for that stimulus. The familiarity index (FI) generated will determine the extensiveness of the search. A subjective criterion is set such that if the FI is high (positive match) or low (negative match) the response is initiated without a search of memory set. If however the FI value falls between the two criterion levels, then a scan of the memory set is initiated. The properties of the decision based on the FI are an increase in error rates but a decrease in decision time. The reverse holds for decisions based on extended search. This model would suggest that information not available for semantic or conceptual coding may in fact always require a longer memory scan. The assumption in the present study is that by comparison of RT's of the different movement attributes it may be possible to speculate on the type of coding available to the individual attributes. In support of this view Craik and Lockhart (1972) considered the differential rate of forgetting as a function of depth of encoding. That is, the persistence of the memory traces is a function of the depth of perceptual analysis or stimulus elaboration, with deeper levels of processing (e.g. semantic) associated with more elaborate, longer lasting, and stronger traces.

Presumably the recognition of items encoded on a deeper level and with stronger traces in memory would be faster and more accurate than the recognition of items with more superficial encoding properties. Craik and Lockhart (1972) suggest two levels of processing:

(a) Type I processing by which the items in primary memory are rehearsed at the same level at which they were initially encoded. This process of rehearsal would lead to a rapid decay as soon as attention would be directed to other items.

(b) Type II processing would involve deeper analysis of the stimulus as for example, encoding according to some semantic attributes.

Therefore the speeded recognition paradigm should produce RT's which are reflective of the types of encoding processes carried out on the movement information. With the assumption that the experimental factors manipulated only affect the encoding stage, variation in the RT may indicate:

1) type of coding available for the information and

2) whether certain attributes of a movement stimulus enhance or detract from the legibility or quality of

the information available for encoding.

It should be noted that the mode of operation in the comparison stage will influence the mode of operation of the encoding stage (Smith, 1968). Sternberg (1967) hypothesized that initially in the encoding stage there is a process of filtering and/or normalizing of the nominal stimulus. This results in a refined representation of the input (a stimulus selection process). Therefore as Girouard (1974) suggested, if the memory representation of the test item is also a template of the stimulus, then the comparison operation is in the form of template matching. If the memory representation is in the form of a refined image, then the comparision operation would be in the form of feature testing. Finally, if both the stimulus representation and the memory representation are in the form of a feature list, then the resulting operation of the comparison stage might take the form of a feature-list matching. Therefore whether template-matching, feature-testing, or feature-list matching takes place during the comparison stage will influence the encoding processes of either the formation of a feature-list or a refined image.

Smith (1968) indicated that template matching may be used in the instance of unanalyzable (poorly organized, poor legibility) or very infrequent stimuli. Again, task demands may control the selection of process.

(ii) Recall

The reproduction or recall paradigm has been extensively used in the motor STM literature (Appendix B). Several researchers have used the paradigm specifically to look at the difference in retention characteristics between distance and location cues (Posner, 1967b; Marteniuk and Roy, 1972; Marteniuk et al., 1972; Keele and Ells, 1972; Laabs, 1973; 1974; 1975).

Marteniuk and Roy (1972), Marteniuk et al., (1972) and Marteniuk (1973) found that when location or distance plus location was available to the S, the recall performance was superior to the condition in which distance alone was the primary cue. Furthermore, Marteniuk (1973) found that active movement produced better recall than passive involvement in the movement to be reproduced. He concluded that all movement attributes had access to the central processing capacity, since forgetting did not occur until rehearsal was blocked by the introduction of an interpolated task. However each attribute was centrally represented in different degrees of exactness.

Laabs (1973), using an E controlled movement, obtained results which showed that distance information decays rapidly over time while location information does not. Furthermore, when a verbal IT was presented, interference effects were found on the retention of the location information but there was little effect on distance information over and above that of a decay effect. Thus, all attributes do not seem to show exactly the same retention characteristics. This may indicate that the form of the encoded information in memory is also different. Location information appears to be more stable than distance information which would be in agreement with Marteniuk and Ryan's (1972) findings from psychophysical data. In this study, judgements by the Ss seem to be made through the use of the positional attribute rather than through the use of the amplitude (distance) attribute.

These results indicate that the Ss do not attend in an undiscriminating fashion to all K information that is presented to them. The Ss seem to be engaged in an active process of selecting and organizing the information which may be more useful, reliable or replicable. The Ss may even completely disregard some supplemental K that is provided by the experimentor (Wilberg, 1969). This is agreement with Underwood's (1963) nominal versus functional stimulus concept.

Conflicting evidence concerning codability of extent and location information indicates that the external nature of the movement attribute itself is not the only determining factor in the production of the encoded information.

Laabs (1973) re-examined the cues of extent and location studied by Posner (1967b). He examined the retention of these cues without vision over a 12 second retention interval which was either unfilled or filled with a backward counting task. The results indicated that after immediate reproduction, extent and location were equally well retained. Both showed forgetting over the 12 second interval when the retention interval was filled. However when the interval was unfilled, only the extent condition showed significant forgetting. These results suggested that the kinesthetic attributes of extent and location had different encoding properties. As forgetting occurred only for extent cues over an unfilled interval, Laab's study suggested that only extent attributes are not centrally coded.

As previously stated, Marteniuk (1973) concluded that both extent and location attributes were codable. Forgetting occurred for both attributes over a filled 20 second interval and no forgetting for either attribute was observed over a comparable unfilled interval. The conflicting findings of Laabs (1973) and Marteniuk (1973) regarding the central codability of kinesthetic extent information are enigmatic at first. However, closer examination of the methods used by these investigators suggests a reason for the discrepancy. Laabs (1973), in presenting the criterion (C), had the S move a slide with his arm between two metal stops thus defining the C for the S. Marteniuk (1973), on the other hand, had S make his own C. S moved his arm through a total distance (T) and back. He was then told to move a distance which was some fraction of T, (this movement represented the C). He was then required to reproduce either the end location or the extent of C from a new starting location. The fundamental difference between the two conditions was whether E or S determined C . When S determined his own C it would appear that extent information was codable (Marteniuk, 1973) while when C was prescribed to S by E, extent information was not codable (Laabs, 1973).

The results of a study by Jones (1974b) provides support for the previous observations. Jones examined the retention of the extent attributes under three modes of C presentation: passive, constrained and active. In the passive and constrained conditions, stops were used to define C. In the passive condition, E moved S's arm between the two stops. In the constrained condition, S moved his own arm. In the active condition, no stops were used to define C rather S was instructed to make any movement he wished and this movement defined the criterion. In all conditions, the original starting position used for the C was changed and S reproduced the extent of C from the new starting location. These conditions were examined at a zero and 15 second retention interval which was either filled on unfilled. The results showed that the active condition resulted in significantly less forgetting than the other two conditions at immediate reproduction and after an unfilled 15 second interval. When the interval was filled however, all groups exhibited a similar degree of forgetting.

Clearly, it appears that when S is allowed to define his own criterion movement, (e.g. Marteniuk, 1973; Jones, 1974b), extent of movement is codable contrary to the evidence forwarded by Posner (1967b) and Laabs (1973). The question remains as to why extent of movement is codable only under these restricted conditions. It is possible that when S actively defines C, a more active process of encoding extent information occurs in that S is required to search for the extent of the C. In the constrained presentation, a more passive encoding process may ensue in which S relies on E to provide the extent information. This difference in encoding processes might be reflected in an increased attention demand for encoding in the active condition which may account for the better retention in this condition. Roy and Diewart (1975) indicated that a major difference in terms of encodability between the active and constrained conditions was the absence of strategy during the constrained condition. In the Jones' study (1974b) reproduction accuracy was comparable under both conditions when a strategy was given. They (Roy and Diewart, 1975) suggest that the codability of extent information is not related to whether E or S determines the C as Jones (1974b) suggested. Rather, codability seems to be related to whether the S has prior information about the to-be-remembered movement regardless whether he or the E determine its extent.

Further support of this notion is found in a study by Nacson, Jacqer and Gentile (1972). They found that strategies for grouping stimuli (i.e. responses to be recalled) was also an important aspect of motor STM. They also found that providing the S with instructional sets about a conceptual rule or plan describing the relationship among stimuli (organized into 5 distinct areas or categories) facilitated recall as evidenced by absolute error (AE) and constant error (CE). Furthermore, Ss who did not receive verbal instruction were found to generate their own subjective organization of the stimuli, as evidenced by their CE scores. The results indicated that they were using three categories as opposed to the five that were employed by the experimenters.

Although many studies have been done on motor STM (Appendix B) few have used a directed forgetting cue to bias the encoding process. In recall studies like the ones previously reviewed, the nature of the errors produced or what is forgotten, may indicate more than what is remembered. Bjork (1972) stated that the fidelity of retrieval is affected by the state of the encoded information.

As previously stated, the process of maintaining the information in STM could be regarded as an optional encoding process. Active rehearsal may entail application of information gleaned from LTS to increase the ease of information in STS. The information in STS would most likely be encoded in a form with optimal maintenance quality. This view of a STM is compatible with Waugh and Norman's (1965) primary or working memory in which information is consciously given further organization by incorporation of new information into the structure.

Buschke (1968) stated that encoding strategies were partially dependent on task demands. The inference could be made that encoding for recall would necessitate conservation of all information. That information which is unanalyzable or of poor quality (Sternberg 1969a) should not be as reproducible or show as high a transmission rate at recall as that information available for deeper encoding. Partial recall may indicate on what dimensions the subject is encoding, especially if the stimulus consists of several integrated attributes. If the functional stimulus or stimulus-as-encoded is a representation, it may only contain certain aspects of the integrated stimulus which lend themselves to ease of coding and storage and from which the total input could be reproduced. Recall of any aspect in isolation not contained in the functional stimulus should lead to depressed recall performance.

If a motor recall task is carried out under the condition of directed forgetting, the result errors may indicate the attribute(s) used in the formation of a functional stimulus in the encoding of an integrated movement stimulus.

(B) Cue Effects

The exact nature of the coded information cannot be answered by observation of the products of a response alone. Tulving (1968) concluded that there is a great deal more information available in memory but not accessible for retrieval and that accessibility of relevant information depends not only on the content of the store but also on the retrieval cues. Therefore, investigation of cue effects may in fact reveal the information available from the STSS that is encoded in STM, and in what form.

The cue can be regarded in two ways:

(a) as an instruction such as a cue to attend to certain elements within a stimulus array. This cue is usually varied temporally (i.e. before stimulus presentation or after stimulus presentation).

(b) as a functional part of the stimulus array.

Generally, from the experimenters point of view, one directs the other. That is, the directive cue should reduce the nominal element set to which the S has to attend and possibly limit the choice of a functional cue.

(i) Precuing versus Postcuing

In a study by Hinricks (1968), pre- and postcuing techniques were used to designate partial reports of a larger set of stimulus items. Better recall performance was gained under the precue condition. On examining the nature of the recall errors, he found no effect of cue position on the shape of the recall curve. It would appear that the precue biased the choice of what was to be rehearsed or encoded.

In the postcue condition, the subject may have had one of two choices of strategies:

(1) select aspects of, or parts of the stimulus set to ensure fidelity of reproduction for those particular items and either disregard or rehearse to a limited extent the rest of the set.

(2) encode the totality of the stimulus set, possibly accepting a poorly encoded product and tolerate a poorer reproduction fidelity.

In the Hinrichs (1968) study, it appears that the Ss chose the second of the two. This would seem to be the most optimal strategy if all items were equi-probable and had equal encoding potential. Hagman and Frances (1975) investigated the effect of precuing the S on the TBR movement. They crossed three precue instructions with two types of recall. There was equivalent recall performance between distance and location information when the precue contained the TBR item. When the precue did not contain the TBR item, recall performance decreased on TBR item but showed superior recall for the non-TBR item. This they concluded indicates that the coding process was biased by the precue. Similar results are found in directed-forgetting experiments. Numerous studies (Bjork, 1972; Epstein, 1972) indicate that forget instructions generally result in reduction or elimination of interference from the to-be-forgotten (TBF) items and increased recall performance for the TBR items, relative to a control condition in which the total stimulus set is retained. Homa and Spieker (1974) and

Howard (1976) showed similar trends for recognition performance with a decreased RT under the forget cue condition. Homa and Spieker (1974) suggested that on the basis of serial position data the S in the intentional forgetting task may engage in a serial self-terminating memory search of the TBR items alone. Howard (1976) found virtually no difference in RT between a forget during cue (precue) and a forget after cue (postcue), but showed by questionnaire that Ss who reported visual imagery or meaning association strategies used the after cue les fectively than those S's who did not report such strateg t has been found (Mandler, 1967; Tulving, 1966) that organizational strategies such as imagery and mean associations lead to very different properties of the resulting memory trace. Howard (1976) suggests that this type of integration would make it difficult to functionally segregate the TBR items and the TBF items when a post cue is given. According to Underwood's (1963) stimulus selection concept, the internal representation after a cue may only contain the functional elements of the stimulus.

In a precue condition the S is presented with all elements of the matrix (X') and is cued to specific aspects of that matrix (X II to X nn). In this situation the encoding strategy (ES) could be viewed as a function of precue instructions or in other words a stimulus selection bias by task demands. The decoding strategy (DS) or retrieval would be a function of the functional stimulus.

Precued Response = X'[ES f(precue)] [DS f(Xnn)]

In the postcue condition the encoding strategy may have to be a function of the total stimulus matrix. Retrieval would then be a function of the task demands as dictated by the postcue.

Postcued Response = X'[ES f(x')] [DS f(postcue)]

If the subject adopts a selective stimulus strategy (i.e. a reduction encoding process) and the directive postcue does not ask for those aspects of the stimulus, the response performance possibly may be poorer than if the Ss adopts a conservation encoding strategy. By analysis of recall and recognition performance under both conditions of cuing, the information encoded for the task demands may be delineated. This is assuming that efficiency of coding will be reflected in response fidelity.

(ii) Retrieval Cue Efficacy

Tulving and Pearlstone (1966) found that many items available in the memory store that cannot be recalled under noncued recall conditions do become accessible in the presence of appropriate retrieval cues. Subsequently Tulving and Osler (1968) provided experimental evidence in support of the encoding specificity hypothesis. This hypothesis states that no cue however strongly associated with the TBR item or otherwise related to it can be effective unless the TBR item is specifically encoded with respect to that cue at the time of its storage. The implication is that item A could be used as a retrieval tag for item B. In the present study the stimulus materials is actually a multi-component, integrated stimulus array consisting of two locations (start and end) and distance. It may be that part of the stimulus array acts as a retrieval cue for the remaining item(s). By cuing for recall or recognition of a single item before the stimulus presentation, the attributes may be encoded independent of one another. However if the cue appears after the stimulus, the array may be encoded as an integrated set. This experimentally imposed bias can only refer to the nominal stimulus.

Solso (1974) predicted that in the postcue condition, if functional stimulus selection was operating, cue selection would be a function of meaningfulness. Meaningfulness (M) is defined in the verbal literature as the number of associations that the stimulus elicits (Ellis, 1972). An increase in meaningfulness would imply an increase in encoding potential (Solso, 1974). When an S is presented with a multi-component stimulus composed of high and low meaningful terms, the S will tend to select the high M component as the functional stimulus and more or less disregard the low M component (Underwood, Ham and Ekstrand, 1962). The components of the functional stimulus are most likely the potential retrieval cues. Although their (Underwood et al., 1962) stimulus materials were multi-modality, there is not reason to assume that the same hypothesis would not hold for uni-modality compound stimuli. Subsequent studies (James and Greeno, 1967; Lockhart, 1968, Solso, 1968, 1971, 1972) support the notion that meaningfulness is an outstanding factor in stimulus selection. Solso (1974) concludes that higher M stimulus have a greater probability of being selected as functional stimuli. He further states that the S , when confronted with a stimulus array with different levels of M attached to the elements, will react by: (a) differentiating between the stimuli of the compound and (b) tentatively selecting among them for a functional stimulus. This is assuming that the S is aware that the response will fractionate the stimulus set.

Solso (1974) also concludes that the S will most likely select the highest M stimulus element during the encoding process and that retrieval will be enhanced if the cue used is the component with the highest M. Solso (1968, 1974) offers two explanations of why retrieval cue efficacy is related to cue meaningfulness:

(i) initially high M stimuli are more readily encoded into the memory structure and he suggests that since high M components have multi-association it is probable that memory structures are more receptive to those stimuli of similar associative frameworks than to stimuli of different or improvished associative frameworks. If the item has low M value, that may indicate that there is little available in LTS for any type of elaborative encoding strategy and storage of that material may be hindered.

(ii) from the inference that a high M term should be part of the functional stimulus, the cue consonant with the encoding stimulus should maximize the recovery in the same sense that the A:B:A:B transfer is better than A:B, A:B or A:B; C:B transfer. Solso (1974) also speculates that high M stimuli are recovered with more ease from memory even if low M terms are as well learned.

The results and subsequent hypothesis presented here are based on verbal studies. However, interpreted within the framework of coding theory they have definite implications for information derived from a multi-component movement task.

The techniques used in the recall portion of this study are based on a study by Solso and Biersdoff (1973) in which they examine the effects of multiple cuing on retrieval. The efficacy of the retrieval cue should be reflective of the encoded product.

In summary the major factors examined in the literature that will aid in the delineation of the nature of the coded movement information a :

(1) different movement attributes appear to have different encoding and retention characteristics.
(2) depth of encoding may be reflected in recall and recognition performance. Generally a stimulus encoded at a deeper level will be reproduced with more fidelity and recognized faster than a stimulus with superficial encoding properties. This phenomena may be due to several factors: meaningfulness of the stimulus, type of memory scan necessary (serial-exhaustive vs. self terminating) type of comparison necessary (template match vs. feature abstraction).
(3) precuing should bias the stimulus selection and subsequent formation of the functional stimulus. Postcuing may indicate the attributes used as functional elements and as efficient retrieval cues.

The purpose of this research, based on these factors, is to describe the functional nature of the encoded information in a movement stimulus consisting of location and distance attributes.

METHODOLOGY

Experiment I

Stimulus Materials

A set of twenty-eight (28) movement items were used in the experiment (Appendix C). Each was unique in that they differed from each other in at least two of the attributes of (a) start location (SL) (b) distance to be moved (D) and (c) end location (EL).

For each trial one item of the 28 equi-probable items was selected as the stimulus set. The probe set (Appendix C) consisted of the attributes of the same movement item as the stimulus in the "match" condition or the attributes of a probe item different from the stimulus in the "no-match".

For the "no-match" conditions the probe items were balanced over trials for their position or magnitude relationship to the stimulus items. That is, for the location (SL and EL) "no-match" probe sets, one half occurred before the stimulus location was reached on the track and the other half occurred after the stimulus location was reached. As for the distance probe sets, one-half were longer than the stimulus set and the other half were shorter than the stimulus set. (See Appendix C).

Subjects

The subjects (S) were twelve (12) university students with selection limited only by right hand dominance.

Apparatus and Task

The S was seated in front of a raised platform (Fig. 1) which covered the apparatus for the linear movement task. In front of the S at a distance of 100cm was a vertical display board. A Panascope Viewer (30cm x 41cm) was mounted in the display board and instructions for the task, photographed black on white, were projected onto the viewer using a Kodak carousel projector. The S wore earphones and a Bogen Challenger CHB 20A amplifier and an EICO audio generator were used to produce an auditory signal indicating the initiation and termination of the task phases.

The experimental task consisted of three phases:

(1) Input Phase:

The S grasped a 10cm handle on a slider which was mounted on a linear track. Both slider and track (70cm long) were mounted on a metal frame and covered by the raised platform. Attached to the slider was a light source of a photo cell Sigma Model 8L3-115. Two photo relay receivers, Sigma Model 8P8-115, were mounted on a calibrated bar 30cm above the linear track. The S produced a linear positioning movement by moving the slider along the track. When the S lined up the source and receiver of the photo cell, one of two light indicators mounted on the display board was activated defining a start location (SL). The S again moved the slider

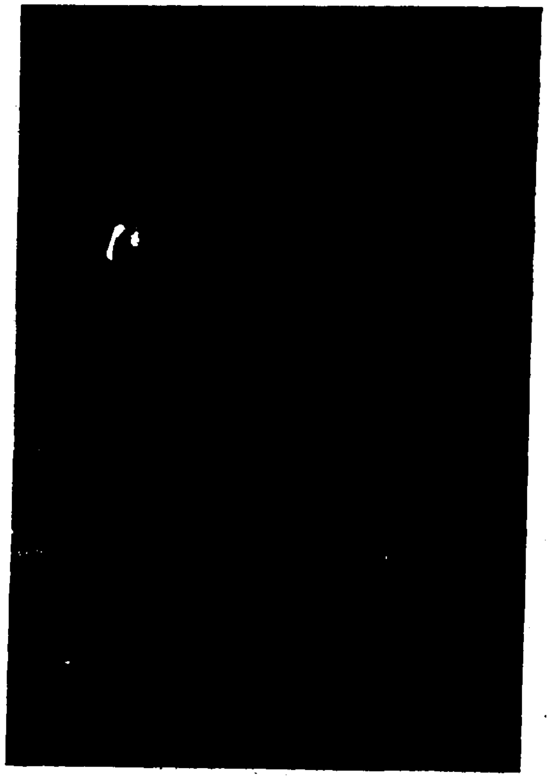

Fig. 1. Subject's position in relation to the apparatus.

