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CODING PROCESSES IN ACTIVE AND INACTIVE MEMORY

DISSERTATION

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

by

Gregory Lee Peters, A.B., M.A.

* * * * *

The Ohio State University
1972

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TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	ii
VITA	iii
LIST OF TABLES	v
LIST OF FIGURES	vi
INTRODUCTION	1
EXPERIMENT I	
INTRODUCTION	19
METHOD	21
RESULTS AND DISCUSSION	28
INTRODUCTION TO EXPERIMENTS II AND III	42
EXPERIMENT II	
INTRODUCTION	43
METHOD	44
RESULTS AND DISCUSSION	46
EXPERIMENT III	
INTRODUCTION	47
METHOD	48
RESULTS AND DISCUSSION	51
GENERAL DISCUSSION	55
APPENDIX	65
BIBLIOGRAPHY	82

LIST OF TABLES

Table		Page
1	List of Conditions in Experiment I	29
2	Correct Match Reaction Times and Relative Errors of all Conditions in Experiment I	30
3	Average Reaction Times and Relative Errors in Experiment III	52
4	Average Reaction Times Including Both Correct and Incorrect Responses in Experiment I	69
5	Analysis of Variance of Reaction Time Data of Experiment I collapsed across Memory Load in Opposite Memory System	70
6	Analysis of Variance on Relative Errors in Experiment I	71
7	Subject's Rating of Visual Similarity for Stimulus Materials	72
8	Analysis of Variance on Match Reaction Times in Experiment III	73
9	Analysis of Variance on No-Match Reaction Time Data in Experiment III	74
10	Analysis of Variance on Relative Error Data in Experiment III	75
11	Reaction Times on which Analysis of Variance of Experiment I was performed	76
12	Reaction Times on which Analysis of Variance of Experiment III was performed	80

LIST OF FIGURES

Figure		Page
1	Data from Previous Experiments	13
2	Sample Series of Trials from Experiment I	26
3	No-Match Reaction Time as a Function of the Total Number of Items in Memory	32
4	Reaction Time as a Function of Central Processing Uncertainty and Memory System	35
5	Reaction Time as a Function of Memory System and Type of Match	37
6	Reaction Time as a Function of Central Processing Uncertainty and Memory System with Type of Match as a Parameter	38
7	Diagramed recoding operations	58

INTRODUCTION

The major issue to be dealt with in this paper is the coding of memory items as a function of the memory system in which those items are stored. The literature background will be dichotomized into two areas for purposes of clarity. The first will concern coding processes in a variety of short-term memory or recognition memory situations. Here it will be suggested that when it is economical or when the subject chooses to do so, the representations used are of a visual nature. The second area will be the literature dealing with differences between active and inactive (or short-term and long-term) memory. It will be noted that there are some discrepancies in this area. The present study is an attempt to combine the two major areas, explain some existing discrepancies in both areas and present a meaningful statement of coding processes as a function of the memory systems involved.

Coding Processes in Memory

Man has labeled most of his environment with names, symbols or other linguistic devices which not only enable him to ponder the objects around him but also to communicate with others about events and concepts. This verbal behavior has been explored by psychologists in an attempt to determine how man stores and uses information about his past for present or future reference. Verbal materials have been used for this purpose since Ebbinghaus' (1885) pioneer work in the experimental examination of memory. One hundred years of this type of research has promoted the notion that memory in verbal form is of much

greater relative importance than other nonverbal forms (graphic, tactile, etc.).

Many theories of information storage and retrieval (e.g. Atkinson and Shiffrin, 1968) have been based entirely on the registration, transfer and storage of linguistic or verbal information. Conrad (1964) demonstrated that error analysis for brief visual presentation and auditory presentation of letters results in positively correlated error matrices. He suggested that these errors reflect acoustic confusions thus, both modalities of presentation are presumed to lead to storage in a linguistic form. Such errors may reflect acoustic confusions or articulatory confusions (Hintzman, 1965, 1967) but presently these are not experimentally distinguishable (Wickelgren, 1969).

Examination of modality differences in the presentation of a memory list also suggests verbal coding. From Murdock's (1966) "ahistorical" position, if memory codes or traces are stored in linguistic or verbal form, then it should make no difference whether the item was presented in the visual or auditory modality - that is, the historical aspects of the stimulus (e.g. presentation modality) are irrelevant or lost in storage. If modality differences do exist in recall or recognition one explanation is that stimuli presented in the auditory mode are encoded more easily and/or efficiently. The empirical demonstration of the superiority of auditory over visual presentation in memory tasks (Laughery and Pinkus, 1966; Chase and Calfee, 1969; Murdock, 1966 and Craik, 1970) can also be interpreted as an indication that the visual input is recoded into phonemic form for storage. Unless it is instantaneous, the time required for recoding might be sufficient to

reduce the efficiency of the visually input material - thus, accounting for the superiority of auditory input. In the Sperling (1967) processing model, which is based on such a recoding concept, visual input is registered and transformed prior to its storage in the acoustic information store (AIS). Acoustic input is fed directly into this store thus, a recoding step is eliminated and processing is facilitated thereby.

The evidence for auditory superiority seems to indicate that verbal labels or names are the basis of the codes used in memory tasks. Another possibility, however, is a nonverbal memory representation which contains stimulus information that is not necessarily present in the verbal label. Visual presentation will be of primary concern here, so for purposes of definition Parkinson, Parks, and Kroll's (1971) "retention of appearance," Sternberg's (1966) "raw image," and Bregman's (1968) "graphic identity" are all synonymous with the author's concept of a visual code. The term 'image' will not be used because of its associations with dreams, hallucinations and other somewhat peripheral concerns (Neisser, 1967). The nature of the internal stimulus representation has become a matter of interest with the growth of the information processing approach to human cognitive activity. A debate has centered on the use of linguistic associates versus visual representation in binary character classification tasks (see Nickerson, 1970, for a review).

In an attempt to examine coding processes, Posner and Keele (1967) presented to their subjects two letters, which when viewed sequentially were judged as "same" or "different." These judgments were based on physical identity which occurred when two letters (AA) were identical

physically (Physical Match) or nominal identity which occurred when two letters (Aa) had only the same name. Posner has used the term "Name Match" but associational match will be used here as the result of evidence to be presented. Posner and Keele have shown that physical "same" matches are faster than associational "same" matches. The difference ($N-P = 80$ msec.) was interpreted as a difference in processing time for different "nodes" or levels. The assumption was made that a physical identity match is based on a comparison of codes representing only the visual information, while associational matches are based only on a comparison of verbal labels or names.

Posner and his co-workers have shown that the visual code manipulated in their studies is not of a sensory or iconic nature. Typically, brief sensory storage can be manipulated by changes of exposure duration, post-exposure field, luminance level and other factors. Posner, Boies, Eichelman and Taylor (1969) replicated Posner and Keele's (1967) study using a different exposure duration and luminance level. The similarity of the results suggested that sensory storage was not a factor in these studies. Also, even Posner and Keele's conservative estimate of the duration of the visual information is longer than most estimates of sensory storage.

Posner and Mitchell (1967) gave two possible explanations for the associational-physical match difference. First, physical matches could be made prior to associational matches, or second, both comparisons could occur simultaneously with the associational match taking longer to complete. An alternative explanation is that in the associational match condition (Aa) one item is recoded into the format of the other

and physical matches are then made. Swanson, Johnsen, and Briggs (1972) supported the hypothesis that the first item(s) is recoded not the final item (probe).

Posner and Keele (1967) demonstrated that physical matches are made faster than associational matches only when the delay between the two stimuli is less than about 1.5 sec. During this time physical matches become slower (associational matches do not become faster) suggesting a loss of this information or an increase in the potency of the associational matches relative to the physical matches. Further work (Phillips and Baddeley, 1971; Cohen, 1969 and Parks, Kroll, Salzberg and Parkinson, 1972) suggests that the estimate of visual information (N-P) lasting only 1.5 sec. may be an underestimate.

In summary, it seems that with the comparison of two successive stimuli the identity judgments are facilitated when physical identity exists. Such facilitation lasts for at least 1.5 sec. and probably as long as 6 to 9 sec. or longer (Phillips and Baddeley, 1971). So, it appears that visual information is used primarily in active or short-term memory.