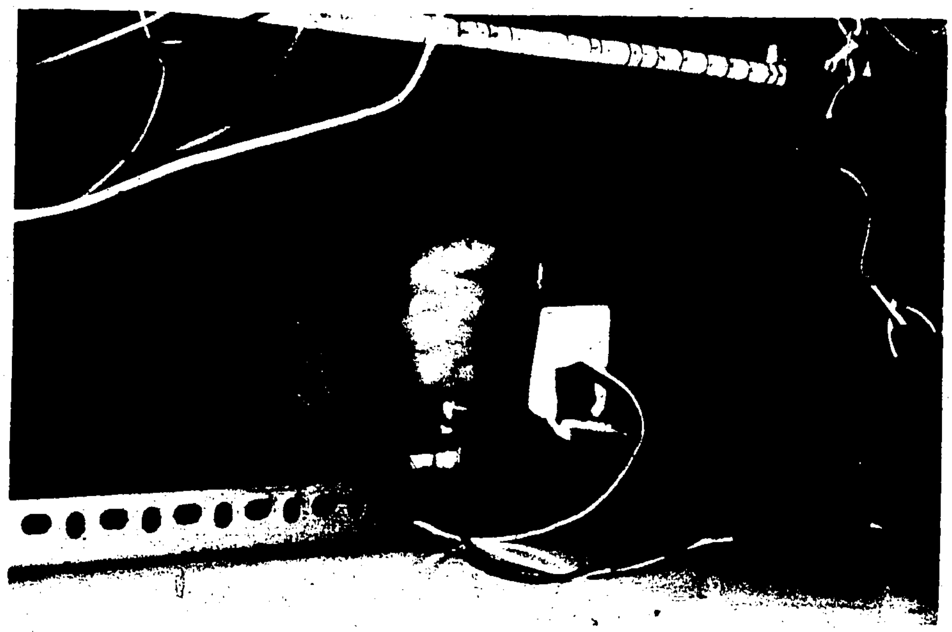

Fig. 2. Linear positioning apparatus and response keys.

along the track and lined up the source light with the second receiver which activated the second light indicator and defined the end location (EL) and the distance (D) between SL and EL of the stimulus set.

(2) Probe Phase:

The S was presented with a movement probe set consisting of one, two or three attributes. The input of these probe attributes were handled in the same manner as the input of the stimulus set and presented sequentially in the order of occurrence within the stimulus set. As the linear movement was produced a light indicator defined each movement attribute and a digital millisecond timer (Hunter Klockcounter, Model 120S) was activated.

(3) Reaction Time Phase:

The S responded to each defined movement attribute by pressing one of two plexiglass keys which were mounted on a small box to the left of the S (Fig. 2). The key press stopped the digital timer and indicated either a positive or negative response by the S. One half of the subjects were instructed that the left key was a positive response and the opposite arrangement was used for the remaining half.

Design

The experiment was a 2 x 12 x 2 factorial design with repeated measures on all factors. Factor A was the temporal placement of an attribute cue to indicate to the S as to which attribute(s) of the movement he is to make his "match-no-match" judgement. The cue was either a pre stimulus set cue or a post stimulus set cue. Factor B was the attribute type and refers to the individual attributes within the probe set (PS) consisting of one, two or three of the established attributes (PS= S (Start Location alone), E (End Location alone), D (Distance alone), SE, SD, DE, SDE) in all possible combinations. The individual attributes within each PS are referred to as SL (Start Location Attribute), EL (End Location Attribute) and D (Distance Attribute). Factor C was the nature of the attribute within the selected probe set, either a "match" or "no-match" to the stimulus.

Procedure

The test session was broken up into five blocks of ninety-six trials, with each block corresponding to two complete replications of the experimental conditions. The first block of trials constituted a practice session wherein the S was given complete instructions (Appendix C) and familiarized with the apparatus. Therefore there were eight replications of each experimental condition. However due to the sequential nature of the task, data could only be collected on four replications (Appendix C). Each S was tested in five separate sessions with the first block used for instruction and practice trials. The order of the blocks was randomized for each S and the trial order within the blocks was pre-selected on a random basis.

Each trial consisted of the following format:

(a) in the precue condition the S received a visual instruction on the Panascope Viewer as to the number and type of attributes to be contained in the probe set (i.e. the TBR items).

(b) following the visual cue, a "ready" auditory signal was given. (In the post-cue condition, this is the initial step and Item A occurs in Step C). This indicated to the S to grasp the slider at the home position either to the extreme right or the extreme left of the linear track as indicated by the E. The S then moved the slider until the light indicator on the display board triggered by the photo cell connection defined the start location (SL). The SL was held for three seconds then a buzzer signal indicated to the S to move the slider in the same direction to a second light indicator defining the distance (D) and the end location (EL). The S again held this location for three seconds until a buzzer signal to disengage from the slider was given.

(c) following a five second interval, the buzzer signal was given to the S to grasp the slider at a neutral position[3]. In the postcue condition, the visual instructions were now given. A signal indicated to the S to move the slider along the track until the light indicator defined the probe item or the first item in the probe set. The method of probe set presentation was essentially the same as the input of the stimulus set. The production of the probe item activated the Hunter Klockcounter, initiating the reaction time phase.

(d) upon completion of the probe item, the S responded by pressing the same or different button. That action stopped the timer and recorded the RT to the probe item.

(e) if the probe set consisted of more than one attribute, the S then proceeded with the slider along the track until the ensuing probe attribute was encountered and a subsequent reaction time was taken.

(f) the S then disengaged from the apparatus.

Each trial was separated by a 10 second interval.

Data Analysis

For each experimental condition the mean reaction time

[3] The neutral position was defined to the S as a location anywhere between the middle of the track and the "home" position from which he received the stimulus set.

and mean error score was calculated. The reaction time scores were submitted to an analysis of variance and Scheffe's post hoc test for multiple comparisons for significant differences. Analysis of variance was also performed on the mean error scores and multiple comparisons for significant differences using the Scheffe's method were calculated.

Hypothesis

Due to a lack of previous research in this particular area of motor STM, it was not possible to form any logical directional hypothesis. It then remained to look at possible questions of experimental interest that may be answered by the experiment.

1. What does the speeded recognition process indicate about any individual attribute of the movement in regards to the robustness of the code used?
2. Do any of the attributes of the movement facilitate the quality of the recognition (speed and accuracy) of any other attributes of the movement?
3. Do the components interact in terms of their cue efficiacy or do they act independently in the recognition process?

Experiment II

Stimulus Materials

The stimulus materials were exactly the same as in Experiment I.

Subjects

The S were 12 university students limited only by right hand dominance. None of the Ss had been a subject in the previous experiment.

Apparatus and Task

The apparatus was the same as in Experiment I with three exceptions:

(i) the RT keys were removed since no reaction times were required,

(ii) the slider was attached by a wire pulley system to a ten turn potentiometer whose output was fed into a Fluke 8000A digital multimeter. Therefore any movement of the slider along the track was recorded as a change in millivolts. The potentiometer was calibrated such that a 1 millimeter displacement of the slider registered a 1 mv change on the multimeter digital readout, and

(iii) a photo cell connection activated the light indicator only.

The experimental task consisted of two phases:

(i) Input Phase:

the S moved the slider along the track. The linear movement was again defined by light indicators mounted as in Experiment I.

(ii) Recall Phase:

the S reproduced the TBR items of the stimulus set as dictated by an attribute cue.

Design

The experiment was a 2 x 12 factorial with repeated measures on all factors. Factor A was the temporal positioning of an attribute cue and refers to a pre stimulus or post stimulus set instructions as to what attributes the S would be required to recall.

Factor B was the nature of the cued to-be- remembered item (TBR). This refers to the type of the to-be-recalled attribute within all combinations of the probe set:

(TBR = S, E, D, SE, SD, DE, SDE)

The individual attributes within the probe set are SL (Start Location Attribute), EL (End Location Attribute) and D (Distance Attribute).

Procedure

The testing was broken up in five blocks of forty eight trials each block corresponding to two complete replications of the experimental conditions. The first block consitituted a practice session resulting in 8 replications for experimental analysis. Each S was tested individually in 3 sessions. The first consisted of instruction on the procedure and the practice block. The other two sessions contained two blocks of trials. The block order was randomized for each S and the order of trials within the blocks were preselected on a random basis.

Each trial followed the following format:

(a) Precue as in Experiment I.

(b) Stimulus set input as in Experiment I.

(c) Following a five second interval, a buzzer signal was given indicating to the S to regrasp the slider at a neutral position. In the postcue condition, the TBR cue was then given. A buzzer signal indicated to the S to move the slider and reproduce, in sequence, the TBR attribute(s) as indicated by the cue. The location and distance reproductions were recorded on a digital multimeter. The dependent variable, error scores, were obtained by comparing the stimulus set items to the reproduced items.

(d) Following the reproduction the S disengaged from the apparatus.

Each trial was separated by a 10 second interval.

Data Analysis

Algebraic (constant), absolute and variable error scores were calculated for each attribute reproduction in each experimental condition.* Analysis of variance was performed on each individually. Multiple comparisons were carried out using the Scheffe's method for comparing all pairs of means.

Hypothesis

There is no research on which to base a directional hypothesis concerning the outcome of this experiment. The design was formulated from the following questions of experimental interest:

1. What attribute(s) of the movement-item is a salient retrieval cue?
2. Do the attributes contribute to the retrieval process from memory independently or does an interaction take place?

The assumption taken here was that a salient retrieval cue which is part of the nominal stimulus set should be a viable learning cue, (Solso, 1974), or part of what Underwood (1963) termed the functional stimulus. Therefore, the questions asked within the experimental design, should indicate more about the encoding of information from a motor task, in regards to the nature of the code and how it is handled by the subject.

* Note that where attributes were noncued (NR) but produced with the cued attributes data was collected in the same manner as for the cued attributes. The data analysis included the produced but noncued attributes of <u>EL</u>(NR) from the SD probe set and <u>D</u>(NR) from the SE probe set.

RESULTS AND DISCUSSION

Experiment I

Results

In the four-way analysis of variance on the error scores, the main effects of cue ($F(1,11)=15.05$) and attribute type ($F(9,99)=12.58$) were significant at $p \leq .01$. There was a significant interaction ($p \leq .05$) between cue and attribute type ($F(9,99)=2.54$). Summary of the four way ANOVA is presented in Table 1. Figure 3 illustrates the form of the Cue X Attribute Type interaction. Table 6, Appendix D shows the mean error scores for each condition.

A posteriori comparisons using Scheffe's procedure ($p \leq .05$) were carried out on the mean error scores. Several comparisons of interest showed significant differences (see Table 8, Appendix D for summary of Scheffe's test). Of the major comparisons:

(a) condition postcue D, attribute type D yielded significantly greater mean error scores than all other conditions.

(b) condition postcue SD, attribute type D showed significantly greater mean error scores than all other conditions except that of the previously mentioned condition.

(c) condition precue D, attribute type D showed significantly greater error scores than all other conditions except for the conditions previously mentioned.

The presentation of any attribute in a probe set was balanced such that one half of the presentations was a "match" and one half a "no-match". If the probe set contained two or more attributes again the "match - no-match" attributes were balanced. Therefore if the first attribute in the probe set appeared with a second attribute which was a "match" (e.g. PS= SL "match" + D "match") a subsequent probe set would present the second attribute as a "no-match" (e.g. PS= SL "match" + D "no-match").

When D appeared with a "no-match" SL the error scor for recognition was 27 or 71.1% of the total error. When D appeared with a "match" SL the error scores only totalled 11 or 28.9% of the total error score. No other condition produced this trend.

The analysis performed on the RT data revealed that only the main effect of attribute type ($F(9,99)=23.13$) reached significance at $p \leq .01$. Both main effects of cue ($F(1,11)=5.72$) and subjects ($F(11,33)=2.38$) were significant at $p \leq .05$ (Table 2). There was no significant difference between positive and negative responses. The mean RT for each condition is shown in Table 7, Appendix D. A graphic representation of the mean RT's as a function of attribute type and cue is presented in Figure 4.

Of the a posteriori comparions made using Scheffe's method several were significant at $p \leq .01$ (See Table 9, Appendix D for all comparisons). Of the major comparisons the following differences were found:

(a) condition postcue D, attribute type D had significantly longer RT's than all other conditions.

(b) condition precue D, attribute type D had significantly longer RT's than all other conditions except postcue D, (significantly different at $p \leq .05$).

(c) condition postcue SD, attribute type D had significantly greater RT's than all other conditions except for the two conditions previously mentioned.

Of note were the RT's for D when it appeared in the SD probe set. Following the trend for the error scores, when D appeared with a "match" SL in the SD probe set the mean RT equalled 375.11 msec. However when the SL item was a "no-match", the RT to D inflated to 557.14 msec. This difference in RT was not found in any other condition.

TABLE 1

4-WAY ANALYSIS OF VARIANCE

MEAN ERROR SCORES

EXPERIMENT I

Source	S.S.	D.F.	M.S.	F Ratio
Subjects (A)	1.057	11	.096	.265
CUE (B)	9.919	1	9.919	15.050**
AB	7.256	11	.659	1.817
Response Type (C)	.052	1	.052	.077
AC	.743	11	.067	.185
BC	.002	1	.002	.027
AxBxC	.817	11	.074	.204
Attribute Type (D)	70.290	9	7.810	12.580**
AD	10.781	99	.109	.299
BD	10.227	9	1.136	2.54*
ABD	44.348	99	.448	1.234
CD	1.677	9	.186	.585
A C D	31.600	99	.319	.879
B C D	2.643	9	.294	.809
ERROR	35.931	99	.363	

** Significant at the .01 level

* Significant at the .05 level

TABLE 2

5-WAY ANALYSIS OF VARIANCE

MEAN REACTION TIME SCORES

EXPERIMENT I

Source	S.S.	D.F.	M.S.	F Ratio
Cue (A)	45338.90	1	45338.9	5.720*
Response Set (B)	5363.30	1	5363.30	.487
AB	4597.30	1	4547.30	.552
Attribute Type (C)	9783463.00	9	108705.10	23.130**
AC	77716.69	9	8635.19	.682
BC	72610.38	9	8067.80	.608
ABC	76329.06	9	8481.03	.669
Subjects (D)	120197.18	11	10925.20	2.380*
AD	47768.25	11	4342.60	1.310
BD	73604.56	11	6691.30	1.670
ABD	55468.62	11	5042.00	1.670
CD	736303.00	99	7437.41	1.170
ACD	660960.94	99	6676.37	1.130
BCD	649660.13	99	6562.22	1.060
ABCD	668055.38	99	6748.03	1.280
E	15528.21	3	5176.07	.987
AE	7739.90	3	2579.97	.777
BE	3523.10	3	1174.36	.293
ABE	28048.60	3	934.95	.311
CE	159815.19	27	5919.08	.802
ACE	115721.25	27	4285.97	.723
BCE	185632.81	27	6875.29	1.160
ABCE	130086.13	27	4818.00	.919
DE	151483.13	33	4590.42	.875
ADE	109571.75	33	3320.36	.943
BDE	132283.56	33	4008.59	.823
ABDE	99215.81	33	3006.54	.972
CDE	191116.00	297	6367.39	1.215
ACDE	1761272.00	297	5930.21	1.131
BCDE	1752837.00	297	5901.80	1.126
ERROR	1556964.00	297	5242.30	

** Significant at the .01 level

* Significant at the .05 level

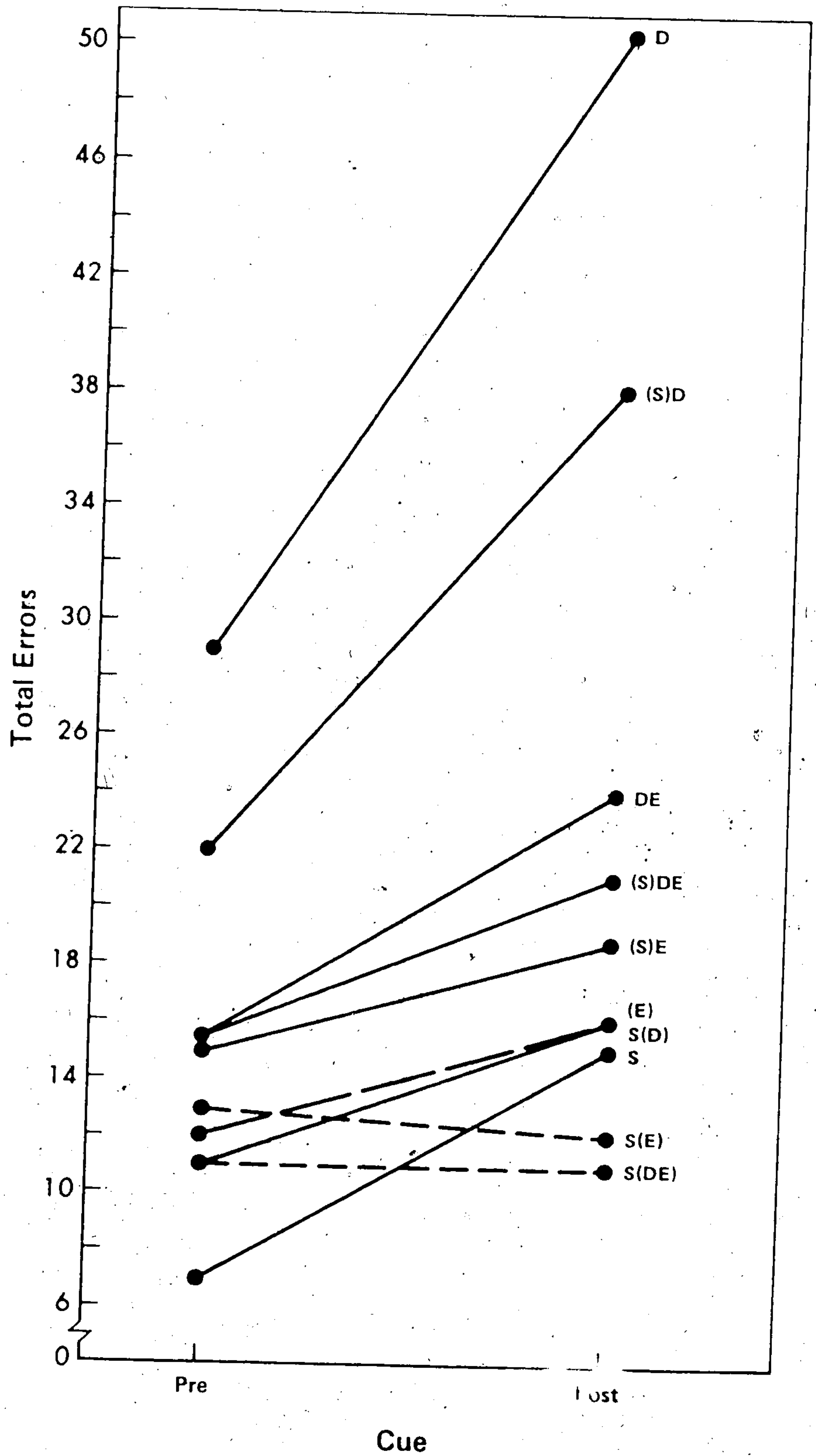

Fig. 3. Cue X Attribute Type Interaction for the Error Score Data

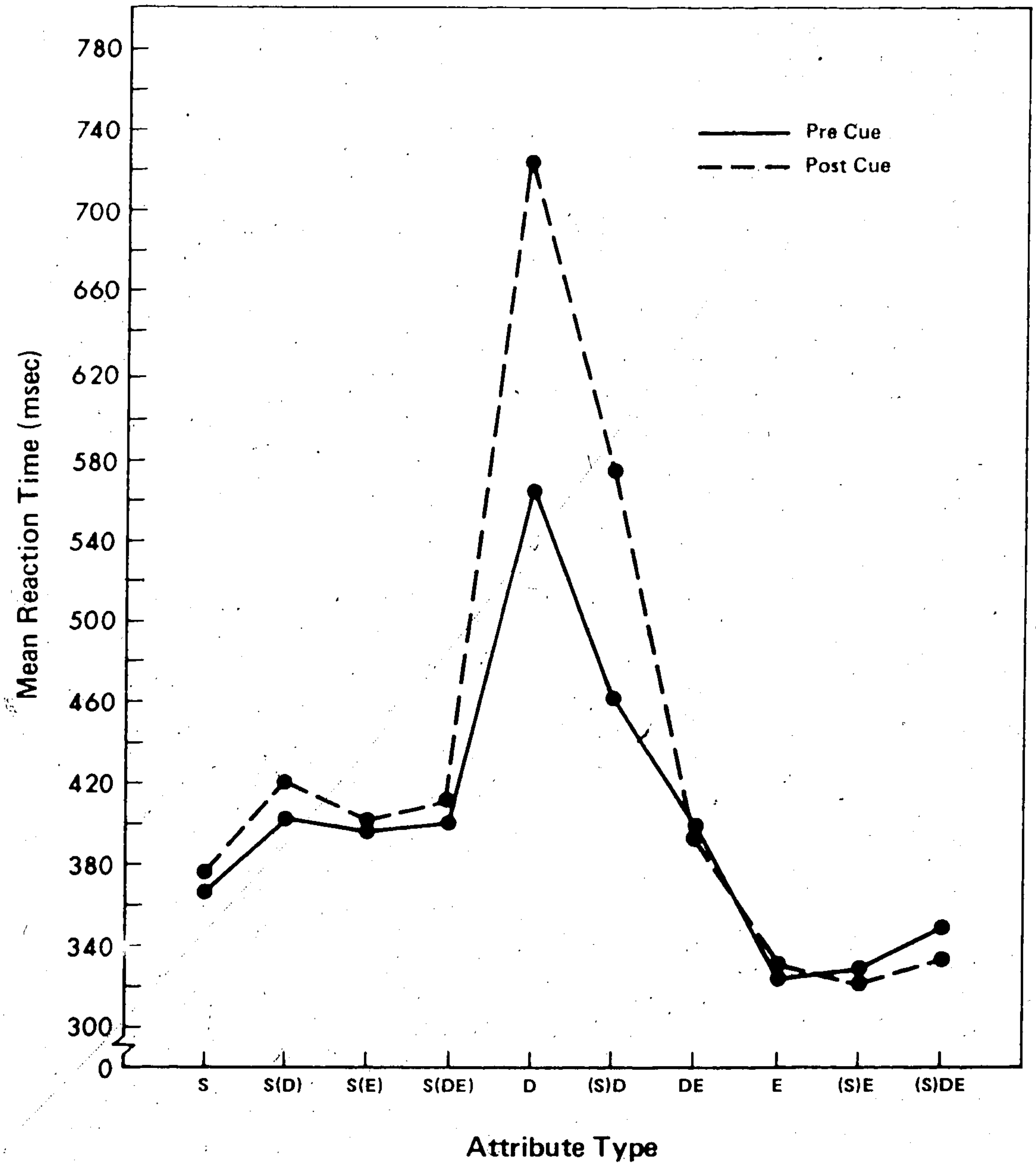

Fig. 4. Mean Reaction Time as a Function of Attribute Type and Cue Condition

Discussion

As previously stated no significant difference was found between the positive and negative response times (positive $\bar{x}$ = 410.14 msec; negative $\bar{x}$ = 411.72 msec). This is in agreement with the results of Sternberg (1966), Dardley, Klatsky and Atkinson (1972) and Lively (1972). However the memory scan in the present study was limited to one item in the stimulus set. That is, although there were three items in the stimulus set each were different attributes of the movement (SL, D, EL). Therefore if there was to be a recognition of SL, the remainder of the set (D and EL) was not scanned. The comparison took place between two items only, the item in memory from the stimulus set and the probe item. No difference was expected between the positive and negative responses for all conditions. As a result there should be no lengthening of the comparison stage in the recognition process due to set size since set size was not a factor. There are several reasons why the RT should vary if the staging model of Sternberg's model (1966) is accepted. As previously noted the form of the encoded stimulus item may affect the type of comparison made between the stimulus item and the probe item. Presumably if the stimulus material is unanalyzable (Smith 1968) template matching may be used. This comparison method appears less efficient than a feature match method since a template match implies a point-by-point match whereas a feature match only involves a match on specific features of the stimulus. The template match method would most likely lengthen the comparison stage. Extrapolating from this point, an increase in the comparison stage length would be expected if the stimulus item was superficially encoded resulting in a weak, poorly elaborated memory trace (Craik and Lockhart, 1972).

Stage 3 or the Binary Decision Stage (Sternberg, 1969a), is largely affected by the central processing uncertainty (Hc) which is determined by the number of possible outcomes or responses available. In the present study only a positive or negative (same - different) response was available. Thus the Hc was equal to one bit. This was constant across all conditions so that the effective length of this stage was constant and minimal due to the small central processing uncertainty.

The Translation and Response Organization Stage (Stage 4) is inflated by S-R compatibility and response bias. (Sternberg, 1969a). Again any effect on this stage was constant across all conditions in the present study. No response bias was established since the probability of either response was .50.

Any increase in RT between conditions in this study would have to be attributed mainly to the encoding stage which is affected by the quality, detectability and intensity of the stimulus-as-presented (Sternberg, 1969a). An increased RT may also be reflective of a poor memory trace upon which the comparison of the probe to the stimulus item is performed.

(a) Attribute Type

The RT for the D measure in the D and SD conditions were significantly longer ($\bar{x}$ = 645.51; $\bar{x}$ = 470.74) than all other recorded RT's. In addition total error scores for distance recognition were highly inflated in comparison to those for SL and EL recognition. As previously stated when a D probe item occurred in the SD condition with an SL probe item which was not a match to the stimulus SL, the probe SL lost its reliability as a discriminative cue for the recognition of the subsequent D item. The RT for D when the SL was a "no-match" inflated well above the concomitant scores for D when SL was a "match". This trend was also reflected in the error scores.

The tentative conclusion that could be drawn from these results is that the memory trace for distance is weak as reflected in the large number of errors. The encoding of the D stimulus item when it appears in isolation or in conjunction with a "no-match" probe location does not appear to have the robustness of t: encoded product for the location (SL and EL) items. This suggests that distance information may only be available to Type I processing (Craik and Lockhart, 1972) and presumably available for primary encoding only. Conversely the recognition of SL and EL resulted in relatively few errors reflecting a strong memory trace. The RT's for both locations were much shorter than those for the D attribute when D appeared in isolation or with an unreliable location cue. This indicates that the location information may be encoded at a deeper level since Craik and Lockhart (1972) have stated that deeper levels of encoding of a stimulus would result in better recall and recognition of such a stimulus.

(b) Cue Effects

Differences in RT's between the precue and postcue condition were only significant ($p \leq .01$) for D when it was to be recognized alone out of the stimulus set and for D when it appeared with SL in the probe set. In all other conditions there was no difference in the RT to the probe for either D, SL or EL between the precue and postcue condition. The purpose of the cue was to reduce or delineate the nominal set. It was proposed that by doing this the efficiency of each attribute as a retrieval cue could be observed. SL recognition under all four attribute type conditions (S, SD, SE and SDE) showed no significant difference as previously stated. There was a slight increase between the condition S and SD, SE and SDE but this was probably due to an increase in information retained in STS for recognition of subsequent attributes. In addition there was no difference ($p \leq .01$) between any of the precue and postcue conditions. Also the error scores for SL did not show any differences over the cue factor.

The same trend is evident for the EL RT data and error scores. Unfortunately when D appears in the probe set with EL, the RT is in response to both factors so little can be said about either attribute under this condition due to confounding effect of one RT to both attributes. However, the lack of difference for both location attributes due to cue effects indicates that the memory traces for the location attributes are as equally robust when the S is aware that the location attribute will be in the probe set before stimulus presentation as when the S receives this information at the onset of the probe set. Presumably both location attributes were utilized by the S for storage regardless of task demands as dictated by the pre and post cue technique. The distance attribute was not treated in the same manner as location. The inflation of the RT in the postcue D condition suggests that distance is well integrated with the SL and EL and was not available as a separate attribute for recognition. Support for this is also demonstrated in the SD condition. When the SL was an unreliable cue ("no-match"), the RT and the error scores for D under both cue conditions were inflated. The SL appeared to be used as the functional cue in the storage of D. EL although it was not in the probe set for the SD condition remains as a viable cue when SL was a "match". It is quite possible that location provides all the necessary information for recognition of a linear movement. In the SDE condition where RT was in response to both D and EL, the RT and error scores were less than the RT and error scores to D alone. Briggs and Swanson (1970) found that RT was a linear function of central processing uncertainty. However in the recognition of both D and EL simultaneously, RT did not vary significantly from the RT to EL alone. Recognition of two items should increase the central processing uncertainty but this was not shown here. It is possible that the S is reacting to one [illegible]ly or that the D and EL are integrated and [illegible] unique item in the probe set. However this [illegible] speculative due to the confounding effect of a recorded RT to both attributes of D and EL.

Reaction time to D in the precue D condition was still highly inflated (565.49 msec) in comparison to the RT's for location. Obviously the encoded product for distance was of very poor quality resulting in a weak memory trace with low accessibility (Burrows and Okada, 1971). Possibly there is a lack of elaborative or associative information in LTS with which to maintain the trace in STS. The result would be a limited amount of information on which to make a comparison. Comparison for recognition on this type of information would most likely be a template match or point-for-point match in memory in order to achieve a criterion confidence level on which to make a decision. As a result there would be an increase in the sampling time in this stage. The error rate in the precue D condition (15.1%) indicates that the S's ability to recognize distance even from a stimulus set of one is fairly poor.

To summarize, location information (SL and EL) appears to be utilized fairly efficiently by the S for recognition. The lower RT's for location as opposed to those for distance indicates shorter encoding and comparison stages for location. Since the length of the encoding stage is dependent upon the quality, detectability and intensity of the stimulus as presented (Sternberg, 1969a), presumably location has more encoding potential than distance. Error scores for location indicate that the results of comparison to a criterion on which to make a decision was fairly accurate although less time was required as indicated by the RT. Because it is not possible to fractionate the length of the total RT into the length of each individual stage for recognition, it would only be speculation as to the locus of the increase in stage length. However as previously mentioned the type of encoding will influence the type of comparison performed on the functional stimulus. The type of encoding will be directly dependent on the quality of the stimulus as presented. Any inflation in the length of the encoding stage due to a poor quality or unanalyzable stimulus should also have a concomitant increase in the length of comparison stage. This would be due to the necessity for to a more complete match to reach a criterion level of confidence on which to base a yes-no decision.

The distance attribute appears to be an unreliable storage and retrieval cue. When stripped of any location tag, recognition becomes very poor in terms of both speed and accuracy of performance. It appears reasonable to suggest that distance when presented with location becomes integrated with this additional information. This should be expected since it seems distance alone is not handled efficiently by the S and thus the S would tag it with location for optimal maintenance purposes. If the S is asked (postcued) to recognize D without SL or EL recognition he may not be able to take advantage of that cue assuming that the S has adopted an organizational strategy (Howard, 1976). The resulting memory trace from an organizational strategy would be integrated (Mandler, 1967; Tulving, 1966) and have different properties than if the movement attributes had been functionally separated initially. Recognition on a portion of the integrated stimulus would then be expected to be poor. This may result if the functional cue was not present or if the individual probe attribute as encoded did not have the same properties as the stimulus in memory. Because SL and EL data do not conform to the D data it appears that it is upon these attributes that the movement is stored. That is, the integrated memory trace would contain all of the location properties intact, with distance being recovered from these two attributes upon decoding. Therefore the memory trace for location would contain all the properties necessary for successful recognition of location in isolation. In addition, both the locations (SL and EL) should be viable discriminative attributes (Underwood, 1969a) for the recognition of the linear movement task.

Experiment II

Results

The analysis of the data involved the calculation of three types of errors scores, constant error, absolute error and variable error. Each will be treated separately.

(a) Constant error.

The constant error scores (CE) were subjected to a three-way ANOVA. The main effect of attribute type ($F(13,143)=4.97$) was significant at $p \leq .01$. The subjects main effect ($F(11,143)=2.40$) reached significance at $p \leq .05$. The cue main effect ($F(1,11)=1.68$) was non-significant (Table 3).

Sheffe's test for post hoc multiple comparisons was applied to the mean CE error scores and yielded several significant differences. The scores were divided into two categories: overshooting (positive values) and undershooting (negative values). None of the negative scores differed significantly from each other (Scheffe's critical difference =1.43, $p \leq .05$). Of the positive scores the Scheffe post hoc comparisons indicated that CE scores for D (postcue D) and D (postcue SD) were significantly greater than all positive CE scores for *EL* and *SL* except for *EL* (post SDE), (Scheffe's critical difference=1.43, $p_{.05}$=.05), (Table 11, Appendix D).

All scores for *SL*, *D* and *EL* in all conditions were ranked from the greatest negative value to the largest positive value. Of all CE scores obtained, those relating to the distance attribute (*D*) had the largest mean positive and negative errors (i.e. largest mean CE - *D*, condition precue SD; largest mean negative CE - *D*, condition DE). Figure 5 shows the mean CE for each condition and the means are also tabled in Appendix D, Table 10.

(b) Absolute error.

In the three-way ANOVA the main effects of cue ($F(1,11)=34.76$) and attribute type ($F(13,143)=24.63$) reached significance at $p \leq .01$. The subjects main effect ($F(11,143)$) was significant at $p \leq .05$. There is a significant ($p \leq .01$) interaction between cue and attribute type ($F(13,143)=7.11$) (Table 4). Figure 7 is a graphic representations of the form of the Cue X Attribute Type interaction. The mean AE for each condition is shown in Figure 6, and is also presented in Table 10, Appendix D.

The Scheffe's post hoc comparisons showed that all the AE's for the distance measure (*D*) in all conditions except in the precued SE, precued SDE and the postcued SDE conditions, were significantly greater (Scheffe's critical difference = 1.29, $p \leq .05$) than the AE's for all the *SL* measures and the majority of the *EL* measures. End location

TABLE 3

3-WAY ANALYSIS OF VARIANCE

CONSTANT ERROR SCORES

EXPERIMENT II

Source	S.S	D.F.	M.S.	F Ratio
Cue (A)	4.86	1	4.86	1.68
Attribute Type (B)	425.22	13	[illegible]71	4.97**
AB	75.40	13	5.80	1.60
Subjects (C)	81.17	11	7.37	2.40*
AC	31.82	11	2.89	.64
BC	640.38	143	4.48	1.23
ERROR	516.88	143	3.62	

** Significant at the .01 level

* Significant at the .05 level

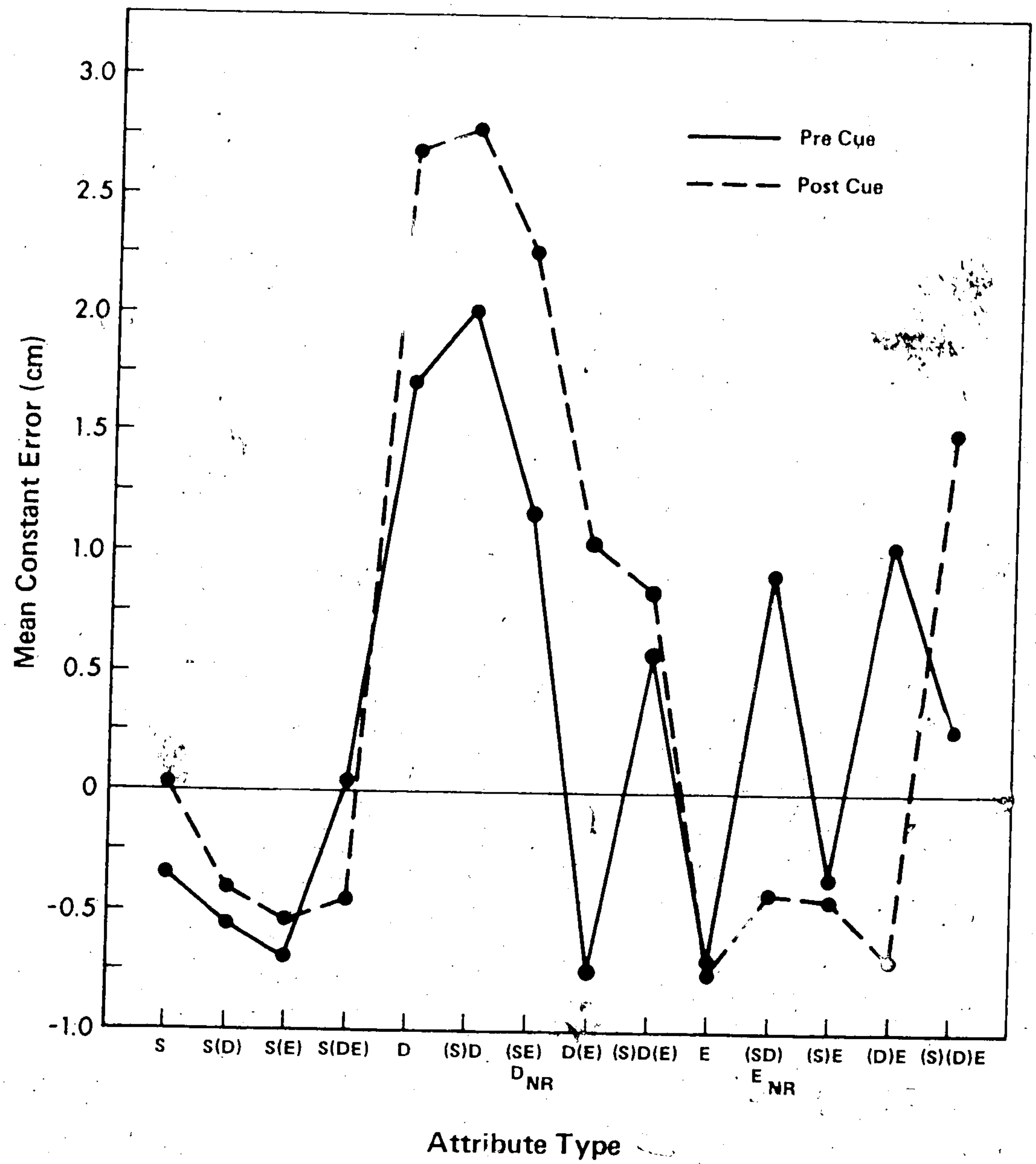

Fig. 5. Mean Constant Error as a Function of Attribute Type and Cue Conditon

TABLE 4

3-WAY ANALYSIS OF VARIANCE

ABSOLUTE ERROR SCORES

EXPERIMENT II

SOURCE	S.S.	D.F.	M.S.	F Ratio
Cue (A)	38.94	1	38.94	34.76**
Attribute Type (B)	477.12	13	36.70	24.64**
AB	84.29	13	6.48	7.11**
Subjects (C)	21.46	11	1.95	2.14*
AC	12.39	11	1.13	1.24*
BC	114.35	143	.80	.88
Error	130.34	143	.91	