Sternberg (1966) proposed another method for examining stimulus processing and decision making. He asked his subjects to memorize a small set of stimuli (memory set) and to determine whether a subsequently presented probe item matched any one of the memorized items. He found that the reaction time to make this judgment was a linearly increasing function of the number of items in the memory set. The intercept of this function was interpreted as the time to encode the probe item as well as the time to decode or select the appropriate

response ("match" or "no match"). The slope constant was used as an estimate of the rate at which comparisons between probe and memory items can be made.

The results from several of Sternberg's studies indicated that memorial comparisons are made with visual representations not verbal labels. Sternberg (1967) degraded the test stimulus (digit) with a checkerboard pattern and found not only the intercept (presumably the encoding) affected, but also the comparison process (slope) differed in the noise and the noise-free conditions early in practice. This implies that the quality of the stimulus (physical characteristics) influences the comparison process (see also Sternberg, 1969). If the encoding process involved naming or assignment of a verbal label, any visual degradation should not be evident during the comparison process, short of a comparison of an incorrect item leading to an incorrect response. So, Sternberg concluded that subjects do compare visual representations. Further, the slope effect disappeared with practice presumably as the "cleaning up" operation of the encoding process became more efficient. Bracey (1969) was unable to show an effect of noise on the slope while Chase (1969) was. However, nonrejection of the null hypothesis (i.e. no slope effect) is not evidence against the use of visual representations; it may be simply the result of efficient normalization even early in practice.

Briggs and Blaha (1969) and Sternberg (1969) found that nonsense figures were compared at about the same rate as Sternberg's (1967) digits (31 msec. vs. 38 msec.). It is reasonable to assume that verbal labels for the forms would be more complex than the verbal labels

for the digits, and so the former should have been compared more slowly if they were the basis of comparison. However, neither of these studies used both nonsense forms and simpler stimuli (letters or digits). Lyons and Briggs (1971) did use both types of stimuli, and they found an increase in the slope with nonsense forms compared to that with letters (83 and 54 msec., respectively). However, if visual codes were compared in both cases, it is not improbable that lesser familiarity and greater complexity of the forms could alter the speed of each comparison; thus accounting for Lyons and Briggs' results. It would be desirable to manipulate the complexity of the name to see if it has an effect where presumably visual codes are used. The present experiment is, in part, addressed to this issue.

As suggested above, another way to examine the form of the represented stimulus is to manipulate variables which should have an effect on either a visual or an associational code only. Chase and Posner (1965) varied both the visual and acoustic similarity among members of the memory set. They found that there was no effect of acoustic similarity but visual confusability slowed down the search through memory relative to a neutral control list. Taylor (1969) attempted to manipulate the associational code by using "nameable" and "name ambiguous" stimuli. This variable should have been important if in fact names were the basis of comparison. He found that nameability was not a significant source of variance. Thus, acoustic and verbal properties seem to be ineffective in a memory search task and even when names are presumably used (in Taylor's name match condition) the verbal characteristic of nameability is ineffective. This final

point seems contradictory but three possible explanations may account for it. First, the support of the null hypothesis by Taylor might be spurious and misleading due to experimental error or inappropriate methodology - suggesting that names or verbal labels are actually used in associational matches. Second, associational matches involve verbal characteristics not necessarily including "names" - Taylor suggested that "plans" are used. And, third, the associational match is a recoded physical match. This is best illustrated as follows:

present - 'A'
 probe with 'a'
 recode 'A' to 'a' and match 'a' with 'a'.

The additional time to recode into the opposite case may explain Posner and Mitchell's (1965) N-P difference. The present study examines these three possibilities.

Though the bulk of the evidence supports use of visual codes in binary character classification tasks it is not unchallenged. Wattenbarger (1970) expressed doubt that a short-term memory system could hold visual codes for very long. The basis of this doubt is the work of Posner and Keele (1967) which provided evidence for storage of visual information for only about 1.5 seconds or less. As indicated above, however, this is probably an underestimate. Further, Wattenbarger doubted that short-term memory could hold as many items in visual form that might be needed for the larger memory sets (4, 5 or 6 items) as would be required in the Sternberg methodology. This doubt arises from examination of a study by Posner and Taylor (1969). Here, subjects were to judge whether a probe letter had the same name as the member (in the same position as the probe) of a previously exposed array (1, 2 or

4 letters). They found a difference between associational and physical match reaction times only for the initial two items in the simultaneously presented array. That is, if the 3rd or 4th item were physically identical to the probe item the match based on this physical identity was no faster than a match based on associational identity, whereas this difference did exist for the first two memory items. So, it does appear that storage of visual information is limited to only a few items. However, because the "mixed list" procedure was used the results are weakened. In the mixed list, matches are based on physical identity with a probability of .25 and associational identity with a probability of .25. In this case, the subjects might be encouraged to always use or be biased toward associational matches. In the "pure list" methodology of Posner, et al., (1969) half of the trials had physically different stimuli (different) and half were physically identical (same). They found that with the mixed lists the physical matched became slower with increased ISI. With pure lists there is less tendency for this to occur. They concluded that paying attention to physical or visual information (in the pure lists) facilitated maintenance of this information. Thus, had Posner and Taylor (1969) used pure lists it is conceivable that all items in the array could have been retained in visual form because of increased attention to those codes.

Wattenbarger's (1970) own experiment supported the hypothesis that names are used in the comparison operation. However, his subjects were exposed to both associational and physical match conditions and all instructions mentioned case (upper and lower) so that name information was emphasized. As such, associational matches may have been carried over

into conditions where physical matches might otherwise have occurred.

So, notwithstanding possible objections to Wattenbarger's study, his results do conflict with a majority of the extant literature. The present study is designed to explore further the type of codes used in binary character classification and to determine under what conditions each code is used.

In Wattenbarger's study the interval between the final memory item and the probe item was 3.5 sec. The retention time for other items was a function of the size of the memory set (each was presented only every 1.7 sec.). Other studies more suggestive of visual coding have used final item-probe intervals of less than 1 or 2 sec. However, the suggestion that this is responsible for the type of code used seems unwarranted because of studies showing prolongation of the effectiveness of visual codes with attention to them (Phillips and Baddeley, 1971 and Posner et al., 1969). It seems more reasonable to suggest that the codes used may be a function of the memory system involved.

Most of the above studies can be most appropriately placed in the realm of tasks emphasizing active memory as opposed to inactive memory. Thus, it is reasonable to conclude from them that when active memory is involved the preferred coding method is visual. This suggests that for probes of active memory physical matches should be faster than associational matches. Further, a variable such as acoustic similarity should effect the speed and/or accuracy of the associational match if in fact names are used as the basis of comparison for this type of match.

Information Processing in Active and Inactive Memory

A distinction that is frequently made involving storage of information is that between short- and long-term stores or active vs.

inactive memory. Waugh and Norman (1965) were among the first to make such a distinction and provide empirical support. They suggested that the two systems (they used the terms primary and secondary memory) were independent. This conclusion was based on differential effects of number of intervening items. Subsequent research has supported this distinction in terms of serial position recall differences (Glanzer and Cunitz, 1966; Loftus and Wickens, 1970 and Kintsch, 1970) as well as physiological evidence (Milner, 1967). Baddeley (1966) suggested that semantic variables were most important in inactive memory while phonemic ones were important in active memory. Shulman (1970, 1971) showed that this may be due to temporal and strategical factors and that both variables can be effective in both systems. However, the coding process must be time shared with other on-going processes. "If, in addition to time sharing, it is also assumed that rehearsal is a useful means of maximizing retention and that the encoding of phonemic features is faster than or begins before the encoding of semantic features, then it follows that the use of phonemic encoding is a useful means of maximizing the amount of rehearsal and therefore the amount retained. Hence, whenever the encoding of semantic features is not a task demand and would lead to a loss of rehearsal opportunity, encoding in STM will be primarily phonemic (Shulman, 1971)." It is desirable (and Shulman's data, 1970, suggested it is warranted) to extend the above comments to visual coding. That is, visual coding will be more salient in active memory when the above conditions exist or when more adequate responses can be made on this basis rather than on the basis of names or semantic verbal labels.