** Significant at the .01 level

* Significant at the .05 level

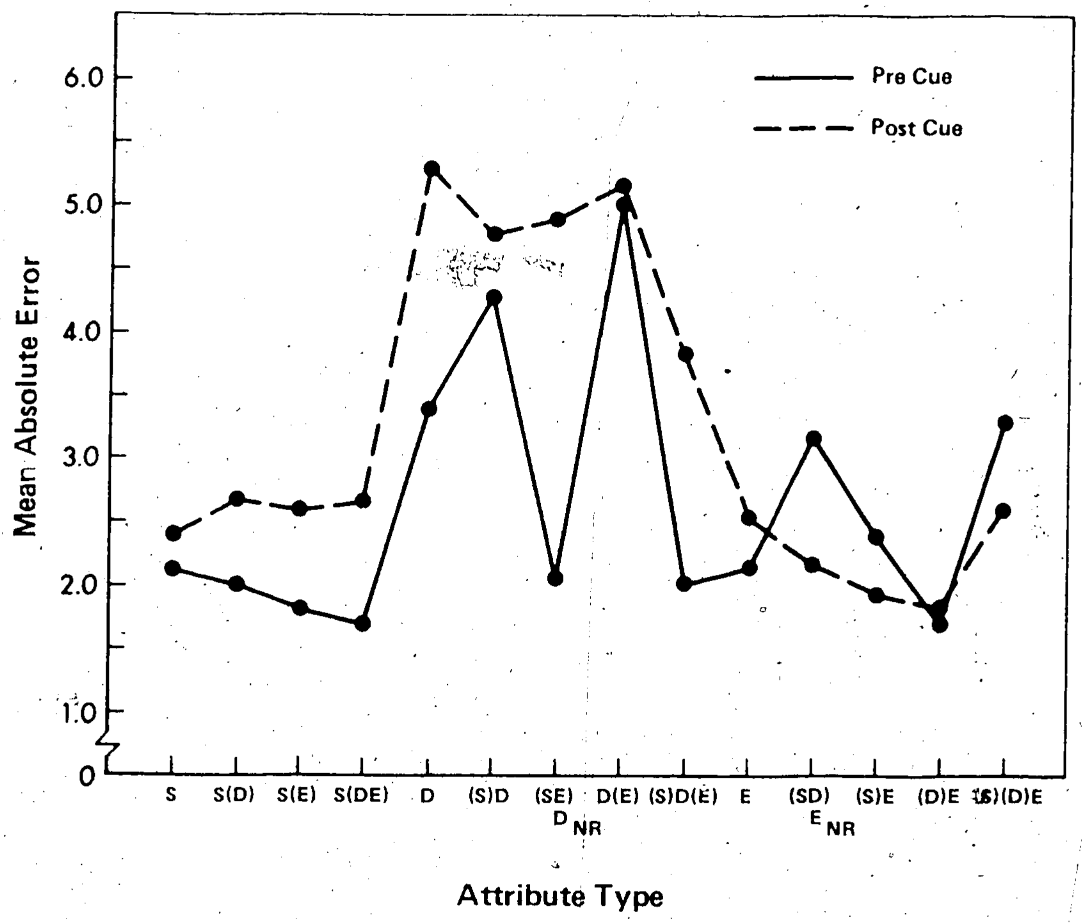

Fig. 6. Mean Absolute Error as a Function of Attribute Type and Cue Condition

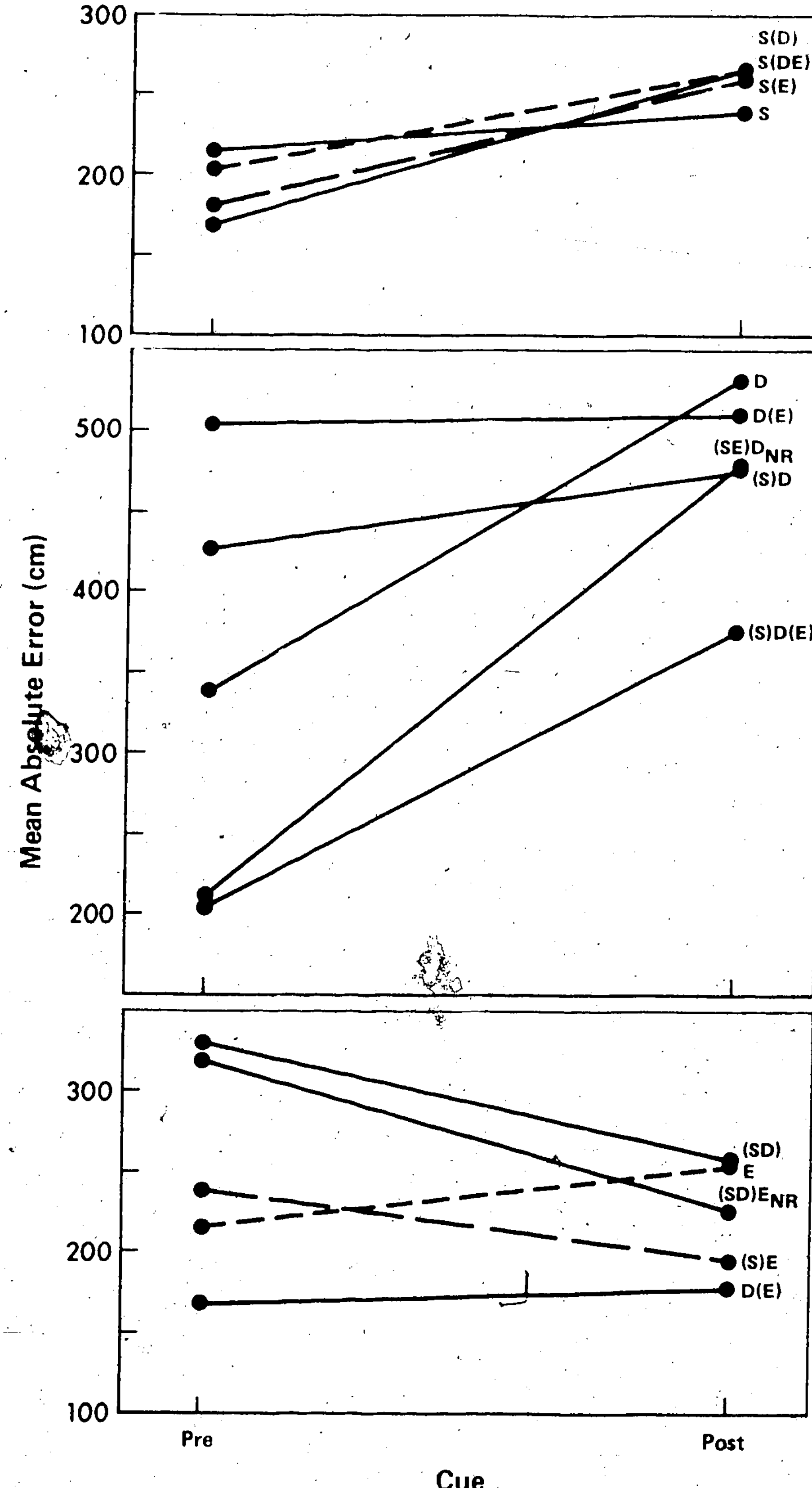

Fig. 7. Cue X Attribute Type Interaction for Absolute Error

(precue SDE) and EL (precue SD) were not significantly different from D (precue SD), D (postcue SDE) or D (precue D) (Table 12, Appendix D).

(c) Variable error.

From the three-way analysis on VE, the main effects of cue ($F(1,11)=16.46$) and attribute type ($F(13,143)=24.60$) were significant ($p\leq.01$). The interaction of these two factors (Cue X Attribute Type) ($F(13,143)=6.57$) was also significant ($p\leq.01$), (Table 5). The form of the interaction is shown in Figure 9.

The mean VE for each condition is presented in Figure 8 and tabled in Appendix D, Table 10.

Scheffe's a posteriori comparisons on the mean VE scores (Table 13, Appendix D) indicate that as with the CE and AE scores the VE error scores for distance under most Attribute Type X Cue conditions were significantly larger than the concomitant scores for SL and EL.

Specifically, VE for D (postcue D) was significantly larger (Scheffe's critical difference=1.56, $p\leq.01$) than any other VE for D, SL, or EL. Variable error for D (postcue DE), D (precue DE), D(postcue SE), D (postcue SD), D (precue SD) and D (precue D) were all significantly greater (Scheffe's critical difference=1.43, $p\leq.05$) than all other VE scores except for EL (precue SDE). As with the AE measure, the D VE measure in conditions precue SE, precue SDE and postcue SDE were not significantly greater than any EL or SL VE scores.

TABLE 5

3-WAY ANALYSIS OF VARIANCE

VARIABLE ERROR SCORES

EXPERIMENT II

Source	S.S.	D.F.	M.S.	F Ratio
Cue (A)	24.53	1	24.53	16.46**
Attribute Type (B)	470.27	13	36.17	24.60**
AB	99.28	13	7.64	6.57**
Subjects (C)	22.09	11	2.01	1.73
AC	16.40	11	1.49	1.28
BC	210.90	143	1.47	1.27
ERROR	265.98	143	1.16	

** Significant at the .01 level

* Significant at the .05 level

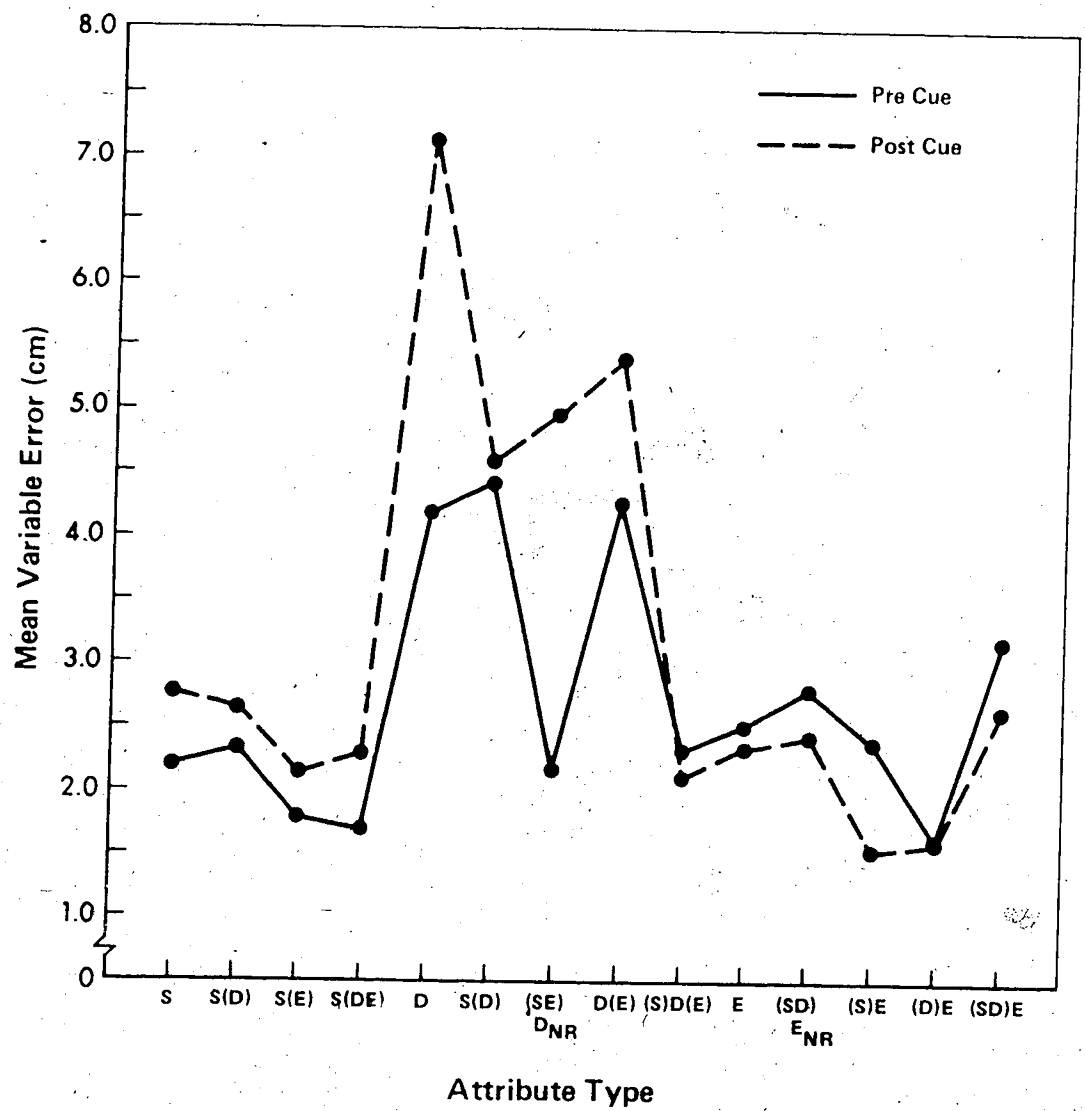

Fig. 8 Mean Variable Error as a Function of Attribute Type and Cue Condition

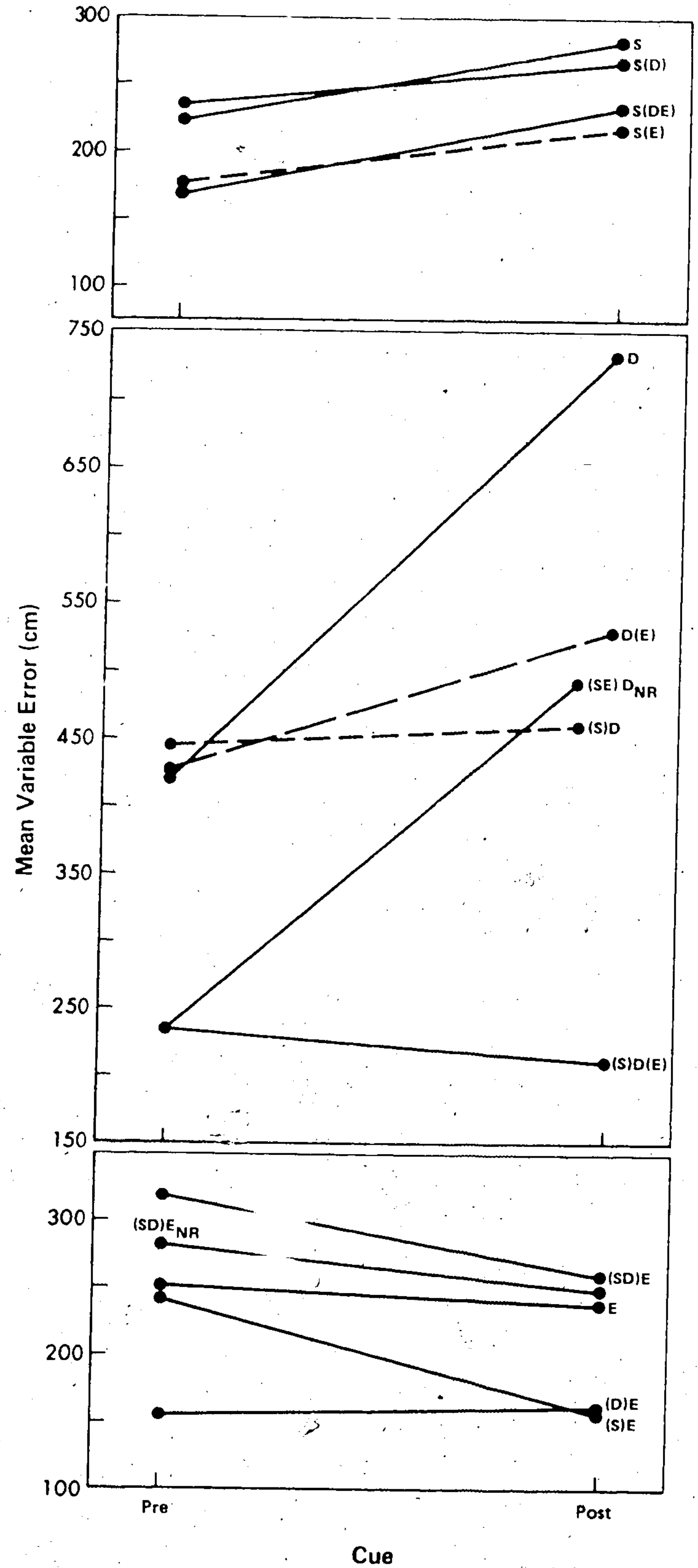

Fig. 9. Cue X Attribute Type Interaction for Variable Error

Discussion

The three dependent variables measured although not mutually exclusive (Shutz and Roy, 1973) reflect different characteristics of the motor recall performance. Constant error is reflective of a bias to overshoot (positive errors) or undershoot (negative errors). Absolute error is a magnitude measure and reflects the average deviation from the target or zero point with no stipulation as to direction. Variable error indicates the consistency of the subject's recall performance and is calculated as the standard deviation of the algebraic error.

(a) Attribute Type

There was a significant difference between the CE's for attribute type ($F(13,143)=4.97$). Reproduction of distance resulted in a larger response bias both positive and negative than the bias found for most locations (SL and EL). A response bias is thought to be created by the physical nature of the linear movement (Pepper and Herman, 1970; Laabs, 1971). This results in longer movements being undershot (negative bias) and shorter movements being overshot. Extent of movements in this study were varied to give an equal number of long (greater than 15 cm) and short (less than 15cm) movements so overshooting and undershooting was expected. The type of bias should not differ between attributes. However, the large bias magnitude associated with distance indicates the unreliability of the stored encoded information. This may be a result of a poorly formed percept of the attribute or a lack of elaborative information stored in LTS. (Craik and Lockhart, 1972). An alternative possibility is that only D information is subjected to the bias of the range affect.

The results for absolute error conform to most of the findings in recent research (Marteniuk and Roy, 1972a; Marteniuk, 1973; Laabs, 1973). In general, the AE's for D were much larger than those for SL and EL indicating a more accurate recall performance for location. When D rec[illegible]l performance did not deteriorate in the [illegible] condition where D was produced but not cued and in the SDE condition, distance appears to have been developed from the location cues and not as a separate entity.

Variable error scores reflect the same trends but represent a consistency score rather than magnitude error. Again D attribute recall resulted in the largest error scores. Most notable is the instance where D is recalled in isolation without a location tag. The consistency with which the S produces the same errors is very low (VE=5.64). The indication is that the memory trace from which distance is reproduced is not very precise and that the encoding process which produced the trace is non-elaborative and inefficient. Variable errors for location are significantly smaller as would be expected from previous research or immediate recall of location (Marteniuk, 1973; Laabs, 1973; Leavitt and Hall, 1977). When D is tagged with location (in the SDE and SD) conditions, the variable error decreases significantly (VE<2.36). Interpretation of these error scores are fairly straight forward. Recall performance as measured by the parameters of bias (CE), error magnitude (AE) and consistency (VE) is much poorer for distance than for location.

Hall (1974) has suggested a more descriptive explanation of error scores. He interpreted CE as a measure of a predetermined error detection level; that is a deviation from zero beyond which the output is deemed a error. Constant error would be moved closer to zero by the S, the less error the S is willing to tolerate. Variable error is interpreted as the index of sensitivity of the error detection process and AE is thought to be an index of accuracy of the memory trace. That is, the larger the AE the poorer the state of the trace in memory. Using this framework for the results of the present study, it would appear that the S, for D reproduction, is willing to tolerate large deviations from the target distance; is not very sensitive to deviations beyond the error detection level; and does not have an accurate representation of the distance stimulus in memory. Possibly these all could result from a poorly encoded product for distance. Assuming no elaborative information in LTS to enhance maintenance of the trace in STS, the code used would likely be a point-by-point representation of the distance stimulus which is continuous in nature and varies from any other stimulus in that category along the extent dimension alone. This type of coding process would be similar to Posner's (1967b) kinesthetic image which he stated could not be encoded semantically or conceptually and would result in rapid deterioration of the information n memory.

(b) Cue Effects

The effect of precuing or postcuing the TBR items was not significant when reflected by CE scores. Using the Scheffe' post hoc test for differences only the CE for D in precue DE (-.74) and postcue DE (+1.09) reached the critical difference level. No explanation can be given for this result other than D CE trend follows the EL CE trend in the reproduction set. That is, when EL was undershot in the precue DE condition (CE=-.69) so was D. In the postcue condition the CE for EL was positive (+1.08) as was the CE for D. It appears that the S may have [illegible] to tag the D with the SL from the stimulus set but this is speculative. The lack of significance of cue effect on CE implies that the response bias is not dependent on the form of the nominal stimulus; that is whether the attributes are integrated or are functionally separate.

The cue effect as measured by AE scores was significant at $p \leq .01$. However the only significant comparisons found by the Scheffe' post hoc method were between D scores under the conditions of D in isolation and SE where D was produced as a result of reproducing the locations on the linear track but was not cued. The significant difference between distance recall in the precue *D* condition and the postcue *D* condition indicates that the *S* was unable to utilize the postcue as an effective forget cue to reduce the nominal set or to isolate the distance attribute. If as Howard (1976) has suggested this attribute is integrated or organized with location during the encoding process then the properties of the encoded product in memory would be different than that of a functional *D* stimulus presented in isolation. This being the case a poorer reproduction of *D* should be expected if *D* alone were to be recalled from the stimulus set without an efficient retrieval tag (Solso, 1974).