Several recent studies are relevant to the question of processing in active and inactive memory. Forrin and Morin (1969) combined the Sternberg (1966) fixed and varied set procedures (active and inactive memory) by presenting 'A', 'AB' or 'ABC' ($M = 1, 2$ or 3) to be retained across a block of trials (fixed set). This set is presumably held in inactive memory. Each trial then, consisted of presentation of a varied set ($M = 1, 2$ or 3) followed by a probe of either active or inactive memory or neither. This is a classification task which is assumed to load both memory systems at the same time. That the items remain in two distinct stores rather than being transferred to a common store (e.g. Sternberg's comparator or active memory) is supported by the independence of active memory probe reaction times and the number of items in inactive memory and the independence of inactive memory probe reaction times and the number of items in the active set. Thus, they concluded that "it appears that subject is able to maintain the two lists of items separately and to operate on one independently of the other." Also, there was no evidence that the inactive set was processed first because overall the reaction times to the inactive memory probes were slower. Figure 1 shows that the comparison process for inactive items was faster than for active items. Forrin and Morin (1969) proposed "that the classification of long-term elements within a highly familiar set is accomplished by means of a simultaneous test procedure (or associative mechanism) with duration independent of the size of the set . . .". Kincaid (1971) in a replication of Forrin and Morin's study also found (see Figure 1) faster processing rates for inactive memory probes. However, familiarity and practice both tend to decrease the slope constant in choice reaction time tasks

Figure 1. A comparison of the results of Sternberg, et al. (1969) - top - Forrin and Morin (1969) - middle - and Kincaid (1971) - bottom.

(Lyons and Briggs, 1971; Mowbray and Rhoades, 1964). The inactive set in Forrin and Morin's study was both highly familiar and highly practiced (relative to the different active sets) as well as overlapping in the formation of the memory groups. This overlap also could conceivably reduce the slope constant. And in Kincaid's study the inactive set was highly practiced (it was introduced two sessions prior to the active sets). So, familiarity and practice effects alone probably are sufficient to account for the faster processing of the inactive set probes in Morrin and Forin's and Kincaid's studies. Sternberg, Knoll and Nasto's (1969) approach, however, is less subject to these criticisms. They compared performance on active set (only) with performance on inactive set (only). To be assured that the inactive set items were, in fact, stored in inactive memory the subject was asked to remember seven item letter strings while storing (1, 2 or 4) digits in inactive memory. After presentation of the letter string the subject either recalled the string or was probed with an item belonging to the inactive set or not. Also, fewer trials were given than in Forrin and Morin's study. This condition, however, becomes a time-sharing condition whereas the active set only condition was not. This could certainly be manifested in a lower estimate of processing speed for the inactive set condition (i.e. greater slope). So, there was less difference in practice of inactive and active probes and because the same items (digits) were used in both tasks there was no differential familiarity. They found that the processing rate for the inactive memory probes was slower than for the active memory probes. See Figure 1. The higher intercept for the inactive memory

probes was interpreted as the time required to find the proper ensemble in inactive memory while the increase in slope constant reflected a serial retrieval process of the inactive items into an active memory for comparison.

However, Briggs and Blaha (1969) have shown that there is a retrieval component involved even in the processing of items stored in what Sternberg (1966) called active memory. Further, this retrieval time is a function of the level of practice. Now, since both inactive and active sets require "retrieval" and even in Sternberg's (1969) study there is a somewhat greater level of practice for the inactive ensemble, it is suggested that retrieval should be faster for inactive items. Kincaid's (1971) data which separated retrieval time and comparison time supported this but, as shown above, Sternberg's data do not (at least as he interpreted them). This confusing picture suggests that retrieval differences may be only one salient factor involved in the obtained slope differences between active and inactive memory probes but more careful experimental procedure is required. This study is designed to determine what differences between active and inactive memory function are due to coding differences. Thus, in this section it has been shown that probes of active and inactive memory do support a distinction between the two systems. However, the three major studies cited here (Sternberg et al., 1969; Morrin and Forin, 1969; and Kincaid, 1971) are in conflict (Figure 1) despite similar methodological approaches. Reasons for the discrepancies and suggestions for clarification have been offered and are incorporated as improvements in the present experiment.

The present study is an attempt to determine the nature of the coding used in binary character classification tasks as a function of the location of the stored memory set - active or inactive memory. It is predicted that visual or representational codes will be used in active memory when verbal associates are not required for appropriate responding while coding in inactive memory will be based on the verbal labels even when these labels are not strictly required. The methodological approach will be to visually present a set of symbols to be memorized and retained for a block of several trials. Following this inactive set the subject will be presented with a series of active sets each followed by a probe item. Each probe can be a member of the active set or the inactive set or neither. The subjects are asked to judge a match to have occurred if the probe has the same name (verbal associate) as either an active or inactive item. Thus, two types of match can occur - physically identical (e.g. AA or aa) or associatively identical (e.g. Aa or aA) in either active or inactive memory. It is important to note that the distinction between active and inactive memory in this research is an operational one. A theoretical distinction however, may find support in the results. The critical comparison will be the difference between the reaction time for a physically identical match and the reaction time for an associatively identical match as reflected in the two memory systems. If physical matches can be made, then they should be faster than associational matches (Posner and Keele, 1967) in active memory. However, if only verbal information is used in inactive memory then names will be used in both associational and physical matches and the reaction times should not differ.

Summary and Hypotheses

Two points are clear in the above literature. First, when same-different (or match no-match) judgments are made on visually presented probe and memory items, the basis for the comparison seems to be the visual representations involved. Second, there is little agreement concerning the processing of memory sets stored in active vs. inactive memory. The purpose of this paper is to examine these two points simultaneously in an attempt to better define coding processes as a function of the memory system involved.

The following hypotheses are tenable:

1) Inactive probe reaction times are slower than active probe reaction times. This is supported by agreement among all three studies illustrated in Figure 1.

2) The rate of processing in inactive memory is slower than the rate of processing in active memory. This is a point of considerable disagreement among the studies shown in Figure 1. However, as suggested above, practice, familiarity, and set overlap must be properly controlled to permit appropriate comparisons. This difference in processing rate will be reflected as a slope difference between active and inactive memory equations as a function of the memory load. It is due presumably to the necessity of retrieving the inactive items to a site for the comparison process.

3) Both associational and physical matches are made in active memory. This hypothesis is suggested by the results discussed under "Coding Processes in Memory" above which illustrated the effectiveness of visual representations for use in active memory situations.

4) Only associational matches are made in inactive memory. That is, there should be no facilitation of the matching process due to physical similarity when items are stored for long-term use. This would occur if subjects preferred or were able to store items for very long periods only in verbal form.

5) If names are used in the associational matches then the reaction times for these matches are a function of the acoustical similarity of the stimulus materials. Manipulation of acoustic similarity is used here to converge on the coding differences between active and inactive memory. It is expected that acoustic similarity will slow associational matches in both active and inactive memory as well as "physical" matches in inactive memory because such matches are in fact associationally not physically mediated.

Thus, it has been shown that visually stored information is effective in active memory tasks. Further, some differences between active and inactive memory (which are at present points of disagreement) may best be explained by differential coding processes between these two systems. The purpose of the experiment is to combine the concepts of coding processes and memory systems to more clearly define binary classification in active and inactive memory as it is effected by available coding methods.

EXPERIMENT I

The purpose of this experiment was to examine the use of visual and associational codes in active and inactive memory in a binary character classification task. The stimulus material was chosen to be comparable to that used in previous research (Posner and Keele, 1967 and Posner et al., 1969). Swanson et al., (1972) used Sternberg's active memory procedure and asked their subjects to indicate "match" if the probe was physically or associationally identical with any memory item in the just-presented set. They found that the reaction time-memory load functions for associationally and physically identical matches differed primarily in the slope constant. This was interpreted as an indication of a serial recoding of the memory items into the format of the probe item when necessary. This approach will be extended here to include the probing of items stored in inactive as well as active memory. An obtained difference between associational and physical match reaction times would be suggestive of representational differences in the comparison process. However, these differences may be due to factors which are uncontrolled yet systematic in the experiment. To more carefully examine the question of representational differences in the different memory systems, acoustic similarity was manipulated in such a manner so as to affect reaction time as a function of the presumed type of match. It was felt that acoustic similarity should alter the reaction time-memory load functions only when in fact the stimulus letters are stored

as associates and these associational representations are used as the basis of comparison. That is, when physical representations are compared, acoustic similarity is not expected to be a potent factor in the comparison process.

METHOD

Design. Each subject experienced a total of 168 trials during each of six experimental sessions. Practice and warm-up effects were reduced by allowing one entire practice session prior to the data collection and four warm-up trials at the beginning of each block of trials during the final six sessions. These trials, of course, were not included in the data analyses. A repeated measures design was used in which 48 conditions were defined by the factorial combination of the following variables: memory load (1, 2 or 4 letters), memory system (active or inactive), type of match (physical or associational), similarity (acoustic or neutral), type of response (match or no-match). During each session two blocks of 84 trials were given and the first four trials were excluded from analysis. Twenty of the remaining trials involved a no-match of the probe and memory items and required a negative response. Of the remaining 60 trials there were 15 trials of each of the following types of match:

- (1) physical match of probe with active set
- (2) physical match of probe with inactive set
- (3) associational match of probe with active set
- (4) associational match of probe with inactive set

Each match required only a positive response. The presentation of each type of material was randomized to minimize guessing. One level of memory load for the inactive set was used each day and the levels were counterbalanced so that across subjects each level was used equally often in each ordinal position (1st, 2nd and 3rd) across three

consecutive days. The inactive memory load was constant within each session to minimize confusion as to the contents of this set. All three levels of memory load for the active sets were used equally often in each block (10 trials each). Given that restriction, the order of occurrence of the active memory load levels was randomized. Half the subjects had memory sets and probes drawn from an acoustically similar list for the first three experimental sessions and a neutral list for the final three sessions. For the remaining subjects the order was reversed.

Stimulus Material. Nineteen letters of the alphabet were selected as stimuli and divided into two (overlapping) sets of 12 from which both memory items and probes were drawn. One set was composed of 12 acoustically similar letters - B,C,D,E,F,G,P,S,T,V,X and Z. Note that B,C,D,E,F,G,P,T,V and Z all contain the root 'e' sound while F,X and S are also acoustically similar based on Conrad's (1964) data. The second set was an acoustically neutral list comprised of the letters - A,C,D,H,K,M,Q,S,U,X,Y and Z. When visual similarity exists between the upper and lower case appearance of the letters the resulting associational match is slower than the average physical match and faster than the average associational match (Posner and Mitchell's analog match, 1967). For this reason letter font was carefully selected to reduce such similarity. The stimulus materials were typed with Royal Contemporary Elite Code 517 type font on Craftint No. 45 tracing paper. The letters appeared black on a light grey background when projected. Each letter or set of letters was mounted in a plastic slide mount for projection.

Indices of acoustic confusion (Conrad, 1964) were calculated separately for each set of letters revealing much less acoustic similarity for the acoustically neutral list than for the acoustically similar list. The indices of visual confusion within each list (Townsend, 1970) were nearly identical.

The presentation of the memory sets was visual and simultaneous. For $M = 1$ the letter was in the upper left corner of a 2×2 cell matrix. The remaining cells were unfilled. For $M = 2$ the upper 2 cells contained the letters and all 4 cells contained letters for the $M = 4$ condition. Both cases could be represented in the memory sets. The occurrence was randomized, but across a block of trials both cases were represented equally often in the active memory sets. For the inactive sets, which were changed only across days, this randomization was completed with the restriction that for all inactive set occurrences in the experiment there were an equal number of upper and lower case instances represented. Nearly every possible combination of memory set items with probe item was used in the active memory sets. However, due to the smaller number of inactive sets the following sets were selected:

<u>M = 1</u>		<u>M = 2</u>		<u>M = 4</u>	
<u>acoust.</u>	<u>neut.</u>	<u>acoust.</u>	<u>neut.</u>	<u>acoust.</u>	<u>neut.</u>
B(b)	A(a)	Bf(bF)	Ai(aI)	BfDe(bFdE)	AiDh(aIdH)
C(c)	C(c)	cP(Cp)	cQ(Cq)	CpgV(cPGv)	CqmX(cQMx)
X(x)	Y(y)	xZ9Xz)	yZ(Yz)	XzSt(xZsT)	YzSu(yZsU)

One half of the subjects had the letter(s) in the parentheses.

The probe letters, which could be in either case, appeared in the center of the subjects viewing screen and were selected from the

same subset as the memory items. The probes were selected such that across the final 80 trials in each block there were 60 match and 20 no-match trials with an equal number of (1) upper and lower case probes (40 each), (2) associational matches and physical matches (30 match), (3) match with active set item and match with inactive set item (30 each) and (4) active set match probes of $M = 1, 2$ and 4 (10 each). Thus there were 720 reaction times per data point excepting errors and equipment failures.

Procedure. In the initial session instructions were given and the subjects had one block of 84 trials. All three levels of memory load for the active sets were used but only $M = 4$ for the inactive set. The purpose of this was to develop a tendency for the subjects not to group or combine the memory sets into one set which is then rehearsed as a unitary active set. This of course, is most difficult to do when the largest sets are used.

At the end of each session the subject was shown his inactive set for the next session and asked to memorize it. At the beginning of the next session the subject was asked to record his memory set to assure its storage in inactive memory. If the set or any part could not be recalled, he was again shown the entire set and given five minutes to memorize it. This was felt to be sufficient time to memorize a maximum of four letters. Then at the beginning of each block of trials this set was displayed again and the regular sequence began. Following the inactive set, an active set was displayed for three seconds followed by a one second inter-stimulus interval. The probe item was then displayed and terminated after two seconds. The time from the

onset of the probe item to the initiation of the subject's response was recorded as the primary dependent variable. The response was made by pressing a microswitch with the left or right index finger. For half the subjects the left finger indicated a "match" while the right indicated "no-match." The reverse was true for the other subjects. Following the probe there was a three second inter-trial interval prior to the presentation of the next active set. Thus, the total duration of one trial was ten seconds. This sequence was repeated until the end of the block of trials. After a brief rest, the inactive set was again displayed and the sequence was repeated. A sample of trials is shown in Figure 2.

Subjects. The 24 right-handed subjects were volunteers responding to an ad in the campus newspaper. Each was paid \$1.25 for each session. There was one practice session, six experimental sessions and one debriefing session on eight successive work days.

Instructions. In addition to the general instructions and a task description, the subjects were told not to rehearse the inactive set items with the active set. They were told to memorize the inactive set items well enough so that rehearsal would be unnecessary. A positive response was to be made when the probe matched any of the active or inactive set items. Examples of the four types of matches were shown visually - e.g. Aa, aa, aA, and AA. Associational vs. physical match was not a distinction drawn for the subject. Instructions to respond as rapidly as possible without making errors were stressed. Complete instructions appear in the Appendix.

Apparatus. The subject sat in a dimly-lighted sound-damped room before a response panel and ground-glass screen. On the response panel

Inactive Set	Type of Match	Probe 3	Type of Match												
<table><tr><td>j</td><td>L</td></tr><tr><td>A</td><td>g</td></tr></table>	j	L	A	g		<table><tr><td></td><td></td></tr><tr><td>E</td><td></td></tr><tr><td></td><td></td></tr></table>			E				Physical Active		
j	L														
A	g														
E															
Active Set		Active Set													
<table><tr><td>b</td><td>F</td></tr><tr><td></td><td></td></tr></table>	b	F				<table><tr><td>f</td><td>n</td></tr><tr><td>Y</td><td>m</td></tr></table>	f	n	Y	m					
b	F														
f	n														
Y	m														
Probe 1		Probe 4													
<table><tr><td></td><td></td></tr><tr><td>L</td><td></td></tr><tr><td></td><td></td></tr></table>			L				Physical Inactive	<table><tr><td></td><td></td></tr><tr><td>J</td><td></td></tr><tr><td></td><td></td></tr></table>			J				Associational Inactive
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i															
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Probe 2		Probe 5													
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I															
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Active Set															
<table><tr><td>Q</td><td>r</td></tr><tr><td>t</td><td>E</td></tr></table>	Q	r	t	E											
Q	r														
t	E														

Figure 2. Sample series of trials used in Experiment I.

which was at table top level were two buttons marked "match" and "no-match." The marking, of course, corresponded to the particular finger assignment of each subject. The stimulus materials were back-projected at eye level on the screen and measured 20 x 20 mm. for the 2 x 2 array. Each letter was approximately 10 mm. high and was viewed at 60 cm. (less than 1° visual angle). A paper punch tape unit controlled two Carousel RA 950 Kodak projectors which presented the proper memory sets and probe items. An electronic clock (accurate to 1 msec.) measured the subject's reaction time to the probe item and a print-out of the time and response were made on paper tape. An Iconix timing system was used to control the several intervals and stimulus durations. The subject heard white noise over earphones during the trial to mask distracting sounds. This noise could be silenced to allow 2-way communication with the experimenter. Also, the noise was interrupted 1 sec. prior to the onset of the memory slide for one-half second duration to serve as a warning signal.