The distance attribute when recalled with *SL* in the SD condition or with both locations in the SDE condition, was recalled equally well under both condit[illegible]of cue as reflected in AE. It seems that the enc[illegible]ormation for *D* is integrated with encoded location information and although location cannot be extrapolated from distance information, *D* can be extrapolated from location information. In the DE condition, *D* AE's were no different with a precue or a postcue, however the absolute error scores were very high (precue AE = 5.04 cm; postcue AE = 5.12cm). In this condition the *S* reproduced *D* from a neutral position so that *SL* was not a reliable cue. Therefore the end point of the *D* did not coincide with the TBR *EL*. The *S* then produced an *EL* subsequent to the *D* so that *EL* was not a reliable tag for *D* either. Even with the *EL* in the TBR set, location was not available to enhance the retrieval of D. As indicated by the larger AE score the postcue appears not to have been effective. However the large AE for the precue condition indicates that the S was also unable to use prior instructions. Assuming the S took an integrative encoding strategy when precued to D and E, reproduction of D and E in the isolated matter required would not be optimal for that type of strategy and could account for the inflated AE scores.

A significant difference was also found for cue effects as measured by VE. As with AE results, the only significant differences between attribute types due to cue effects appear for the distance attribute in the D condition and for the distance attribute (non-cued) in the SE condition. The assumption is that in the D condition the S did not or could not utilize the postcue as effectively as the precue to isolate D for encoding and storage in memory. The VE reflects an inconsistency or lack of precision of reproduction over trials. As previously suggested for the AE results, the large VE may indicate that the form of the encoded distance information when encoded with location is very different from the form of the encoded D information when D does not have location tags. This suggests an integrative coding form for movement information. The lack of cue effect on location (SL and EL) as reflected by VE and the fact that the VE scores are much lower overall demonstrates that location is not necessarily dependent on distance information for retrieval. However D appears highly dependent on location for effective retrieval. In the SD condition D VE scores were fairly large (precue VE=4.48cm; postcue VE=4.60cm) whereas EL which was non-cued but produced, had relatively small VE's (precue VE=2.83cm; postcue VE=2.48cm). The S's appear to be acting on the EL and SL to produce the distance. The consistency of D reproduction in the precue SD condition is not any greater than for the distance attribute in the precue D condition. However in the precue condition, task demands are available before encoding of the stimulus set. Buschke (1966, 1967) suggested that recall demands influence the way information is encoded for STM. Possibly the encoding form used was optimal for the task demands and therefore some degree of consistency should be expected for recall of any information in the precued TBR set.

The consistency of reproduction (VE) for location does not vary under the postcue condition from the precue condition. If the encoding process does in fact vary for the task demands, the encoding process used with the precue resulted in equal reproduction fidelity to that used with the postcue. It is possible that location is encoded in the same way regardless of the task demands in this study since distance may be extrapolated from location if it is included in the TBR set.

To summarize the discussion for Experiment II, recall performance for location is more stable and accurate than the recall performance for distance. This is reflected in all three types of error scores (CE, AE and VE). When distance is recalled from a stimulus set containing location information distance reproduction is enhanced if location information is reproduced also. If location information is not retrieved with distance then the reproduction errors increase drastically. However location does not need distance retrieval to give a recall performance in the postcue condition equal to the precue condition.

Since recall was almost immediate, maintaining a memory trace in STM should not be a problem for the S. However the state of the memory trace is reflective of the encoded product. Presumably more deeply encoded information would result in a more stable and accurate trace (Craik and Lockhart, 1972). Distance when recalled from the precued TBR set containing only D, was recalled with little accuracy, indicating an improvished memory trace and an ineffective encoding process. Recall for D deteriorated further when postcued. It appears that in this condition the distance attribute was encoded in an integrative fashion with location. Therefore, the task demands would not have coincided with the type of code or the process used to encode D unless location was retrieved in conjunction with distance.

GENERAL DISCUSSION

The coding concept and its variants, encoding, recoding and decoding represent the phenomena that between the external world and the memorial representation of that external world there operate specific processes for the purpose of translating external information into internal information. Melton and Martin (1972) have implied that the critical determinants of learning and memory are to be discovered in the coding response to an external event or sequence of events. That is, if memory includes the use of specific coding processes, then these processes must have domains from which to receive information. In order to delineate the function of the processes, the nature of the domains and the interface between the process and the input domain must be understood (Melton and Martin, 1972). In the area of motor memory, one main focus of research has been the delineation of various types of information available from movement and the specific nature of that information in regards to its storage and retrieval potential. Researchers have access to the nominal form of the movement alone but infer the functional form from the products of recall memory tasks. This functional stimulus forms the interface between the input movement domain and the central coding processes. The purpose of the present two experiments was to investigate within the constraints of both a recall and a speeded recognition paradigm the functional nature of a movement stimulus. The three major assumptions upon which the present research rests are (i) that all the information available to the subject is not necessarily contained in the functional stimulus but rather the subject uses an optimal cue selection strategy (Posner, 1967a), (ii) that the level of recall or recognition performance is reflective of the robustness of the encoded stimulus (this may be indicative of the level of encoding the stimulus has reached (Craik and Lockhart, 1972)), and (iii) that the task demands influence the type of encoding processes that are used on the available information (Buschke, 1966; 1967).

Several researchers (Laabs, 1973; Marteniuk, 1973; Roy and Diewart, 1975; Hall and Leavitt, 1977) have isolated location and/or distance information in a motor STM task. The general conclusion drawn from these various results is that location information, in its encoded form, has different characteristics in terms of resulting storage and retrieval potential than that of distance information in its encoded form. That is, in general, location information was reproduced more accurately and precisely as reflected in the error scores than was distance. The results in the recall experiment in this study were in agreement with these findings. However the major difference between the forementioned studies and the present study was the multiple input process (SL, D, EL available at input) and the pre input and the post input forget cue. These input/output constraints in the recall paradigm allowed for investigation of several aspects of the information-as-coded. Specifically these constraints allowed for the investigation of the functional retrieval cues among the available movement cues and the form of the ur tional movement stimulus when location and distance c were available. Distance recall was very poor when distance was retrieved in isolation. However distance recall improved in both accuracy and stability when a location attribute was retrieved in conjunction with distance. Location recall performance was not affected by the presence or absence of the distance attribute retrieval. The indication is that the encoded form of distance in isolation is not well maintained in store nor does it provide any basis for retrieval fidelity. The encoded form of location appears to have been developed to a deeper level of the encoding process. The stability of the location reproduction indicates a rehearsal or elaborative strategy, mapping the information in STS into elaborative information in LTS to increase the ease of the data handling in STS. Lockhart, Craik and Jacoby (1976) view this process as further encoding within a specific domain. They state that it should result in the facilitation of the distinction between the TBR item from similar items in memory. Perhaps distance information cannot undergo this type of elaborative encoding.

The speeded recognition technique has not been used to any great extent in movement research. The paradigm enables one to investigate memory through the use of the speed and accuracy of recognition. In the present study the input and output constraints of the multiple ensemble stimulus and the pre and post cue within the speeded recognition paradigm allowed for inferences to be made regarding the length of the encoding and comparison stages, and subsequently the type of processes taking place in these stages. In addition the movement cues used as discriminative attributes in the recognition process could be isolated. The inference was that these same attributes would be included in the functional stimulus for the recognition of a linear movement.

In general, the recognition performance for location attributes (SL and EL) was faster and more accurate than the recognition performance for the distance attribute as reflected by recognition latency (RT) and mean error scores. This indicates that location is well distinguished from other similar items in memory probably as a result of elaborate encoding (Lockhart, Craik and Jacoby, 1976). Distance recognition without the benefit of a reliable location cue was very poor. The encoded form of distance in memory appears to be impoverished probably consisting of a primary code form which is highly susceptible to loss from memory. If distance information is not available for further processing (eg. application of a conceptual code) no familiarity index (FI) could be generated and the recognition scan would be based on the initial form of the encoded distance information (Juola et al., 1974). Presuming that location is available for conceptual coding, an FI could be generated. This would account for the faster recognition time for location since a response would be initiated without a memory search. The deeper level of encoding would also ensure a more accurate recognition performance (Craik and Lockhart, 1972). Solso (1974) has stated that information which has elaborative encoding potential would most likely have high meaningfulness (M) value. When a multicomponent stimulus is presented, the S will tend to select the high M components as the functional stimulus and disregard the low M component (Underwood, Ham and Ekstrand, 1972; Solso, 1974). The results of the present investigation tend to suggest that the location attribute is the main component in the functional stimulus for a linear movement task. The location appears to have an elaborative encoding potential and therefore a correspondingly high M. On the other hand the distance attribute seems to have a lesser encoding potential and as a result, a low M. Very likely, the distance attribute is not used as an integral part of the functional stimulus.

The cuing technique derived from an intentional forgetting paradigm produced some interesting results regarding the relationship between attributes in the linear movement task for both the recognition and recall experiments. The pre and post cuing technique is purported to produce selective rehearsal/ recycling (Bjork, 1970) or a selective search during a memory scan (Epstein, Masaro and

Wilder, 1972). Since the TBF items were dissimilar from the TBR items produced by the cue it was assumed that any effect of the cue would be a result of a selective rehearsal phenomena. Distance was the only attribute to be effected by the cue technique. Location (SL and EL) recall and recognition performances remained stable under both cue conditions. Distance information only showed an effect when it was cued in isolation. If a location appeared with distance, the recall and recognition performances for distance under the two cue conditions were equal. Presumably when both distance and location were available and the task demands were not stated (postcue condition) location was selectively rehearsed and distance was either disregarded or only recycled in STS. The recycling strategy implies that the information was held in its initial encoded form, a process similar to Type I processing (Craik and Lockhart, 1972). If distance was then postcued, the recognition and/or reproduction performance would be expected to be poor. The experimental results support that contention. Postcuing on either location attribute should be equal to the precue condition when selective rehearsal is required. The results of this investigation confirm that view.

When the distance attribute was postcued, and a reliable location was included in the TBR set, distance maintained its precue performance level. This was most evident in the recognition experiment. The conclusion from these results again was that the location attribute was contained in the functional stimulus for the linear movement task and that distance information could be extrapolated from the functional location information.

Another possible conclusion is that distance information may not be disregarded in the forming of the functional stimulus but that distance is integrated with location. According to Howard (1976) the encoded form of the integrated distance information would be different from the encoded form of distance as a unique item. Recall or recognition of the unique item from an integrated functional set would result in poor performance as was shown in the present study. Location appears to be a discrete spatial item and may not necessarily show this degradation in recall or recognition even it if was integrated with distance. Distance, however, as a continuous item can only be well defined by location items (SL and EL).

In the present study the only distinction made between the processes of recognition and recall was that recognition does not require the overt retrieval of the stimulus item. Therefore in recognition the S relies on discriminative attributes whereas in recall it is both the discriminative and retrieval attributes that are acted upon (Underwood, 1969a). Underwood (1969a, 1972) states that discriminative attributes and retrieval attributes are distinct and have little overlap. He states that the attribute responsible for discrimination is situational frequency whereas the attributes responsible for retrieval are those linking the stimulus with the context or the stimuli with one another. The results from the present recall and recognition studies are very similar in that location emerges as the functional attribute for both processes. There are several explanations for this result. Brown (1976) has stated that certain features of recognition tasks may encourage the use of recall to mediate recognition. If a target is embedded in a coherent structure, recall of some or all of this structure may be required before a decision on the target is made. If distance is integrated with location and not handled as a distinct entity then the embeddedness feature could have been present in the recognition task. This would also account for the facilitative effect of location in the TBR set since the S produces the item to be recognized.

Several researchers (Kintsch, 1970a; Anderson and Bower, 1972; Brown, 1976; Lockhart, Craik and Jacoby, 1976) argue that there is no real difference between the recall and recognition process. Lockhart, et al (1976) assumes that there are two basic modes for both recall and recognition. The first is a reconstruction process in which an approximation to the initial form of the encoded stimulus is generated in the perceptual/ cognitive system. The second process is scanning which is the search of recent episodic traces for the presence of a pertinent feature of the probe item to be retrieved or recognized. Kintsch (1970a), Anderson and Bower (1972) and Brown (1976) purport the generation-discrimination theory in which there are two basic underlying processes, one of which is involved in recognition.

The present studies although not conclusive indicate that the recall and recognition processes for a linear movement task are based on the location attributes of the movement as opposed to the distance attribute. It is possible that the location attributes contain those cues that form the basis of both retrieval and discrimination proposed by Underwood (1969a; 1972). If such were the case, it would not be possible to draw any conclusion from these studies concerning the underlying similarities or difference between the two processes.

In summary, the purpose of this study was to investigate the nature of the encoded motor information in a linear movement task and by so doing delineate the functional motor stimulus in the task. Location information, both start point and end point, emerge as the reliable attributes for both recall and recognition. It appears that location information is more readily available for elaborative encoding and to a deeper level of encoding than is distance information. Distance information appears to be encoded in a primary form, similar to Posner's (1967b) description of kinesthetic image or a point-by-point perceptual representation.

The most probable encoded form for the linear movement task is an integrated form in which all the information (location and distance) is maintained with location information acting as the retrieval tag due to its encoding and retention potential. As an initial study using the multiple cue technique and the speeded recognition paradigm, the results can only be interpreted in light of results from verbal memory research. Further investigation into the recognition and recall processes using such techniques is a necessity not only to define the basis of movement recognition but to investigate further the viable notion of the integrated code for movement.

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APPENDIX A

REVIEW OF THE CODING LITERATURE

The Concept of Coding

The primary question to consider in elaborating the concept of coding is what advantages are there to using such a concept in the explanation of the processes of learning and memory? Reynolds (1972) suggests that a model (as derived from a concept) should do three things:

1. simplify the existing explanations
2. support the existing empirical observations, and
3. organize the observations with the result that the ideas may be generated that may not have occurred without the model.

As a result of the swing from the traditional associative explanations of learning to an approach which views the learner as an active processor of information, the concept of coding appears to provide a viable model which fulfills the previously stated prerequisites.

The earlier attempts to explain learning were quite mechanistic and for the most part, research was aimed at identifying the conditions under which an association was established (J[illegible]son, 1975). The nature of the learning atom was relatively ignored with the assumption that the performer learned two-place direct relationships between items which were externally defined.

The approach in which coding theory has flourished, views the performer as interacting actively with the information of his environment. The empirical effort is then directed at understanding learning by investigating the mechanisms and processes by which the performer acquires information. This approach makes no assumptions as to what is learned and is, therefore, available to empirical investigation. By understanding what is learned leads directly to some assumptions regarding the processes used by the performer to acquire that information. So, rather than assuming an association between items, the trend is to investigate the organization of items in memory. With an eye to the organizaticnal approach, Lawrence (1950) introduced a theory of attention to stimulus cues to account for some findings in P.A. learning This was followed shortly in 1953 by Bousfields' article on clustering of responses in free recall relating the idea of organization by category. Millar (1956) used the concept more extensively in his notion of chunking of information for storage in short-term memory. Relying on the coding jargon of communication, he stated that, the input is given in a code that contains many chunks and that the operator recodes the input into another code that contains fewer chunks.

The first appearance of the coding concept in the learning literature was in another paper by Lawrence (1963) when he likened the stimulus-response mediation of the idea of coding. With this initial application of the communication theory concept and Underwood's (1963) notion concerning the stimulus-as-coded versus the stimulus-as-presented, a plethora of reseach was initiated applying coding theory to learning and memory (Melton, 1973).

Returning to the primary question of the advantages of the coding concept, one of the assumptions inherent in the use of a code is that it is an optimizing device. This assumption is in keeping with the current view of the performer as an active participant in the information-acquisition process. Welford (1974) states that the performer works on an economy principle in that maximum data will be stored in minimum terms. In other words, by use of a code the performer may optimize on the information available to him for storage. The notion of optimization on the part of the performer is a necessary one when considering the functional limitations on process and capacity that do exist.

To delineate the concept of coding still poses somewha of a problem. The concept itself covers a wide variety of functionally different coding operations, the specifics of which, within the framework of human performance theory, still remain to be experimentally determined.

Coding should be regarded in a purely informational way; as a psychological construct which is not tied to physiological fact but which has as a base only experience according to which some structural scheme of internal relations is created. This model of the relationships then exhibits the required effect in a manner most similar to that of human behavior.

To make the concept of coding more succinct, the following section will define the term coding operationally and within the framework of learning and memory theory.

(a) A Definition of Coding

The distinction must initially be made among the terms, coding, a code and coded information. By in large, coding can be considered a process; the process being the application of a code to available information resulting in extraction or elaboration of that information. The result of this process is what is termed coded information. The use of the coding construct makes no inferences as to the temporal or spatial properties of the process within an information processing flow diagram of the performer. However, it should be pointed out that, what can be defined as peripheral coding or the coding processes engaged in by sensory receptors in order to convey information to the central processors [cerebellar level] will not be considered. The major concern is the coding processes which take place centrally in the human performer.

In the literature, the distinction between code and coded information is not so precise as previously stated. Broadbent (1971), Melton and Martin (1972) and Warren (1972) define the code as the performer's memorial representation of the external world, or an internal representation of the external stimulus event.

The definition is actually what will be called, in this study, the coded information. Using the terminology from Johnson, (1972) a code may be regarded as an opaque container . That is, the code represents the information rather than being the information itself. The implication, then, is that there is no reason that the code should reflect in any way the nature of the content it represents. Therefore, if there is any transformation of the information in the stimulus-as-presented, it should be necessary for the subject to adopt an entirely new code for that information.

By the application of a code to the available information, coded information results, which is the internal representation of an external stimulus. It should be noted that the stimulus-as-coded is not necessarily a point-by-point representation of the stimulus-as-presented. In fact, a code is used on the external information with the intent of representing it in the simplest, most economical way possible and may be regarded as a device for organization and possible reduction of information contained in the stimulus.

The coding process can the[illegible] defined very generally as the application of a code to incoming information for the purpose of transforming it into an efficient coded form. Posner and Boies (1972) suggest that the coding process involves the contact of the external stimulus with the appropriate representational code that is available in memory. This explanation can be further elaborated by considering it within the Atkinson and Shiffren (1968) two-structure model of memory. They differentiated between the structural aspects of storage and the process of memory, postulating a short-term store (STS) and a long term store (LTS) with the memory processes involving both systems. More specifically short term memory would involve both STS and LTS. Under the assumptions of these two independent but interacting systems, coding processes could be viewed as selective alteration and/or addition to the information in STS, as a result of a search in LTS (Atkinson and Shiffren, 1968). This then, accounts for the role of past experience in the processing of information.

To put the concept of coding into the framework of the information processing I/O model, we can attempt to briefly develop the sequence of events that transforms the information-as-presented into the information-as-coded. It has already been assumed that peripheral coding takes place in order for information to enter into a short term sensory storage. The nature of the information can be termed precategorical or unidentified. The next step is to input the information into the STS. This information flow may entail a process of categorization and/or identification in order to optimize on the nature of the STS. This may necessitate the interaction of LTS with STS (storage search) which was previously defined as a coding process. The nature of the process will be heavily dependent on both input and output demands elicited by both the information itself and the response or task requirements.

Although briefly elaborated, the major implication of the coding concept in the information processing framework is the flexibility it brings to that model. The result is a more dynamic view of the performer who is not the pawn of environmental stimulation, but rather can selectively organize and optimize on that information available to him.

(b) Types of Coding Processes

Although there is not as yet a well defined taxonomy of coding process within the learning-memory literature, the application of the coding concept to specific research areas has delineated three specific processes. The functionality of an encoding process was initially highlighted by Underwood's (1963) work on stimulus selection, introducing the notion of the transformation of the nominal stimulus into a functional stimulus. The uncertainty relationship between the stimulus-as-presented and the stimulus-as-coded became more distinct and was generalized by Martin (1968) in his concept of stimulus encoding variability. The encoding notion is very general and is usually defined as transformation of information from one form or state to another without alteration in the actual information content within the human organism (Underwood, 1972; Postman and Burns, 1973; Kulhavy and Heinen, 1974).