RESULTS AND DISCUSSION

Each subject contributed ten positive reaction times (excepting errors and machine failures) to each of the cells in Table 1 for each similarity condition (acoustic similarity or acoustic neutrality). Medians of these scores were taken while all further measures of central tendency were derived by use of arithmetic means. Table 2 shows the average correct reaction times and percent errors for each condition collapsed across both subjects and similarity conditions. Table 4 of the Appendix contains average reaction times including both correct and incorrect responses.

Error Analyses. The attempt to maintain a low error rate was shown to be successful by the 2.31% average error rate for match responses. An analysis of variance on relative error rates is shown in Table 6 of the Appendix. Only the main effect of memory load is significant, $F(2, 46) = 151.35$, $p < .001$. Given the characteristics of the speed-accuracy tradeoff (Swanson and Briggs, 1969) it is expected that if constant error rates for each memory load had been achieved then the slope of the reaction time-memory load functions would have been larger. However, the lack of any interactions indicated that all slopes would be altered to the same degree due to an increase in errors with memory load which is constant for all conditions. Thus, the error rate data provide little additional information beyond that shown below by an analysis of the reaction times.

Table 1
List of Conditions - Experiment I

When Inactive =	1	2	4
Physical Active =	1	1	1
	2	2	2
	4	4	4
Associational Active =	1	1	1
	2	2	2
	4	4	4
When Active =	1	2	4
Physical Inactive =	1	1	1
	2	2	2
	4	4	4
Associational Inactive =	1	1	1
	2	2	2
	4	4	4

Table 2

Average Correct Reaction Times (in msec.) and
Relative Errors (in percent) from Experiment I

When Inactive =		1		2		4	
		<u>RT</u>	<u>RE</u>	<u>RT</u>	<u>RE</u>	<u>RT</u>	<u>RE</u>
Physical							
Active = 1		439	0.41	454	0.62	469	0.83
	2	465	0.80	497	0.62	510	1.26
	4	535	2.78	554	3.64	566	8.63
Assoc.							
Active = 1		469	1.04	474	0.83	489	1.46
	2	497	1.04	516	1.73	530	2.08
	4	558	10.29	570	3.78	580	2.50
When Active =		1		2		4	
Physical							
Inactive = 1		480	0.20	490	0.20	547	2.55
	2	548	0.83	562	1.69	608	3.13
	4	608	4.00	639	6.49	656	3.45
Assoc.							
Inactive = 1		476	0.41	500	0.20	547	1.93
	2	557	1.26	577	1.93	622	1.46
	4	626	2.74	639	5.57	682	3.57

It is important to note the lack of significance of the acoustic similarity variable in terms of errors, $F(1, 23) = 2.96$, $p > .10$. This suggests the comparison of reaction times for the levels of acoustic similarity is valid.

The average relative error rate for "no-match" responses was 8.74%. If in this case the subject is responding more quickly, thus producing the higher error rate as predicted by the speed-accuracy tradeoff, then the obtained difference in "match" and "no-match" reaction times (see below) becomes even more suggestive of slower processing of no-match trials.

Reaction Time Analyses. A detailed analysis of no-match responses is difficult because such responses cannot be categorized as arising from the use of either the active or inactive memory sets. It was expected that no-match responses would be slower than match responses and this expectation was supported (no-match grand mean = 720 msec., match grand mean = 543 msec.). It was also expected that with an increased total number of items (active + inactive sets) on any trial that "no-match" reaction times would increase. Figure 3 indicates that this increase did take place.

The major reaction time data analysis is that defined by the factorial combination of four variables: (1) memory system (active or inactive), (2) type of match (associational or physical), (3) memory load (1, 2 or 4) and (4) acoustic similarity (similar or neutral). A summary of the analysis of variance on these factors is shown in Table 5 of the Appendix. Table 11 of the Appendix contains the data upon which this analysis was performed.

Figure 3. Average "No-Match" reaction times as a function of the total number of items in memory (active + inactive sets). Experiment I.

The following main effects were significant at $p < .05$ or less: memory system, $F(1, 23) = 45.27$, $\omega^2 = .083$, type of match, $F(1, 23) = 41.80$, $\omega^2 = .077$, memory load, $F(2, 46) = 73.13$, $\omega^2 = .272$. Also, two first order interactions reached significance: memory system x type of match, $F(1, 23) = 10.72$, and memory system x memory load, $F(2, 46) = 3.63$.

The significance of the three main effects supports the results of numerous prior studies. First, the overall superiority of active set probe reaction times (509 msec.) over inactive set probes (576 msec.) was found earlier by Sternberg et al., (1969), Forrin and Morin (1969) and Kincaid (1971). These results are certainly not due to the subjects forgetting the inactive set of letters. Even though the inactive set was shown after the session prior to, and immediately before its use, there was only slight evidence of forgetting. Only three different subjects forgot any letters and each memory load level was forgotten only once. Thus, out of 144 recall opportunities (24 subjects x 6 sessions) only three showed evidence of loss. Furthermore, at each of these times the subject was given five minutes to study the set. So, it is unlikely that the slower reaction times for the inactive set are due to retention problems.

Second, the main effect of type of match shows that physical matches (535 msec.) are made faster on the average than associational matches (551 msec.). Posner and Keele (1967), Posner et al., (1969) and others also found this difference. The magnitude of the difference found here (16 msec.) however, is smaller than that found by Posner and Mitchell (1965), e.g., 70-80 msec. This is due to the use here of

the mixed list procedure (see above), inclusion of some analog matches, the one second inter-stimulus interval and the inclusion of associational-physical differences from both active and inactive memory set probes (the latter should reduce the overall difference).

Finally, the characteristic increase in reaction time with an increase in memory load (Sternberg, 1967; Briggs and Blaha, 1969 and others) is evidenced in the significant main effect of memory load.

The significant memory system x memory load interaction is illustrated in Figure 4 and this suggests that the slopes of the two functions are not parallel. The best-fitting linear equations are:

$$RT = .440 + .068 (H_c) \quad \text{Inactive memory}$$

$$RT = .417 + .047 (H_c) \quad \text{Active memory}$$

It is important to note that the H_c scale of the number of items in memory is an equal interval log transform scale. Such a scale is not without precedent (Briggs et al., 1971 and Nickerson and Fechner, 1964) and more important, the data overall are better fitted in this manner than by a linear scale. Of the four equations which are represented in Figure 6 (physical and associational matches in inactive memory are plotted together) three are better fitted on the H_c scale than a strictly linear scale.

The H_c metric is a Shannon statement (log) of central processing uncertainty which is determined primarily by memory load (see Briggs et al., 1971). The particular scale values selected affect neither the statistical analyses nor the major conclusions drawn from them. Again, the major criterion for use in selecting the log scale is the ability of a linear model to adequately describe the data.

Figure 4. Average "Match" reaction times as a function of Central Processing Uncertainty (H_C) with memory system as the parameter. Experiment I.

The slope differences in Figure 4 more closely resemble the data of Sternberg et al., (1969) in Figure 1 than that of Forrin and Morin (1969) or Kincaid (1971). This is probably reflexive of the present more adequate controls over set familiarity, practice and set overlap which the latter two studies did not have. These results suggest slower processing or increased processing requirements for the inactive memory system.

The prediction that the type of information used in the comparison process will be a function of the particular memory system involved (active vs. inactive memory) is supported by the significance of the type of match x memory system interaction. This interaction (Figure 5) is plotted as a function of memory load in Figure 6. The type of match x memory system interaction (Figure 5) indicated that the main effect of type of match was due to the difference between associational and physical matches in active memory. For this reason the physical and associative match functions for inactive memory:

$$RT = .438 + .066 (H_C) \quad \text{Physical}$$

$$RT = .443 + .069 (H_C) \quad \text{Associational}$$

are plotted as a single regression equation in Figure 6. Furthermore, a regression analysis revealed that fitting three functions as is done in Figure 6 accounts for only slightly less total variance than fitting all four equations.

Thus, the data of Figure 6 support the major prediction that the information used to match stimuli in this task is a function of the memory system involved. Further support comes from the combination of the significant type of match main effect and from the type of match

Figure 5. Average "Match" reaction times as a function of memory system and type of match. Experiment I.

Figure 6. Average "match" reaction times as a function of central processing uncertainty (H_C) and memory system with type of match as the parameter. Experiment I.

x memory system interaction. These effects show that physical matches are faster than associational matches but that this difference occurs in the active memory system. Thus, only associational matches are involved in the inactive memory system while both types of match occur in active memory.

The fact that neither type of match x memory load nor any other higher order interactions involving both of these variables was significant indicates that the difference between associational and physical matches in the active memory set is constant across memory load and thus the functions are plotted as best-fitted parallel lines in Figure 6.

It was surprising that neither the main effect of acoustic similarity, $F(1, 23) = .34$, nor any of its interactive patterns approached significance. It was expected that only the associational matches would be affected by this variable and such an effect would serve to converge on the representational differences presumably existing in the different memory systems.

Three explanations for this nonrejection of the null hypothesis are considered: first, it is possible that either acoustic similarity does in fact, operate in associational matches but the present experimental design was not sufficiently powerful to detect such effects or acoustic similarity was not appropriately manipulated. If so, then the associational matches would be interpreted as involving a verbal label or name.

Second, the associational match process may involve an abstract verbal or associational label and acoustic similarity is ineffective

in manipulating this label. The more appropriate term would then be associational match and not "name" match.

Finally, an associational match may be better conceptualized as a recoded physical match. Thus, when the subject is given 'A' to memorize followed by the probe 'a', he recodes 'A' (see Swanson et al., 1972) into 'a'. This recoding is followed by a physical match of 'a' with 'a'. Experiment II was designed to test the validity of the acoustic similarity manipulation. If such manipulation is real and also if the associational match is in fact a recoded physical match then physical similarity should effect both physical and associational matches. Experiment III was proposed as a test of this hypothesis.

So, while Experiment I leaves open the question of the nature of the associational match, it does provide several meaningful statements concerning the type of codes or memorial representations used in a binary classification task as a function of the memory system involved.

The data in Figure 6 show that physical matches are made uniformly faster than associational matches which suggests that both visual and associational codes are available for use in active memory comparisons. When visual identity exists it can be concluded that the matching process is based on a physical code as opposed to an associational one. A general recoding scheme will be presented in the General Discussion to explain the constant difference between physical and associational matches in active memory.

The lack of difference between the physical and associational functions in inactive memory ($RT = .438 + .066 (H_c)$ and $RT = .443 + .069 (H_c)$ respectively) suggests that only associational matches are made in

inactive memory even when physical identity between probe and memory item exists.

The slope and intercept differences between active and inactive memory (Figure 4) are suggestive of certain modes of processing. The slope constant of the inactive set is greater than that of the active set and possibly indicates increased processing for the inactive set in terms of a serial retrieval of these items prior to comparison - a retrieval not required for the active set items. The greater intercept for the inactive set was also found by Sternberg et al., (1969) and was interpreted as the "time to locate" the proper ensemble of letters in inactive memory. These results and interpretations will be discussed more fully in the General Discussion.

INTRODUCTION TO EXPERIMENTS II AND III

One purpose of Experiment I was to supplement the evidence for the differences in coding between active and inactive memory with independent manipulation of the associational match by varying the acoustic similarity of the letters involved. It was felt that such manipulation would be effective both in associational matches in active memory and in associational and "physical" matches in inactive memory since names presumably were the basis of comparison in these cases.

Acoustic similarity had no effect on reaction times or errors in Experiment I. Three possible explanations were forwarded above: (1) improper manipulation of acoustic similarity, (2) use of abstract verbal labels rather than acoustically represented names or (3) associational match is a physical recoded match.

The purpose of Experiments II and III is to determine which of these three possibilities is most likely and to develop a more complete interpretation of an associational match which is not possible from the data from Experiment I.

EXPERIMENT II

The lack of significance of the acoustic similarity manipulation in Experiment I was unexpected given the strength of this variable in other memory tasks (see Shulman, 1971). It may be that the stimulus materials used did not provide two distinct levels of acoustic confusion. Thus, associative match reaction times would not reflect a manipulation of their acoustic nature. To determine if the stimulus materials in Experiment I did provide a reasonable difference in acoustic similarity, the same letters are used here in a modification of Peterson and Peterson's (1959) memory recall technique.

METHOD

Subjects. The same 24 subjects in Experiment I served in this experiment prior to an explanation to them of the previous experiment. Each was paid \$1.25 for participation in one 30 minute session.

Stimulus Materials. Thirty-eight combinations of five letters were selected from the total ensemble of 19 letters used in Experiment I. Each letter was used 10 times throughout the list and appeared in each ordinal position (1 through 5) approximately equally often. These five-letter combinations were typed in the same font as in Experiment I but were presented on 3 x 5 flash cards. The letters appeared in a single row at the center of each card.

Procedure and Design. Each of the five-letter combinations was presented to the subject for two seconds followed one second later by a second flash card with a three digit number on it. The subjects' task was to memorize the five letters upon presentation and to begin counting backward aloud by three's from the number when it was presented subsequently. The signal for the subject to stop counting and record the five letters was the removal of the number from view after three seconds of exposure. The subject was to record the five letters by writing them down, preferably in the original order. After recording the letters (approximately five seconds) the next trial started with presentation of the next set of letters. The experimenter sat across the table from the subject in a well lighted room and

manually displayed the cards at a viewing distance of approximately 45 cm. Timing was accomplished by stopwatch.

All subjects received identical letter sets in the same order. An attempt was made by the experimenter to standardize the counting behavior due to large individual differences in this activity.

RESULTS AND DISCUSSION

If given five letters to memorize, the subject missed two or more letters on recall it is difficult to determine which incorrect letter was substituted for which correct one. If order is not considered (and subjects were not instructed to maintain perfect order) then it is impossible. For this reason, of the 38 trials per subject only those in which one error was made were examined. There were 141 such trials across all subjects. When a letter was missed, the probability by chance alone that the error was an acoustic associate of the correct letter was .23. Those letters from Experiment I which were in the acoustically similar set were considered acoustic associates. Those in the acoustically neutral set were not. The letters which appeared in both groups were not included in this analysis. Of all the one-letter errors made 31% of these involved acoustic associates. This percentage represents a significant increase above chance level, $z = 2.60$, $p < .05$. Thus, the stimulus materials used in Experiment I do effectively manipulate acoustic confusability in the Peterson and Peterson memory task. This suggests that associational matches made in Experiment I did not involve acoustic representations but rather abstract verbal or recoded visual codes. Thus, the term associational match is more appropriate than the term name match. A test of this question can be made by manipulation of the physical similarity in such matches.

EXPERIMENT III

The purpose of this experiment was to demonstrate the existence of effects of visual similarity in both associational and physical matches. Such evidence would support the hypothesis that associative matches involved recoded physical matches and not some abstract verbal (nonacoustical) representations. Due to a limited population of possible stimulus letters, only memory load = 1 or 2 could be used. If only one level of memory load is used, then any effect of visual similarity may be interpreted either as an encoding (the intercept in Sternberg's reaction time-memory load function) or comparison (slope in the reaction time-memory load function) effect. However, Chase and Posner (1965) demonstrated that in a Sternberg task there is no encoding difference as a function of visual similarity. For this reason, only one level of memory load need be used and $M = 2$ was selected.