The second process, which is functional in terms of its implications for learning memory theory, is recoding. The constraints in function are more specific for this process, since the term infers that the information is initially coded and by the application of different codes takes alternate form. Keele (1973) postulates that the recoding is cross-modality in nature and would allow for matching of stimuli between modalities and for coding a response in a different modality to the input. This has been substantiated in studies by Tversky (1968) and Pavio and Beggs (1974). Although this statement may be correct, it does not necessarily describe the only type of recoding that can take place. Assuming that codes have a hierarchical nature (Bower, 1967a), it would be logical to postulate that any change in the code structure of a stimulus from one level on the processing scale to the next involves a recoding process. This hierarchical code scheme concept (Craik and Lockhart, 1972; Johnson, 1972) would necessarily involve recoding although this is not to say that parallel coding could not exist (i.e. two types or levels of coded information existing for one stimulus). Johnson (1972), also supports this view of recoding and we may conclude that, in depth of processing terms, recoding could take place horizontally, across codes, and between modalities (Keele, 1973) or vertically between codes and within modalities (Postman and Underwood, 1974; Atkinson, Herrmann and Wescourt, 1974).

The last research defined coding process is decoding. Johnson (1972) defines it as a process by which coded information, when recovered, is formed into the information it represents. The concept is closely tied to the processes of retrieval and retrieval cue efficacy (Solso, 1974). Once encoding has taken place and the coded material has undergone processing and storage, some type of decoding is generally hypothesized for the information to be recalled (Johnson, 1974; Postman and Burns, 1974).

Decoding, however, cannot always be considered the reverse of encoding or as Solso (1974) states, the mechanisms for putting certain information into the processing system are not necessarily reversed when that information is recalled. In general, decoding can be termed the transformations made on the coded information for retrieval from memory.

Johnson (1970, 1972) has applied the concept for the explanation of the effects of serial response learning.

To time-base, in a very simplistic manner, these processes for a single stimulus within the information flow-through model, they would occur in succession, encoding the stimulus in its initial functional form, then possible recoding (horizontally or vertically and then decoding when necessary for the formulation of a response.

(c) Types of Codes .

If we accept the assumptions made by Johnson (1972) in his opaque code theory, the exact nature of the code cannot be fully defined. However, it is possible to say something about the types of codes used when the stimulus is stored based on its various properties. In other words, the codes themselves are not self-defined, but can be defined by the nature of the coded information, the nature of which is inferred from experimental investigation of recall fidelity and recall errors.

An alternate way of classifying types of codes is to categorize each one based on the process and/or processing system it is associated with. These two systems of classification are neither synonomous nor mutually exclusive, so both will be reviewed.

The first classification method gives the codes a label depending on the type of information they are associated with. For example, there have been defined in the literature physical codes (Attneave, 1972; Melton, 1974), temporal codes (Bartlett and Tulving, 1974) visual and verbal codes (Tversky, 1968) graphonomic and phonemic codes (Meyer, et al., 1974) and language or name codes (Posner et al., 1969; Liberman, Mattingly and Turvey, 1972).

Posner et al., (1969) made a code classification based on the encoding of physical attributes of the stimulus (physical code) and encoding on the conceptual attributes of the stimulus, either phonetic, auditory, articulatory or linguistic (name code). His study indicated that an identity match based on physical codes (e.g., between A and A) as measured by RT was faster than an identity match based on name codes (e.g., between A and a).

Posner concluded that a physical code could be handled or stored in a sensory register and the identity match could be made directly on this information. The identity match based on a name code would, be postulated, entail a further process to encode into a verbal label which would take time.

This explanation ties codes-based-on-attributes to codes-based-on-processes. Code types have been defined as primary and secondary (Bower, 1967a; Galanter, 1967; Posner et al., 1969). By this scheme, the primary code forms the stored representation upon which the recognition process is based. It is also assumed that the primary code is based on the physical attributes of the stimulus and their corresponding values. This is very similar to the notion of a physical code. The secondary code appears to involve a labelling or categorizing process and seems to be based on the more semantic or conceptual properties of the stimulus (Bower, 1967a).

Juola, Taylor and Young (1974), differentiating codes in terms of the encoding processes with which they are associated, proposed perceptual and conceptual codes. They suggest that the perceptual code forms the representation that is constructed during the analysis of the stimulus (similar to a primary code). The perceptual code is then mapped to a specific location in LTM with perceptual codes of similar items. This mapped representation, together with information stored cross-categorically, form the conceptually-coded information, the organization supplied by a conceptual code (similar to a secondary code).

This type of code scheme is also supported by Atkinson, Herrman and Wescourt (1974). One of the major assumptions underlying these code schemes is the two-structure model of memory (Atkinson and Shiffren, 1968) which allows for interaction of the STS and LTS in both short-term memory and long-term memory.

To develop a framework for types of codes for this study, we will incorporate both the forementioned code descriptions.

Primary or perceptual codes will be associated with encoding processes in memory prior to STM. However, the notion of a physical code, as proposed by Atkinson, Herrman and Wescourt (1974), is extended to refer any code utilized in the processing of physical attributes of the stimulus regardless of the encoding stage (Hall, 1974).

To state that certain types of codes do not require central processing would be, at this time, an unsubstantiated statement. However, Posner's et al (1969) results would indicate that more central processing time and, perhaps, capacity is required for identity matches based on conceptually-coded information.

The terminology, as described for this study, is consistent with contemporary models of memory such as Restle (1974) and Posner and Warren (1972). Posner and Warren (1972) postulate that what is stored in memory are concepts and traces which correspond to conceptually and physically coded information. Restle (1974) supports the same notion although his terminology for conceptual and physical is semantic and episodic with reference to memory.

As was stated previously, to describe a type of code, one must, because of its symbolic nature, rely on inferences based on the properties of the coded information. In summary, we may state that code types are hierarchical in nature; the level of the hierarchy corresponding to the level of processing in which the coding process takes place. Diagrammatically, the development of code types may take the following form:

		Peripheral Code
STSS	Primary	Precategorical
STS		Perceptual Code (Physical)
+	Secondary	
LTS		Conceptual Code (Physical and Semantic)

The Process of Encoding in the Information Processing Model

The purpose of this section is to consider the encoding process in order to relate it to the functioning of the memory structures of STS and LTS. To determine what is stored in memory, it may be necessary to examine the functional limitations of the processes used to store the material and the functional capacities of the systems in which it is stored.

(a) Attributes of the Encoding Process

(i) Time based:

The encoding process can be time-based. The time required is not, however, an absolue value but will vary inversely with the complexity, difficulty and type of stimulus. Newell (1972) indicated that the time required for the encoding process alone would be minimal and an internal representation would be available several hundred milliseconds after the stimulus presentation. Assuming that the performer adopts an optimal coding strategy (Welford, 1974), the time required would vary also with task demands. Buschke (1966, 1967), indicates that recall task-demands influence the manner in which items are encoded in STS. If the output demands are not known, the subject will adopt encoding strategies which will include the maximum information for retrieval and readout, (Buschke, 1968). Time required for processing and amount of information processed are then directly related.

(ii) Encoding variability:

Just as there will be variations in the time-base for the encoding process, it is hypothesized that due to similar factors related to the nature of the input and task demands, there will be variability in the form of the process itself (Martin, 1973). Bower (1972) supports this notion basing his hypothesis on the stimulus sampling theory proposed by Estes (1959). The variations in the encoding process will not be elaborated upon here but it is sufficient to state that the process is not fixed in nature but will adopt, in an optimal manner to the conditions and constraints set by task and the external environment.

(iii) Encoding specificity hypothesis:

Tulving and Thompson (1971, 1973) hypothesize that the effectivness of cuing at recall is strongly determined by the specific encoding of the to-be-remembered item at the time of storage. That is, no cue, however strongly associated with the to-be-remembered item, can be an effective cue unless the to-be-remembered item is specifically encoded with respect to that cue at the time of storage. The results of the Tulving-Thompson study indicates a better retrieval with weakly associated cues presented with the TBR items at input compared to strongly associated cues not presented at the input stage.

In episodic memory, (Tulving, 1971) it is hypothesized that properties of the trace of a word event are determined by specific encoding operations performed on the input and that it is those properties that determine the effectiveness of any given stimulus as a retrieval cue for that event.

(iv) Attention requirements:

The assumption is that attention requirements infer conscious operations such as those proposed by Posner and Klein (1973). If a processing operation demands attention, it is assumed that it demands, therefore, part of the central processing capacity.

To state whether or not the encoding process is a conscious operation, is not possible except under specific conditions. If we are to assume that encoding processes may be, in part, subject controlled (for example a mnemonic device) or optional, then postulating attention requirements is likely necessary. However, it is also recognized that an encoding process is automatic, in terms of transforming the nominal stimulus into a functional internal representation. In this instance, there is no necessity for the components of the coded information to be conscious or reportable (Melton and Martin, 1972; Posner and Boies, 1972).

The attention demands will also depend on the nature of the stimulus and the task demands which governs the encoding strategy. Melton (1973) summarizes this very well:

> "The components of the code may be automatic presumably based on built-in organismic properties or highly overlearned specific habits and structures or information processing skills, or optional, as in rehearsal and recoding operations and the generation and testing of "hypotheses" tailored to the requirements of the tasks." (p. 509).

(v) Encoding processes:

Serial versus parallel processing is one point of debate which is carried over from research on central capacity and the limited channel hypothesis (Rabbitt, 1969). As Garner (1970) states:

> "Why must the organism do one or the other? Very probably it can do neither, depending on the task and the stimuli. And even as likely is that the organism does both, not in the sense of doing one then the other, but in the sense of doing both simultaneously." (p. 350).

If, as was previously stated in this review, that codes are hierarchical in nature (Craik and Lockhart, 1972) and that it is possible to have coded information available about the one stimulus at more than one level, then a parallel processing view could be justified.

(b) Functions of the encoding process

To restate a point mentioned previously, the coding concept is a useful approach to describing the functions and structure of the human performer because it has great flexibility. We are able, within the constraints of the theory, to explain most resultants of the information flow through the system.

A basic theoretical property of a code is economy which by organization allows for maximum information representation in minimum coding terms (Welford, 1974). Therefore, by inference, the basic function of the encoding process would be organization of available information such that the maximal amount of information is represented necessary for the ensuing processes. It appears that the function of encoding can only be described by what is required by the system. Since this study deals directly with tasks requiring retrieval processes, the function under these task demands will be discussed.

Bellezza and Walker (1974) stated that the main coding problems will appear if information is to be stored in and retrieved from LTS, as there is little problem of accessibility from STS. This point arises from Mandler's (1967) distinction between availability and accessibility in memory systems. Therefore, the major function of the encoding process, for LTS in particular, would be organization for the facilitation of recall of information, such that the necessary coded information is not only available (i.e. stored in the memory system) but accessible (i.e. the information ca be decoded and retrieved from the memory system).

How the function of the process is carried out remains as a problem. Various researchers have proposed different transformational/organizational processes to describe encoding. Bower (1972) views encoding as elaboration while Feigenbaum (1967) conceives it as information reduction. As well, Bower (1972) contends that encoding can be viewed as stimulus selection, rewriting and componential description. In line with this multi-process conception of encoding, Atkinson and Shiffrin (1968), state that the encoding process is select alteration and/or addition to the information in STS as a result of search of LTS. Kulhavy and Heinen (1974) divide encoding into two processes: unit transformation and order transformation. Unit transformation appears to be similar to Bower's (1972) elaboration and order transformation is the sequencing and grouping of information. In addition to these, there is the basic view of encoding as a transformation of information from one form to another without alteration in the actual information content (Underwood, 1972; Ellis, 1973).

Actually all of these views can be handled nicely within one classification system, if we consider first that encoding is, in fact, an information processing task. Posner (1964) proposed a taxonomy of information processeng tasks, distinguished on the basis of output requirements. The taxonomy consists of:

(a) a conservation model in which all stimulus information is preserved

(b) a reduction model in which a series of data points are mapped into one point, and

(c) a creation or elaboration model in which a single point is mapped into more than one point.

(1) The conservation model has as its objective to preserve the information for complete transmission. This would be most efficiently handled by an organizational encoding process essentially the same as that proposed by Mandler (1967) in which consistent relationships are specified among members of the set and when information is grouped, classified or chunked for ease of data handling (Millar, 1956).

(2) The reduction model suggests a selective process of data handling wherein only certain aspects of the stimulus are retained. This is related, in part, to research on stimulus selection in which it is hypothesized that the subject need not process all aspects of the stimulus array (from the STSS) for effective storage and recall, assuming that the processed attributes are relevant cues (Garner, 1970). Newell (1972) calls this interval representation of a part of a stimulus. Determination of relevant cues may be a product of the response demand and may in fact be related to response organization (Melton, 1973).

There is a slight problem as a result of Underwood's (1963) distinction of the functional (stimulus-as-coded) versus the nominal (stimulus-as-presented) stimulus. Some researchers (Martin, 1972; Postman and Burns, 1973, Bower, 1972) have considered stimulus selection as an encoding process leadi to the formulation of the functional stimulus (Hall, 1974). However, stimulus selection which is in fact a reduction of information should be thought of as attention process occurring primarily due to a response bias or an optimizing stimulus filtering process (Rudy, 1974). Ellis (1973) defines the difference between stimulus selection and stimulus coding by focusing on the nature of what is transformed:

> "...stimulus coding usually refers to a transformation of stimulus input into some hypothesized representation, whereas stimulus selection refers to the fact that the subjects may select some fraction or portion of the stimulus, once it is perceived."

He (Ellis, 1973) further states that stimulus selection is generally a reduction process with the functional element being definable. The encoding process, however, was previously defined as being a reduction, a conservation or an elaboration process and the resultant product remains an inference in that its properties retain a hypothetical status (Hall, 1974). Therefore, the stimulus selection process may be a result of what the information processing system is willing to receive from the external stimulus array, whereas stimulus encoding is a result of the optimal manner of handling the data within the system.

(3) The elaborative or creative model suggests a process wherein information is added to the information selected for encoding. The function of such a process may provide better accessibility to that information on retrieval. Millar (1956) suggested that as the number of codeable attributes increases for a stimulus, (to an optimal level) recall fidelity will increase. So this process could be regarded as retrieval facilitation. It is necessary to postulate the interactive memory structures propoed by Atkinson and Shiffren (1968) account for such an elaborative encoding process.

It is no necessary to re..rd these processes as working in isolation. Either conservation or reduction may be in effect in the transfer fr.. STSS to STS and further elaboration is then carried out as a rehearsal strategy for the maintenance of the information for STM operations.

Location of the encoding process

In this study peripheral and precategorical coding processes are disregarded and the discussion is limited to encoding processes in a system where retrieval from memory is implicitly or explicitly required. This is not to say that encoding does not occur in a system when recall or recognition is not a prerequisite. However, it is necessary to differentiate those processes required for memory from those required for perception. Because of the flexibility of the coding systems there would, undoubtably, be different funtional aspects and, perhaps, use of different structures for a memory as opposed to a perceptual task (Gibson, 1967).

Therefore, by these constraints we can limit the functioning of the encoding processes to STS and LTS with the further assumption that operational memory may, in specific instances include the use of the central processing unit (Hunter, 1964).

The interactive but independent systems of STS and LTS have been previously described (Atkinson and Shiffren, 1968). The encoding process will, then, transform information (stored in its precategorical state) from STSS for storage in STS, which could constitute the development of the initial internal representation (Melton and Martin, 1972).

Further recoding would constitute contact of this initial encoded information with its representation in LTS (Posner and Boies, 1972), which may be termed the rehearsal process necessary for the development of the STM operation. Warren (1972) found that the category designation of a word was activated as part of the word encoding and postulates that encoding included activation of previously established units in memory.

This terminology is consistent with the Posner and Boies' (1972) view. However, Kahneman (1973) uses a similar concept (unit formation) in describing a pre-perceptual stage requiring no attention or effort and resulting in activation of a recognition unit.

So there is an initial encoding process operating between STSS and STS and a subsequent process between STS and LTS for the purpose of permanent storage (formation of that stored information constituting the memory unit activated in Warren's (1972) model).

As for a sequencing base for these two suggested information transfers, it is possible as Bower (1967b) suggests that the information is accessible from more than one storage system at a time. The difference may lie in the encoding procedures, since several studies in verbal recall have shown that retrieval from STS may operate mainly on a physical code as opposed to operations on a semantic code in LTS (Broadbent, 1971). This is not to imply that both codes may not exist in both systems but it appears logical to infer that one code may be more difficult or of optimal quality in reference to one or the other storage systems (Girouard, 1974).

APPENDIX B

REVIEW OF MSTM PROCESSES

The following section reviews briefly the major research conducted on the storage and loss of K information in MSTM. Each section is categorized by experimental procedure and subsequent effects.

Effects of An Unfilled Retention Interval.

The question of whether or not K is lost as a function of time is a crucial one for the development of a theory of STMM. In this respect, contradictory evidence exists. We will review separately those studies which support and those which do not support the notion that a motor memory trace will decay over time.

In studies using simple linear positioning movements, loss of information has been found for retention intervals, (RTI), of 80 sec (Adams and Dijkstra, 1966), 5 and 90 sec (Adams et al., 1972) and 90 sec (Burwitz, 1972). The Adams and Dijkstra study varied RTI from 0 to 120 sec but found that errors at recall only increased up to 80 sec. The dependent variable for all studies was the absolute error (AE) and all movement cues were controlled for except distance information and location. Unfortunately, the dependent measure of AE does not tell the experimenter anything about the nature of the recall errors.

In a similar task, but with distance as the only reliable cue, decrement over time has been observed for a RTI of 80 sec (Montague and Hillix, 1968), 30 sec (Stelmach and Barber, 1970) and 90 sec (Marshall, 1972). AE was the dependent variable used in these studies. In addition, Marshall (1972) isolated decrement overtime for both movement recall and movement recognition.

Five studies have used a simple angular positioning movement. With similar RTI and the distance plus location cues, decrement overtime was found by Stelmach (1969a; 1969b) and Montgomery (1970). In the latter case, a much shorter RTI was used (10 sec) and the significant effect due to time was found for variable error (VE) only, AE and constant error (CE) not affected by the delay. Using distance and the only reliable cue, Posner and Konick (1966) and Posner (1967a) found decaying effects. In the latter, this effect was also found for K location cues, although that error measure tended to be smaller for K location than for K distance. Finally, Stelmach (1970), using K location only, found a marked effect due to time.

Pepper and Herman (1970), in the second experiment of a series of four, found a significant decrement in recall due to the delay condition. They used application of forces as the motor task to-be-recalled and effects were observed using CE as the dependent measure.

The following studies show no decay over time and provide contradictory evidence for the decay theory of forgetting.

Using a simple linear positioning task and distance plus location as the movement cues, Roy and Davenport (1972) found no evidence of loss of information as a function of RTI of 5, 15, and 50 sec in the former case and 15, 60 and 90 sec in the latter. Schmidt (1968) and Marteniuk (1973) obtained similar results for an angular positioning task and location plus distance as the movement cues available to the subject. Pepper and Herman (1970), in the first experiment (force reproduction) found no significant decrement in recall for an unfilled RTI for 4 to 60 sec for both AE and CE.

Hughes (1969), Wilberg (1969) and Keele and Ells (1972) found no decrement as a function of time for RTI of [illegible] sec in the first cases and 7 sec in the latter. In all experiments, a simple rotational positioning movement was used as the input and location was the primary cue.

Using a complex angular positioning movement for which distance plus location were available, Sharp, (1971), Wilberg and Sharp (1970) and Salmela (1972) found no decrement for an unfilled RTI of 15 sec in the first two cases and 20 sec in the latter case. The apparatus used in these experiments was a joy-stick (vertical axis), moveable in two dimensions, and the experimental design involved the serial learning of eight successive positions with ordered recall.

Although the results of these reported studies appear to be contradictory in their evidence, upon comparison, there are definite differences in the procedural methodology that can account for them.

There seems to be a difference associated with the nature of the task involved in the MSTM experiments. Simple linear or angular positioning tasks seem to be more susceptible to a decay function than do simple rotational or complex angular positioning movements. One explanation could be that the types of cues available in these tasks were differentially encoded and certain encoded information is less susceptible to loss perhaps because it has a more robust code.

To elaborate, K distance cue appears to have a much more unstable memory trace than the K location cue since most of the studies have used K distance found decaying effects. This would give support to Marteniuk and Roy (1972) and Marteniuk (1973) who found that, averaged over RTI, reliance upon K distance gives poorer reproduction scores than reproduction of K location. It appears that when location cues are the only available K cues, K seems to be maintained at least for the first 10 to 15 sec. However, when distance is the only cue available, loss of information occurs well within that interval. This also supports a differential encoding notion.