METHOD

Design and Procedure. Each subject was presented with 192 trials during each of four experimental sessions. A trial was defined by the presentation of a memory set (two items) followed by a probe item. There was no co-occurring inactive set as in Experiment I. Practice effects were reduced by the use of 96 practice trials during the first session prior to data collection. Four major conditions were defined by two levels of visual similarity (visually similar or neutral) factorially combined with two levels of type of match (associational or physical). During each session the 192 trials were divided into two blocks of 96 trials to allow a brief intervening rest period. Of the 192 trials 96 involved no-match of either of the two memory items with the probe item. These trials were expected to yield slower reaction times than reaction times to matches but were of little general interest. The remaining 96 trials did involve a match of either the first of the two items with the probe (half of the time) or the second item with the probe (half the time). Of these 96 match trials 48 involved physical matches and 48 involved associational matches. The no-match, match, the associational, and the physical trials were randomly presented. There were eight different lists. Each subject experienced five of these lists (one per day) and each list was used equally often during the experiment. As in Experiment I the match of a memory item and probe evoked a single microswitch press regardless of the type of match. Of course, no-match was signaled by pressing another switch.

Half the subjects had memory sets and probe items selected from a visually similar list for the first three sessions (including the practice and two experimental sessions) and from a visually neutral ensemble for the final two sessions. The remaining half of the subjects experienced the two levels of visual similarity in reverse order.

Stimulus Material. Eight letters were chosen and divided into two sets of four each. Both the probes and the two memory items were selected from the same ensemble (visually similar or visually neutral). The visually similar ensemble was comprised of B,D,G,Q,b,d,g and q. The upper case letters were rated high in visual similarity by Townsend (1970) and also appeared in Chase and Posner's (1965) high visual similarity ensemble which was based on percent visual overlap. The visually neutral ensemble - A,Y,H,M,a,y,h and m - contained upper case letters which were lower in visual similarity according to both Townsend and Chase and Posner. These two ensembles were subsets of ensembles used by Chase and Posner which were equated for both frequency of occurrence in English and naming latency. However, there are no existing norms for visual similarity of lower case letters. For this reason 24 volunteer subjects were asked to rate all possible homogenous (same case) pairs of letters within each ensemble (e.g., bd, bg, am, HY, etc.). These ratings showed that the physical similarity of the lower case pairs was greater than the upper case pairs for those selected from the visually similar ensemble and less visually similar than the upper case letters for those selected from the visually neutral ensemble. Thus, the dimension of visual similarity is strengthened by the use of lower case letters. The average ratings on a scale from 0-10 (dissimilar

to similar) are shown for each rated pair in Table 7 of the Appendix.

The memory sets consisted only of homogenous pairs (i.e., case was not mixed) in order to increase the effectiveness of visual similarity. However, the probe item could be in either case. The 192 trials per session consisted of the 192 possible pairings of 24 letter pairs with eight different probes (four of each case).

The presentation of the memory sets and probes was identical to that in Experiment I. However, in this experiment the exposure duration for the memory set was two seconds rather than three as in Experiment I and the inter-trial interval was 1.5 seconds. Again, reaction time to the probe item was the dependent variable.

Subjects. Twenty-four right-handed students who responded to an ad in the campus newspaper served as subjects. None had participated in Experiment I. Each was paid \$1.25 for each of five sessions (1 practice and 4 experimental sessions).

Instructions and Apparatus. The instructions which appear in the Appendix were similar to those of Experiment I. The apparatus was described above for Experiment I.

RESULTS AND DISCUSSION

Each of the 24 subjects contributed 96 no-match reaction times and 96 match reaction times under each visual similarity condition. Of the 96 match reaction times 48 were physical matches and 48 were associational matches. Thus, there are 1152 reaction times for each type of match response and 2304 no-match responses under each similarity condition. Errors and machine failures were not included in the analyses of reaction times. Median reaction times were calculated for each subject as the basic unit of analysis. An average of these medians across subjects is shown in Table 3.

Separate analyses were performed on the match and no-match reaction times. A summary of the match response analysis of variance is presented in Table 8 of the Appendix. Table 12 of the Appendix contains the reaction times upon which this analysis was performed. The following main effects were significant at $p < .05$ or less: Type of match, $F(1, 23) = 112.84$, $\omega^2 = .448$, and visual similarity, $F(1, 23) = 41.74$, $\omega^2 = .163$. There were no significant interactions.

The significance of the physical match (484 msec.) - associational match (513 msec.) difference is similar in direction and magnitude to the comparable difference in the active memory condition in Experiment I. Again, it simply reflects that when items are stored in active memory, physical identity facilitates reaction times.

The primary evidence for the recoding hypothesis of the associational match is the significance of the effect of visual similarity

Table 3

Average Reaction Times and Relative Errors
in Experiment III

Match Responses				
	Physical		Associational	
	<u>RT</u>	<u>RE</u>	<u>RT</u>	<u>RE</u>
Visually Similar	513	2.68	546	4.25
Visually Neutral	455	1.68	479	3.56
No-Match Responses				
	<u>RT</u>	<u>RE</u>		
Visually Similar	621	3.53		
Visually Neutral	538	2.84		

and its noninteraction with type of match (visual similarity x type of match, $F(1, 23) = 1.98, p > .10$). This combination suggests first that visual similarity does slow down match time and second, the associational matches are affected as much as the physical matches by visual similarity manipulation. Thus, when 'A' is stored in memory followed by 'a' as the probe the subject presumably is using only visual associations in recoding one or the other (presumably that item stored in memory, Swanson et al., 1972). This recoding allows for physical matches to then occur (i.e., 'a' and 'a'). An analysis of no-match reaction times is presented in Table 9 of the Appendix. Table 3 in the text shows that no-match reaction times are substantially slower than match reaction times. This supports those results of Experiment I as well as previous research (Posner, et al., 1969, Posner and Mitchell, 1965, etc.). The significant main effect of visual similarity for no-matches ($F(1, 23) = 33.43, p < .01$) indicates that visual similarity operates on no-match responses as well as match responses. In fact, the difference between visual similarity and visual neutrality is larger for no-match than for match reaction times (83 vs. 63 msec.). However, this may be due simply to the fact that because no-match reaction times are slower there is more time for visual similarity to act as an interfering influence.

Again, any statement of comparison of reaction times needs supporting evidence from error analyses. An analysis of variance was completed on the relative errors on the match responses to allow valid comparisons of type of match and visual similarity reaction time differences. A summary of this analysis is presented

in Table 10 of the Appendix. There were two significant main effects: visual similarity, $F(1, 23) = 4.82$, $p < .05$ and type of match, $F(1, 23) = 29.21$, $p < .01$. Both of these effects (see Table 3 in the text) support the conclusions drawn earlier from the reaction time data because in both cases more errors were made when the reaction times were slower - that is, for associational matches and for visually similar letter ensembles. Thus, the reaction time differences are underestimates if the logic of the speed-accuracy tradeoff is accepted. Finally, the lack of interaction of type of match x visual similarity reinforces the equality of effects of visual similarity on physical and associational matches.

GENERAL DISCUSSION

Representational Differences Between Memory Systems

In the Introduction three studies were reviewed which loaded both active and inactive memory in character classification tasks (Sternberg et al., 1969, Morrin and Forin, 1969 and Kincaid, 1970). It was suggested that differences among these studies (Figure 1) might be artifacts of control procedures - such as practice, familiarity, overlap of memory sets, etc. The present study sought to achieve proper control over these variables and determine other and possibly more meaningful explanations for differences in active and inactive memory probe reaction times. The following major predictions were made:

(1) inactive probe reaction times are slower than active probe reaction times,

(2) the rate of processing in inactive memory is slower than in active memory,

(3) both associative and physical matches are made in active memory,

(4) only associational matches are made in inactive memory.

Support for these predictions is provided in Figure 6. These data suggest that the information stored in active memory is such that both associational matches and physical matches are possible. This in turn implies that visual information, which is more or less isomorphic with the stimulus, is represented in active memory and is

more efficient for use in matching than the associational information. Further, the data suggest that visual information either is lost or becomes relatively less efficient than the associational information in inactive memory. Thus, subjects are able to choose and to use visual information when searching active memory in a recognition task but, when inactive memory is searched they are unable to use such information.

Three prominent features of Figure 6 are most important:

(1) the constant associational-physical match difference in active memory,

(2) the slope constant difference between active and inactive memory and,

(3) the intercept difference between active and inactive memory.