Concerning those studies in which both distance and location cues are available, it may well be that the S uses the most functional cue available to him which may be the location cue. As a result, reproduc[illegible] of both cues as an integrated unit may lead to a reproduction whose goodness is highly dependent on how well he encoded and stored the location information.

Rehearsal.

Rehearsal is the process that can occur during the retention interval. On this point, Posner (1967b) mentioned that: "once the material has been encoded (for verbal material at least) by the S, it may be practiced by him. In this sense, rehearsal may be thought of as being related to learning." (p. 267). Different attributes can be assigned to rehearsal. Waugh and Norman (1965) see rehearsal as an opportunity for information in STS to be elaborated with contact with associated information in LTS. For some kinds of tasks where covert speech is not involved as a means of rehearsal, something akin to concentration may be appropriate to describe one attribute of rehearsal (Posner, 1967b). Furthermore, one attribute of concentration may be thought of as an opportunity to set up retrieval strategies or to encoded functional retrieval cues needed at the time of recall.

Concerning motor responses, two types of rehearsal may be possible: convert rehearsal (like the concentration described earlier) and overt rehearsal (i.e. practice trials of the tasks to be recalled or time spent on the location to be recalled). Regarding the effects of covert rehearsal (CR), the question of whether not CR facilities retention is not easily answered since it is related to the temporal effects already discussed. Studies which have found decaying effects during unfilled RTI will be said to support the notion the K is not, or only partially, rehearsable. On the other hand, studies which have found that preventing rehearsal by means of an interpolated task (IT) resulted in a decrement at recall will support the contention that motor responses are covertly rehearsable.

Wilberg (1969), for example, found that reproduction after a 10 sec. unfilled interval was as good as the immediate reproduction condition. In this study, the S had no specific instruction as to what to do during the RTI, except to wait quietly. Marteniuk (1973), among other experimental conditions, had one condition identical with that of Wilberg's but he asked the S to think, during the RTI, about the movement they would have to reproduce at the end of the interval. He replicated the data obtained by Wilberg (1969). In both cases, it was as if mental rehearsal was acting to postpone forgetting. However when a distractor task interpolated in a retention trail, the results are not always concordant.

On the other hand, there seems to be no doubt that overt rehearsal (OR) does facilitate recall of a motor response (Adams and Dijkstra, 1966; Stelmach and Barber, 1970; Marshall, 1972). In these studies, retention was found to be an inverse function of the number of overt repetitions. It might be of interest to note that the last two studies used

K location as the primary cue and that such cues were already found to yield much more viable traces that distance.

Pepper and Herman (1970) found that successive overt repetitions (1,3,7 repetitions) produced an increase, not a decrease of errors at recall. Since they used CE and by stating increased CE at recall they meant decrement of undershooting (i.é. getting closer to the target by less undershooting), their results are congruent with others already mentioned.

Montgomery (1970) compared directly the effect of OR (holding the handle of the apparatus at the criterion location for 10 sec.) and CR (rest quietly for 10 sec.). He found no difference using AE as the dependent variable although he found a significant decrease in CE and VE for the OR condition. In other words, OR produced a better recall (m precise and less variable) than CR.

If an information model of MSTM holds true, it would be predicted that the effectiveness of a period of rehearsal will depend, for the most part, upon the amount of information and type of information present in the STS at the time of rehearsal (Posner, 1967b). This supports the results of Salmela's (1972) study, in which he found that, using 2,4, or 8 serial positions and asking for an ordered recall of either 2,4, or all of the criterion movements, retention decrease as a direct function of the information load.

Retroactive Interference.

The effect of inserting an interpolated task (IT) into the RTI of the Brown-Peterson paradigm results in either: (i) an interference with the rehearsal process of the information to be recalled or, (ii) the memory trace of the interpolated learning may interact with the original memory trace, resulting in an associative interference (Posner, 1967b).

(a) Verbal IT:

Posner and Konick (1966), Posner (1967b) Williams et al., (1969) and Burwitz (1972) found that no difference exists between an unfilled RTI and a filled RTI. Since Posner and Konick (1966) and Williams et. al., (1969) found specifically that retention of K was totally independent of the amount of information reduction required in the IT, they concluded that the original KI was not occupying, to any extent, the central processing capacity at the time of rehearsal.

However, numerous studies have found that a verbal IT will disrupt rehearsal (Hughes, 1969; Wilberg, 1969; Pepper and Herman, 1970; Keele and Ells, 1972; Tannis, 1972; Roy and Davenport, 1972; Marteniuk, 1973; Laabs, 1973).

From these studies, only one tried to determine if the interference effect was related to the difficulty of the verbal IT, measured in terms of the amount of information reduction (Tannis, 1972). She found that the interference was unrelated to the difficulty of the IT. Laabs (1973) found that a verbal IT produced a strong interference effect on the retention of location information but little effect on the retention of distance information over that produced by the delay. It may be logical to postulate that location may be available to a higher encoding process such as semantic encoding whereas distance information is not.

(b) Motor IT:

Blick and Bilodeau (1963) reported a study frequently cited as supporting the fact that motor IT does not interfere with the retention of the primary motor task. However, since they provided the S with verbal knowledge of results at the end of each execution of the criterion task, their results can hardly be compared with the remaining studies in this area.

Stelmach and Barber (1970) and Sharp (1971) found that retention of a motor response was not affected by a motor IT. However, the results might be attributable to the fact that the IT may have entailed a very low attentional demand and allowed for some rehearsal. Circular movements of the finger of the hand opposite to the one used for the original task (Sharp, 1971) and movements of the same extent but in the opposite direction (Stelmach and Barber, 1972) were used as the IT in those two studies.

Stelmach (1970) used two levels of difficulty of motor IT: replication of the same extent of the movement presented

(0 bits of information reduction) and addition of two movement extents (1.86 bits of information reduction). He found interference effects for the former only, indicating that preventing rehearsal by means of a motor IT is possible by unrelated to the level of difficulty of the IT. Tannis (1972) also found the interference effects totally unrelated to the level of difficulty of the motor IT. She used ITs demanding either 0, 2.8, 4.6 or 5.6 bits of information reduction.

There are an increasingly large number of studies, on the other hand, which have found a motor IT is a possible source of interference. The properties of the interference effects identified by all these studies could be summarized as follows:

(1) Disengagement from the apparatus. The associated effects are interpreted in terms of loss of postural set (Boswell and Bilodeau, 1964), but have little to do with forgetting per se (Nacson and Schmidt, 1971). Generally, this factor is well controlled in the experimental procedures of the studies in this area.

(2) Reinforcement (number of repetitions) of the IT significantly increase the interference effects (Pa[illegible]ck, 1971).

([illegible] [illegible]oduction of the IT at the end of RTI is more [illegible]al to recall than when the IT is presented at the beginning of the RTI (recency effect), (Patrick, 1971; Stelmach and Walsh, 1973).

(4) Recency effects of the IT seem more detrimental than the number of reinforcements of the IT (Patrick, 1971).

(5) The more active the IT, the greater are the interference effects (Faust-Adams, 1972). This point should be viewed with caution since it contradicts the following points (6) and (7).

(6) The amount of interference is not directly related to the level of difficulty of the IT measured in terms of information reduction (Williams et al., 1969; Tannis, 1972; Kantowitz, 1974).

(7) The amount of interference is not directly related to the number of different IT (Roy, 1972).

(8) AE as well as CE on recall are sensitive to the effects of an IT (Stelmach and Wilson, 1970; Stelmach and Walsh, 1972; Roy, 1972).

In summary, these studies have had, as their major purpose, elucidation of the nature of forgetting of motor information from STM, by manipulating the nature of the interpolated task. Indirectly they could, also, indicate the nature of the encoded information stored in the STS and operated upon during the STM process. However, the results, as a whole, are clouded by methodological problems and any clear conclusions on the secondary purpose would not be possible at this time.

Possible Code Forms for K Information.

(a) Primary code:

This code forms the stored representation upon which the recognition process is based. For K this would most likely take the form of what Posner (1967b) called the kinesthetic image and would be represented on the basis of the functional physical properties. Accepting the concept of a familiarity index (Juola et al., 1974), and assuming that certain physical properties are more easily encoded, recognition could conceivably be easier (faster) based on that specific information.

(b) Secondary code:

To postulate a secondary code for K would be to accept the notions of (a) a motor STM process and (b) in the case of further encoding process (deeper encoding) a recoding of the primary code.

This secondary code could take the form of:

(i) semantic or verbal code:

Some evidence of this code strategy has been observed in several studies (Adams and Dijkstra, 1966; Posner and Konick, 1966) but this was not directly tested. Instead, it was a result of post analysis of reported S's strategies.

As Posner (1967b) reported, this strategy did not appear optimal since performance with the verbal aid was not significantly better than those who did not use it.

Colby's (1974) study looked at the effect of verbally encoding a sequence of 16 movements arranged in a serial pattern. The task consisted of inserting sequentially a stylus in one circle with one hand and another stylus in another circle with the other hand. In the first condition, the cues for the movement pattern were always present in the environment (the circles were colored and S's had to produce the same movement pattern, but using this time a verbal strategy. They had to memorize first the movement pattern by "right hand, same hand, other hand, same hand, etc....". Using different S's for each of these two conditions in a A-B, B-A transfer paradigm, she found that S's having the external cues (colored circles) were faster and made fewer errors than S's having to verbally encode the movement pattern. The improvement over trials indicated that the S's may be using the verbal labels as mediators. But this still does not indicate why.

Shea (1977) investigated the effects of a verbal label on MSTM. He found that the provision of a relevant label at the presentation of a criterion position resulted in greater accuracy at recall, (CE, AE and VE) as opposed to the provisions of an irrelevant label or no label at all. He also found that he could bias recall in the direction of a misleading label.

As Girouard (1974) has pointed out, this verbal encoding strategy may work well under specific conditions but would appear to have little value for well-integrated continuous motor acts where there would appear to be little time for retrieval and decoding of verbally coded information, only to be encoded again into the K it represents.

(c) Visual code:

Although not previously discussed, a recoding of the primary K to a visual image would deem it a secondary code. As an efficient code itself, visual imagery appears to be superior to the use of K. For example, vision plus kinesthetic reproduction tasks result in better performance than K alone (Posner, 1967b; Wilberg, 1969). The superiority of the fidelity of the visual system is also apparent in a cross-modality matching task where K to visual matches are better than visual to K (McClements, 1972).

Both the studies (Posner and Klein, 1974); and Wilberg and Girouard, 1974) showed a bias towards available visual information over available K information.

The visual recoding may take the form of a mediation code or as a visual image (Neisser, 1967).

A study by Diewart (1975) investigated the possibilities of a visual code associated with movement information. Four different types of delay intervals were used: (1) immediate reproduction, (2) 30 sec., mental rehearsal, (3) 30 sec., motor interfering activity and (4) 30 sec., visual interacting activity. For both types of interferring activities, a comparative judgement was used in which the S's were required to judge which of the standard or the comparator was shorter. The S's made as many comparative judgements as they could during the 30 second retention interval.

The results indicated that when distance information was the only reliable cue, both the motor and the visual interpolated task interferred with the access to recall of the criterion movement but to a much more significant extent with the motor IT. He concluded that distances were coded in a kinesthetic store only and did not have any appreciable visual consequences. On the other hand, since location information was the most affected by the visual IT, he concluded that this type of information was stored in an integrated store based on both visual and non-visual (kinesthetic) codes. The results were interpreted as being in agreement with Connelly and Jones (1970) and Millar (1972) who hypothesized that some movement information can be coded in a visual and/or a visual-K store.

In summary, it may be possible to recode some K with a visual code, by means of which the original K might be retrieved from STS or LTS.

(d) Conceptual code:

These types of codes imply categorization and classification of the information for ease of location in LTS (Warren, 1972). Activation of the unit (from Warren's definition) could lead to elaboration of the information in STS. The fact that movements can be classified in terms of some of their physical properties allows organization and categorization of the movement types and use of "conceptual tags" such as fast-slow, long-short, etc., to store them in memory. This follows Mandler's (1967) subset membership idea.

The use of such a code for movement would be highly dependent on the number of dimensions available in the movement set and the organizational proprerties of the set. Nacson, Jacger and Gentile (1972) found that non-instructed <u>S</u>'s generated their own subjective organization of the stimuli to be produced. The major indication was the constant error values which revealed three categories of movement lengths. In an alternate condition, conceptual rules were given to the _ s, where movements were organized into 5 distinct categories. The results showed that the <u>S</u>'s were quite effective at using those categories. This study indicated that a conceptual recoding for K should be manifested in the form of the retrieval of the input information as the <u>S</u>'s were free to recall in what they determined as the most optimal way.

APPENDIX C

STIMULUS MATERIALS[1]

FOR EXPERIMENT I AND II

Movement Direction[2]	Movement Attributes		
	Start Location[3]	Distance (CM)	End Location
Left to Right	15	18	33
	18	9	27
	21	33	54
	24	6	30
	27	12	39
	30	15	45
	33	30	63
	36	9	54
	39	27	66
	42	24	66
	45	12	57
	48	15	63
	51	9	60
	54	6	60

Movement Direction[3]	Movement Attributes		
	Start Location[2]	Distance (CM)	End Location
Right to Left	54	18	36
	51	9	42
	48	33	15
	45	6	39
	42	12	30
	39	15	24
	36	30	6
	33	9	24
	30	27	3
	27	24	3
	24	12	12
	21	15	6
	18	6	15
	15	6	9

1. The difference between any two locations or any two distances is at least 3cm. Tannis (1972) found that the JND for a movement length of 17cm was approximately 2.5cm.
2. The stimulus material was presented in two different directions on the track and was

initated either from the far left "home" position or the far right "home" position. The probe set or recall was presented in the same direction as the stimulus set.

3. The location measure refers to the position on the linear track. Therefore the first stimulus set would be read as: start location at 15cm on the track, move a distance of 18cm to the end location at 33cm

PROBE MATERIALS

FOR EXPERIMENT I [1,2,3].

STIMULUS SET			NEGATIVE PROBE SETS		
Start Location	Distance	End Location	Start Location	Distance	End Location
15	18cm	33	21	12	33
			9	24	33
			15	24	39
			15	12	27
			9	18	27
			21	18	39
			21	24	45
			9	12	18
18	9	27	24	3	27
			12	15	27
			18	15	33
			18	3	21
			12	9	21
			24	9	33
			24	15	39
			12	3	15
21	33	54	28	27	54
			15	39	54
			21	39	60
			21	27	48
			28	33	60
			15	33	48
			28	39	67
			15	27	42

STIMULUS SET			NEGATIVE PROBE SETS		
Start Location	Distance	End Location	Start Location	Distance	End Location
24	6	30	27	3	30
			18	12	30
			24	12	36
			24	3	27
			30	6	36
			18	6	24
			30	12	42
			18	3	21
27	12	39	33	6	39
			21	18	39
			27	18	45
			27	6	33
			33	12	45
			21	12	33
			33	18	51
			21	6	27
30	15	45	36	9	45
			24	21	45
			30	21	51
			30	9	39
			36	15	51
			24	5	39
			36	21	57
			24	9	33
33	30	63	39	24	63
			27	36	63
			33	36	69
			33	24	57
			39	30	69
			27	30	57
			36	33	69
			27	24	51

STIMULUS SET			NEGATIVE PROBE SETS		
Start Location	Distance	End Location	Start Location	Distance	End Location
36	9	54	42	3	54
			30	15	54
			36	15	60
			36	3	48
			42	9	60
			30	9	48
			42	15	57
			30	3	33
39	27	66	45	21	6[illegible]
			33	33	6[illegible]
			39	30	69
			39	21	60
			42	27	69
			33	27	60
			42	30	72
			33	21	54
41	24	66	48	18	66
			36	30	66
			42	27	69
			42	18	60
			45	24	69
			36	24	60
45	12	57	51	6	57
			39	18	57
			45	18	63
			45	6	51
			51	12	63
			39	12	51
			51	18	69
			39	6	45

STIMULUS SET			NEGATIVE PROBE SETS		
Start Location	Distance	End Location	Start Location	Distance	End Location
48	15	63	54	9	63
			42	21	63
			48	21	69
			48	9	57
			54	15	69
			42	15	57
			54	21	72
			42	9	51
51	9	60	57	3	60
			45	15	60
			51	15	66
			51	3	54
			57	9	66
			45	9	54
			57	15	72
			45	3	48
54	6	60	57	3	60
			48	12	60
			54	12	66
			54	3	57
			60	6	66
			48	6	54
			57	12	69
			48	3	51
54	18	36	48	12	36
			60	24	36
			54	24	30
			54	12	42
			60	18	42
			48	18	30
			48	24	24
			60	12	48

STIMULUS SET			NEGATIVE PROBE SETS		
Start Location	Distance	End Location	Start Location	Distance	End Location
51	9		45	3	42
			57	15	42
			51	15	36
			51	3	48
			57	9	48
			45	9	36
			57	3	54
			45	15	30
48	33	15	42	27	15
			54	39	15
			48	39	9
			48	27	21
			54	33	21
			42	33	9
			54	27	27
			42	39	3
45	6	39	42	3	39
			51	12	39
			45	12	33
			45	3	42
			51	6	45
			39	6	33
			41	12	30
			51	3	48
41	12	30	36	6	30
			48	18	30
			42	18	24
			42	6	24
			48	12	36
			36	12	24
			36	18	18
			48	6	42

STIMULUS SET			NEGATIVE PROBE SETS		
Start Location	Distance	End Location	Start Location	Distance	End Location
39	15	24	33	9	24
			45	21	24
			39	21	18
			39	9	30
			45	15	30
			33	15	18
			33	21	12
			45	9	36
36	30	6	30	24	6
			42	36	6
			36	36	0
			36	24	12
			42	30	12
			30	30	0
			42	30	12
			33	33	0
33	9	24	27	3	24
			39	15	24
			33	15	18
			33	3	30
			39	9	30
			27	9	18
			27	15	12
			39	3	36
30	27	3	24	21	3
			36	33	3
			30	30	0
			30	21	9
			36	27	9
			27	27	0
			24	24	0
			36	21	15

STIMULUS SET			NEGATIVE PROBE SETS		
Start Location	Distance	End Location	Start Location	Distance	End Location
27	24	3	21	18	3
			33	30	3
			27	27	0
			27	18	9
			33	24	9
			24	24	0
			21	21	0
			33	18	15
24	12	12	18	6	12
			30	18	12
			24	18	6
			24	6	18
			30	12	18
			18	12	6
			18	18	0
			30	6	24
21	15	6	15	9	6
			27	21	6
			21	21	0
			21	9	12
			27	15	12
			15	15	0
			18	18	0
			27	9	18
18	9	9	12	3	9
			24	15	9
			18	15	3
			18	3	15
			24	9	15
			12	9	3
			15	15	0
			24	3	21

STIMULUS SET			NEGATIVE PROBE SETS		
Start Location	Distance	End Location	Start Location	Distance	End Location
15	6	9	9	3	9
			21	12	9
			15	12	3
			15	3	15
			21	6	15
			9	6	3
			12	12	0
			21	3	18

1. Positive probe set are exactly the same as the stimulus sets.

2. Note that in the "no match" condition, the probe set was presented such that there were an equal number of "no-match" items that were smaller in magnitude to the stimulus item and "no-match" items that were larger in magnitude than the stimulus item. In all cases, the difference was greater than one JND for linear movement as reported by Tannis (1972). Because of the sequential nature of the task, to produce a probe distance longer than the stimulus distance, or a probe location farther along the linear track than the stimulus location, the subject must, in essence, produce the stimulus item first and then move beyond it. In the majority of the cases, the subject recognized the probe as being larger than the stimulus item before the actual probe presentation was terminated. Therefore, in this condition (NM, probe>stimulus) the reaction time could not be collected since the probe phase was not terminated. If the reaction time, in these cases, was taken at the offset of the stimulus item, the same problem would be created for the "smaller than" probe items. As a result of the sequential nature of this linear task, reaction time data could only be collected on one half of the "no-match" trials.

3. For each stimulus set there are six possible probe sets, each one appropriate for a specific experimental condition. For example, in the firs set of probe materials, the set would be used as follows:

Attribute	#	SL	D	EL
Stimulus Set		15	18	33
Probe Set				
Type				
SL-	1	21 9		
EL-	1			39 27
D-	1		24 12	

Attribute	#	SL	D	EL
Stimulus Set		15	18	33
Probe Set				
Type				
S- D+	2	21 9	18 18	39 27
S+ D-		15 15	24 12	39 27
S- D-		21 9	12 24	33 33
S- E+		21 9	12 24	33 33
S+ EL-		15 15	24 12	39 27
S- E+		21 9	18 18	27 39
S+ D- E-	3	15 15	24 12	39 27
S- D+ E+ and		(Not possible since distance end location and confounded).		
S- D- E-		21 9	24 12	45 18

INSTRUCTIONS TO SUBJECT

EXPERIMENT I

The purpose of this experiment is to determine how fast and how accurately people recognize movement attributes. The movement attributes you will be dealing with are location or a specific point on a linear track and distance or the extent of the movement you will make on the linear track.

First of all position yourself in the chair comfortably in front of the raised platform. Place yourself so that you are in line with the screen in front of you. R h under the cover of the platform and grasp with your right hand the handle that is directly in front of you. This handle is attached to a slider on a linear track. Move the slider up and down the track as far as possible. To your left is a table and attached to it is a small box with two plexiglas keys on it. Place your left hand on the box with your index finger on the right key and your second finger on the left key. These keys will record the type of response you make and the speed of the response for recognition. Press the keys several times to determine the amount of force needed to depress them. The <u>left/right</u> key is a positive response and the left/right key a negative response.

In front of you is a projection screen. Instructions will appear on this screen so keep your eyes on it at all times.

Each trial will consist of two phases. In the first phase you will make a linear movement consisting of a start location, a distance and an end location. Let us stimulate the first phase. Place your hands in your lap. You will hear a buzzer followed by the command "left" or "right". This requires you to grasp the handle at the end of the track indicated by the verbal command. A five second interval will pass. A second buzzer will sound. This requires you to move the slider toward the middle of the track. Notice the two red lights located on the display board. When one of the lights comes on stop the slider. Where you stopped the slider is the start location that you have to remember. After 3 seconds a third buzzer will sound. This requires you to move the slider in the same direction. You will move the slider until the second red light comes on. Stop the slider at this point and you have made the distance you will have to remember and have stopped at the end location you will have to remember. After 3 seconds a fourth buzzer will sound and this indicates to you to return your right hand to your lap.

Let's do a run through of this first phase.

The second phase of the trial is similar to the first. Place your left hand on the box and your fingers on the response keys. A buzzer will sound for you to regrasp the slider. It is not necessarily at the end of the track so the easiest way to find it is to put your hand under the cover at the middle of the apparatus and move it slowly towards the end where you originally started until you encounter the handle. Then grasp it as before. A buzzer will sound indicating to you to move the slider until the first red light goes on. When this first light goes on you must respond by pressing on one of the plexiglas keys whether this start location is the same (positive) or different (negative) as the start location in the first phase. A buzzer will sound after you have responded and this will tell you to move the slider again in the same direction until you see the second red light come on. The second red light indicates the distance and the end point. If both are the same as the distance and end location in the first phase respond "same" or positive by pressing the positive key. If either or both are different respond negative. Be prepared to tell me which one was different if only one was different.

A final buzzer will sound and you will put both of your hands in your lap.

You were told that instructions would appear on the screen directly in front of you. These instructions will indicate to you what attribute(s) you will have to recognize. Some trials you will only have to recognize one of the three, on some trials two of the three and on other trials all three attributes. Half the time you will receive the instructions at the beginning of phase one and the other half of the time at the beginning of phase two. Look at the screen and I will give you some examples of the instructions.

Let's try one complete trial with the instructions at the beginning of phase one and then one trial with the instructions at the beginning of phase two.

Please remember we want accuracy and speed on the responses. It is very important that you do not guess but also we would like a fast response. Any questions should be asked now. We will do several practice trials before we start the actual testing. Thank you for your co-operation.

INSTRUCTIONS TO SUBJECT

EXPERIMENT II

The purpose of this experiment is to determine how fast and how accurately people recall movement attributes. The movement attributes you will be dealing with are location or a specific point on a linear track and distance or the extent of the movement you will make on the linear track.

First of all position yourself in the chair comfortably in front of the raised platform. Place yourself so that you are in line with the screen in front of you. Reach under the cover of the platform and grasp with your right hand the handle that is directly in front of you. This handle is attached to a slider on a linear track. Move the slider up and down the track as far as possible.

Instructions will appear on the screen in front of you so keep your eyes on it at all times.

Each trial will consist of two phases. In the first phase you will make a linear movement consisting of a start location, a distance and an end location. Let us stimulate the first phase. Place your hands in your lap. You will hear a buzzer followed by the command "left" or "right". This requires you to grasp the handle at the end of the track indicated by the verbal command. A five second interval will pass. A second buzzer will sound. This requires you to move the slider toward the middle of the track. Notice the two red lights located on the display board. When one of the lights comes on stop the slider. Where you stopped slider is the start location that you have to remembe. After 3 seconds a third buzzer will sound. This requires you to move the slider in the same direction. You will move the slider until the second red light comes on. Stop the slider at this point and you have made the distance you will have to remember and have stopped at the end location you will have to remember. After 3 seconds a fourth buzzer will sound and this indicates to you to return your right hand to your lap.

Let's do a run through of this first phase. A buzzer will sound for you to regrasp the slider. It is not necessarily at the end of the track so the easiest way to find it is to put your hand under the cover at the middle of the apparatus and move it slowly towards the end where you originally started until you encoun the handle. Then grasp it as before. A buzzer will sound indicating to you to move the slider to the point on the linear track which you feel is the same as the start location in phase one. Once you have established this location indicate this to me by saying "start location". A buzzer will again sound and you will move the slider until you think you have reproduced the distance from the start location as in phase one and the end location as in phase one. Once you have established the distance and location indicate this to me by saying "distance and end location". A final buzzer will sound and you will put your hand back in your lap.

You were told that instructions would appear on the screen directly in front of you. These instructions will indicate to you what attribute(s) you will have to recall. Some trials you will only have to recall one of the three, on some trials two of the three and on other trials all three attributes. Half the time you will receive the instructions at the beginning of phase one and the other half of the time at the beginning of phase two. Look at the screen and I will give you some examples of the instructions.

Let's try one complete trial wi[illegible]he instructions at the beginning of phase one and the[illegible]ial with the instructions at the beginning of phase two.

Please remember that we want you to reproduce the attributes as accurately as possible so take your time.

If you have any questions you should ask now. We will have several practice trials before we start the actual testing.

APPENDIX D

TABLE 6

FREQUENCY OF ERRORS AS A

FUNCTION OF ATTRIBUTE TYPE, CUE AND RESPONSE TYPE

EXPERIMENT I

	Pre Cue					Post Cue				
	M		NM		TOTAL	M		NM		TOTAL
ATTRIBUTE TYPE	No. of Errors	%	No. of Errors	%	%	No. of Errors	%	No. of Errors	%	%
S	4	4.2	3	3.1	3.6	6	6.3	7	7.3	6.8
S (D)	6	6.3	5	5.2	5.7	9	9.4	7	7.3	8.3
S (D)	6	6.3	7	7.3	6.8	5	5.2	8	8.4	6.3
S (DE)	5	5.2	6	6.3	5.7	7	7.3	4	4.2	5.2
D	13	13.5	16	16.6	15.1	28	29.1	25	26.1	27.6
(S) D	10	10.4	12	[illegible]	11.5	18	18.8	20	21.1	19.8
DE	7	7.3	5	5.3	6.3	9	9.4	7	7.3	8.3
(S) DE	9	9.4	8	8.4	8.9	9	9.4	15	15.6	12.5
E	8	8.4	7	7.3	7.8	9	9.4	10	10.4	9.9
S (E)	9	9.4	8	8.4	8.9	10	10.4	11	11.5	10.9

TABLE 7

MEAN REACTION TIME AS A FUNCTION
OF ATTRIBUTE TYPE, CUE AND RESPONSE TYPE

EXPERIMENT I

Attribute Type	Precue			Post Cue			Total
	M	NM	$\overline{X}$	M	NM	$\overline{X}$	$\overline{X}$
S	362.54	369.56	366.05	374.52	377.96	376.24	371.15
S (D)	418.21	395.96	407.09	425.98	417.25	421.63	414.35
S (E)	399.20	397.00	398.10	420.00	397.00	408.50	403.30
S (DE)	411.69	397.96	404.63	414.18	410.29	412.24	408.53
D	578.56	552.42	565.49	709.60	741.46	725.53	645.51
(S) D	354.48	273.76	463.97	566.69	585.31	576.00	470.74
DE	36[illegible].08	414.25	399.67	389.15	407.06	389.11	398.89
E	326.77	324.15	325.46	322.75	338.44	330.60	328.03
(S) E	329.30	327.00	328.15	320.00	329.00	324.50	326.33
(S) DE	374.94	326.00	350.47	319.21	352.83	336.02	343.25
TOTAL	3940.77	3877.76	4009.28	4262.08	4356.60	4300.37	4110.08
$\overline{X}$	394.08	387.78	400.93	426.21	435.66	430.04	411.01

TABLE

SCHEFFE'S* POST HOC COMPARISONS
ON ALL MEAN ERROR SCORES

EXPERIMENT II

	Pre S	Pre S(D)	Pre S(DE)	Post S(DE)	Pre E	Post S	Pre S(E)	Post S(E)	Pre (S)E	Post S(D)	Post E	Pre (S)DE	Pre DE	Post (S)E	Post (S)DE	Pre (S)D	Post DE	Pre D	Post (S)D	Post D
Pre S	.292	.458	.454	.458	.500	.542	.542	.542	.625	.667	.677	.706	.710	.792	.875	.917	1.08*	1.21*	1.58*	2.21*
Pre S(D)	.458																	*	*	*
Pre S(DE)	.456																	*	*	*
Post S(DE)	.458																	*	*	*
Pre E	.500																	*	*	*
Post S	.542																	*	*	*
Pre S(E)	.542																		*	*
Post S(E)	.542																		*	*
Pre (S)E	.625																		*	*
Post S(D)	.667																		*	*
Post E	.677																		*	*
Pre (S)DE	.706																		*	*
Pre DE	.710																		*	*
Post (S)E	.792																		*	*
Post (S)DE	.875																			*
Pre (S)D	.917																			*
Post DE	1.08																			*
Pre D	1.21																			*
Post (S)D	1.58																			*
Post D	2.21																			*

*Scheffe's Critical Difference = .694
p≤.05

TABLE

SCHEFFE'S POST HOC COMPARISON
ON ALL MEAN PT SCORES

EXPERIMENT I

	Post S(E)	Pre F	Pre (S)F	Post F	Post (S)DE	Pre (S)DE	Pre S	Post S	[illegible]	Post DE	Pre DE	Pre S(DE)	Pre S(D)	Post S(E)	Post S(DE)	Post S(DP)	Pre (S)D	Pre D	Post S(D)	Post D
Post S(E)	324.50	325.46	325.15	330.60	336.02	350.00	366.05	376.24	398.10	398.11	399.67	404.93	407.09	408.50	412.24	421.63	463.97	565.49*	576.00*	725.53*
Pre F	325.46																	*	*	*
Pre (S)F	328.25																	*	*	*
Post F	330.60																	*	*	*
Post (S) DE	336.02																	*	*	*
Pre (S) DE	350.00																	*	*	*
Pre S	366.05																	*	*	*
Post S	376.24																	*	*	*
Pre S(E)	398.10																	*	*	*
Post DE	398.11																	*	*	*
Pre DE	399.67																	*	*	*
Pre S(DE)	404.93																	*	*	*
Pre S(D)	407.09																	*	*	*
Post S(E)	408.50																	*	*	*
Post S(DE)	412.24																	*	*	*
Post S(DP)	421.63																	*	*	*
Pre (S)D	463.97																	*	*	*
Pre D	565.49																		*	*
Post S(D)	576.00																			*
Post D	725.53																			

*Scheffe's Critical Difference = 144.60
p≤.05

TABLE 10

MEAN RECALL ERROR SCORES (CE, AE, VE) AS A FUNCTION OF ATTRIBUTE TYPE AND CUE

EXPERIMENT II

Attribute	Precue			Post Cue		
Type	CE	AE	VE	CE	AE	VE
S	-0.34	2.15	2.23	+0.07	2.42	2.76
S(D)	-0.54	2.01	2.34	-0.43	2.66	2.65
S(E)	-0.68	1.81	1.77	-0.55	2.58	2.15
S(DE)	-0.10	1.69	1.69	-0.46	2.66	2.32
D	+1.72	3.38	4.18	+2.70	5.30	7.11
(S)D	+2.01	4.27	4.88	+2.75	4.77	4.60
(SE)DNR	+1.16	2.13	2.23	+2.25	4.78	4.88
D(E)	-0.74	5.04	4.23	+1.09	5.12	5.35
(S)D(E)	+0.61	2.06	2.36	+0.84	3.76	2.09
E	-0.74	2.17	2.50	-0.74	2.53	2.37
(SD)ENR	+0.91	3.18	2.82	-0.45	2.27	2.48
(S)E	-0.37	2.39	2.42	-0.40	1.77	1.57
(D)E	+1.08	1.68	1.57	-0.69	1.77	1.60
(SD)E	+0.26	3.28	3.19	+1.51	2.54	2.62

TABLE 11

SCHEFFE'S POST HOC COMPARISONS
BETWEEN ALL MEAN SCORES

EXPERIMENT II

	Pre D(E)	Post E	Pre E	Pre (D)E	Pre S(E)	Pre (S)E	Post (S)E	Pre S(D)	Post S(D)	Post S(E)	Post (SD)ERS	Post S(E)	Pre S	Post S	Pre S(DE)	Pre (SD)E	Pre (S)D(E)	Post (S)D(E)	Pre (SD)ERR	Post (D)E	Post D(E)	Pre (SE)DER	Post (SD)E	Pre E	Pre (S)D	Post (SE)DER	Post D	Post (S)D
Pre D(E)	-.74	-.74	-.73	-.69	-.65	-.66	-.55	-.54	-.40	-.43	-.37	-.35	-.34	+.07	+.10	+.26	+.61	+.84	.91*	+1.08*	+1.09*	+1.16*	+1.51*	+1.72*	+2.01*	+2.25*	+2.70*	+2.75*
Post E	-.74																											
Pre E	-.70																											
Pre (D)E	-.69																											
Pre S(E)	-.64																											
Pre (S)E	-.66																											
Post (S)E	-.55																											
Pre S(D)	-.54																											
Post S(DE)	-.46																											
Post (D)ERR	-.37																											
Post S(E)	-.35																											
Pre S	-.34																											
Post S	+.07																											
Pre S(DE)	+.10																											
Pre (SD)E	+.26																											
Pre (S) D(E)	+.61																											
Post (S) D(E)	+.84																											
Pre (SD) ERR	+.91																											
Post (D) E	+1.06																											
Post D (E)	+1.09																											
Pre (SE) DER	+1.16																											
Post (SD) E	+1.51																											
Pre D	+1.72																											
Pre (S) D	+2.01																											
Post (SE)DER	+2.25																											
Post D	+2.70																											
Post (S)D	+2.75																											

*Scheffe's Critical Difference = 1.54
$p \leq .05$

TABLE 17

SCHEFFE'S POST HOC COMPARISONS
BETWEEN ALL AE MEAN SCORES

EXPERIMENT II

	Pre (D)E	Pre S(DE)	Post (D)E	Pre S(E)	Post (S)E	Pre S(D)	Pre (S)D(E)	Pre (SE)DEP	Pre [illegible]	Pre E	Post (SD)EXP	Pre (S)E	Post S	Post E	Post (SD)E	Post S(E)	Post S(DE)	Post S(D)	Pre (SD)EXP	Pre (SD)E	Pre D	Post (S)D(E)	Pre (S)D	Post (S)D	Post (SE)DEP	Pre D(E)	Post D(E)	Post D
Pre (D)E	1.65	1.69	1.77	1.81	1.95	2.01	2.06	2.12	2.1[illegible]	2.17	2.27	2.39	2.42	2.53	2.54	2.59	2.66	2.66	3.18*	3.28*	3.38*	3.76*	4.27*	4.77*	4.78*	5.04*	5.12*	5.30*
Pre S(DE)	1.69																		•	•	•	•	•	•	•	•	•	•
Post (D)E	1.77																		•	•	•	•	•	•	•	•	•	•
Pre (E) E	1.95																		•	•	•	•	•	•	•	•	•	•
Pre S(D)	2.01																		•	•	•	•	•	•	•	•	•	•
Pre (S)D(E)	2.06																			•	•	•	•	•	•	•	•	•
Pre (SE)DEP	2.12																				•	•	•	•	•	•	•	•
Pre [illegible]	2.15																					•	•	•	•	•	•	•
Pre E	2.17																					•	•	•	•	•	•	•
Post (SD)EXP	2.27																					•	•	•	•	•	•	•
Pre (S)E	2.34																					•	•	•	•	•	•	•
Post S	2.42																					•	•	•	•	•	•	•
Post E	2.53																					•	•	•	•	•	•	•
Post (SD)E	2.54																						•	•	•	•	•	•
Post S(E)	2.58																						•	•	•	•	•	•
Post S(DE)	2.66																						•	•	•	•	•	•
Post S(D)	2.66																						•	•	•	•	•	•
Pre (SD)EXP	3.18																							•	•	•	•	•
Pre (SD)E	3.28																							•	•	•	•	•
Pre D	3.38																							•	•	•	•	•
Post (S)D(E)	3.76																									•	•	•
Pre (S)D	4.27																									•	•	•
Post (S)D	4.77																											
Post (SE)DEP	4.76																											
Pre D(E)	5.04																											
Post D(E)	5.12																											
Post D	5.30																											

*Scheffe's Critical Difference = 1.29
$p \leq .01$

TABLE 11

SCHEFFE'S POST HOC COMPARISON
ON ALL TE MEAN SCORES

EXPERIMENT II

	Post (S)E	Pre (D)E	Post (D)E	Pre S(DE)	Pre S(E)	Post (S)D(E)	Post S(E)	Pre S	Pre (SE)DNE	Post S(DE)	Pre S(D)	Pre (S)D(E)	Post E	Pre (S)E	[illegible]	[illegible]	Post (D)E	Post S(D)	Post S	Pre (SD)EPR	Pre (S)D(E)	Pre D	Pre D(E)	Pre (S)D	Post (S)D	Post (SE)DNS	Post D(E)	Post D
Pre (D)E	1.57	1.57	1.60	1.69	1.77	2.09	2.15	2.23	2.23	2.32	2.34	2.36	2.37	2.4[illegible]	[illegible]	[illegible]	2.62	2.65	2.76	2.82	3.19*	4.18*	4.23*	4.38*	4.60*	4.88*	5.35*	7.11*
Post (S)E	1.57																				•	•	•	•	•	•	•	•
Post (D)E	1.60																				•	•	•	•	•	•	•	•
Pre S(DE)	1.69																				•	•	•	•	•	•	•	•
Pre S(E)	1.77																					•	•	•	•	•	•	•
Post (S)D(E)	2.09																					•	•	•	•	•	•	•
Post S(E)	2.15																					•	•	•	•	•	•	•
Pre S	2.23																					•	•	•	•	•	•	•
Pre (SE)DNE	2.23																					•	•	•	•	•	•	•
Post S(DE)	2.32																					•	•	•	•	•	•	•
Pre S(D)	2.34																					•	•	•	•	•	•	•
Pre (S)D(E)	2.36																					•	•	•	•	•	•	•
Post E	2.37																					•	•	•	•	•	•	•
Pre (S)E	2.42																					•	•	•	•	•	•	•
Post (SD)ENE	2.49																					•	•	•	•	•	•	•
Pre E	2.50																					•	•	•	•	•	•	•
Post (SD)E	2.62																					•	•	•	•	•	•	•
Post S(D)	2.65																						•	•	•	•	•	•
Post S	2.76																							•	•	•	•	•
Pre (D)EPR	2.82																									•	•	•
Pre (SD)E	3.19																										•	•
Pre D	4.18																											•
Pre D(E)	4.23																											•
Pre (S)D	4.48																											•
Post (S)D	4.60																											•
Post (SE)DNS	4.88																											•
Post D(E)	5.35																											•
Post D	7.11																											•

*Scheffe's Critical Difference = 1.43
p<.01