As suggested in the Introduction, the difference between associational and physical matches can be considered to be an estimate of additional processing time required to make an associational match above that for a physical match. This additional processing will be called recoding and certain of its characteristics are examined in greater detail below. Swanson et al., (1972) found that with active memory probes, the difference between associational and physical matches was manifested in the slope of the reaction time-memory load function not in the intercept as it was noted here. There, however, is a fundamental difference in the constitution of the memory sets between the two experiments. The Swanson memory sets were homogeneous (i.e., all items were of one format) allowing serial recoding of the memory set items into the same format as the probe (forms vs. digit names) -

thus, the slope effect. Here, the memory sets were heterogeneous - i.e. the sets contained both upper and lower case letters. Thus, if the memory items are recoded (as Swanson et al. suggested) this must be done on an individual basis. That is, all memory items cannot automatically be recoded given the probe item: each recoding must be based on a comparison of each memory letter with the probe. The alternative of an automatic recoding only of those items in conflicting format with the probe seems unlikely. Further, the recoding of the probe (thus yielding an intercept effect) in this experiment is unlikely because such recoding would cause mismatch of case with those memory items that were of the same case prior to recoding the probe.

Figure 7 diagrams several possible physical and associational match conditions. Its purpose is to illustrate associational-physical match differences in terms of the number of recoding operations. Several points must be considered in examining this figure. First, the matching memory item is shown always in the "final" position. There is neither evidence in this experiment that a serial scan exists, making this the final position, nor that the scan is exhaustive. Also, appearance of the probe in other positions changes the numerical values in the figure but not the difference or conclusions. In sum, the figure involves several noncritical, simplifying assumptions. Second, by definition, associational matches require recoding. This recoding occurs once whenever a memory item and the probe item do not match in terms of physical identity. That is, both 'a' (memory item) - 'A' (probe) and 'D' (memory item) - 'A' (probe) require recoding. Thus, for example, in Figure 7 when 'ab' is presented as the memory set and

Active Memory Sets	Probe	Number of Recoding Operations				
<table border="1"><tr><td>a</td><td></td></tr><tr><td></td><td></td></tr></table>	a				A	1
a						
<table border="1"><tr><td>A</td><td></td></tr><tr><td></td><td></td></tr></table>	A				A	<div><div>0</div><div>difference = 1</div></div>
A						
<table border="1"><tr><td>b</td><td>a</td></tr><tr><td></td><td></td></tr></table>	b	a			A	2
b	a					
<table border="1"><tr><td>b</td><td>A</td></tr><tr><td></td><td></td></tr></table>	b	A			A	<div><div>1</div><div>difference = 1</div></div>
b	A					
<table border="1"><tr><td>d</td><td>c</td></tr><tr><td>b</td><td>a</td></tr></table>	d	c	b	a	A	4
d	c					
b	a					
<table border="1"><tr><td>d</td><td>c</td></tr><tr><td>b</td><td>A</td></tr></table>	d	c	b	A	A	<div><div>3</div><div>difference = 1</div></div>
d	c					
b	A					

Figure 7. Diagram of recoding operations to explain constant difference between physical and associational matches in active memory.

'A' is the probe two recoding operations are necessary. The third important point is that the difference between associational and physical matches is represented as recoding operations and the number of such operations is constant (difference = 1) regardless of the number of items in the memory set. It is proposed that this constancy yields the intercept difference between associational and physical matches and that the magnitude of the difference (19 msec.) is due to the necessity of one additional recoding for the associational match situation.

The slope difference between active and inactive memory functions is also of concern. Figure 1 shows widely discrepant results and examination of the studies reveals widely discrepant explanations. The present study (Figure 4) with more adequate controls reveals two important points. First, processing of inactive memory is slower than processing of active memory probes. This precludes Morrin and Forin's (1969) concept of a match in inactive memory which does not involve search and is independent of the number of items in that memory system. A more reasonable explanation is that items stored in inactive memory must be retrieved prior to comparison with the probe. A parallel retrieval would result in an intercept difference only between active and inactive memory functions. The slope difference does suggest a serial retrieval of the inactive memory items. This introduces the second important point. If recoding of physical into associational form is assumed to involve some interaction with inactive memory (e.g. the association between 'A' and 'a' be it verbal or visual is stored in inactive memory) then it would be

expected that the estimate of recoding time should be the same as the retrieval of information stored in inactive memory. Figure 6 shows that the recoding time for active memory items is approximately 20 msec. The difference in slopes between active and inactive memory function is interpreted as an estimate of the serial retrieval time for the inactive memory items. This difference also is approximately 20 msec. Thus, recoding time and retrieval time, which have logical communalities, are estimated to be of approximately equal duration. This is not to say that recoding and retrieval can replace one another. If this were so, then retrieval of the inactive set items would eliminate the necessity for subsequent recoding, which again, would produce equal slopes in Figure 4.

The third predominant feature in Figures 4 and 6 is the intercept difference between the active memory and inactive memory functions (23 msec.). That this is due to parallel retrieval processes was rejected above (in favor of serial retrieval). Sternberg et al., (1969) suggested that it is due to the additional time required to locate the appropriate ensemble of items in inactive memory. A third possible explanation is that this intercept difference reflects time taken to "identify" or recode the probe item into its associate form. This however, assumes that active memory is examined first and such identification follows the examination and is prior to search of inactive memory. Such an assumption finds some support in the present study, however, earlier it was shown that any recoding of the probe, in connection with active memory, is unlikely due to the mixing of cases in the memory set. Because the same logic applies here, the most

parsimonious explanation for the difference in intercept between active and inactive memory functions is simply the "time to locate" (Sternberg et al.) the inactive set ensemble. In a study designed to examine ensemble selection time, Williams (1971) estimated that the selection time was about 25 msec. The similarity between William's estimate and that found in this experiment is noted.

In summary, it has been suggested that the associational-physical match reaction time difference reflects recoding time. The number of recoding operations increases with the number of items in the memory set but the difference in number of operations between those trials involving associational and physical matches is constant (see Figure 7). This explains the difference between associational and physical matches in Figure 6. A serial retrieval of inactive set items is reflected in an increased slope (47 vs. 68 msec.) for the inactive memory function. A logical similarity between retrieval and recoding processes is supported by similar temporal estimates. And finally, a short time does appear to be needed to locate the proper inactive set prior to its use - this is reflected as the intercept difference between active and inactive memory functions.

Nature of the Associational Match

It was predicted that in Experiment I acoustic similarity would increase reaction times when associational matches were made. If so, then the association would be presumed to be a verbal one based on an acoustically represented name. The total lack of a significant effect of this variable coupled with a similar lack of effect of "name-ability" on associational matching in a study by Taylor (1969) cast

doubt on the hypothesis. There are two reasonable alternative hypotheses concerning the nature of the associational match. These were tested in Experiments II and III. First, the association may be an abstract verbal code which involves the name of the item but not in acoustical form (Taylor, 1969 called it a 'plan'). Second, the association may be a recoded physical representation as illustrated in the Introduction above. If the memory set contains 'A' and 'a' is the probe item, then 'A' is recoded into 'a' prior to a physical match of 'a' and 'a.' Intuitive evidence for the existence of associations based on physical qualities is the effect of physical similarity in a wide range of tasks. The fact that two items can be physically similar implies some relationship of physical qualities.

It is possible that the stimulus materials used in Experiment I did not adequately manipulate acoustic similarity. If so, then perhaps names are in fact the basic unit of recoded physical representations. However, Experiment II showed that in another task the same stimulus materials were effective in behavioral modification due to acoustic similarity. Thus, the possibility of the use of acoustic representations remains remote.

Any variable which effects associational match reaction time may, if physical and associational matches are not independent, do so simply because associational matches are made after a check for physical identity has been made. If, in Experiment III, physical similarity slows down this check and if the associational match does follow or depend on the check, then physical identity should affect the associational match reaction time without necessarily affecting the associational

match process itself. There is evidence to suggest however, that the two types of matches are independent and can be independently manipulated. Posner et al., (1969), as suggested earlier, showed that with increased attention to the physical information in a "same - different" task (i.e. pure lists vs. mixed lists) decreases the tendency for physical match reaction times to increase with inter-stimulus interval. However, such manipulation does not affect associational match reaction times. Also, Boies, Posner and Taylor (1968) asked subjects to rehearse eight letters during a "same - different" matching task. These letters were to be recalled after the binary classification response. They found that such verbal activity interfered only with associational match reaction times. It may be concluded, then, that physical and associational matches are independent and that any effect of visual similarity on associational match reaction times is not due to mediation through the physical matches.

Thus, the results of Experiment III, which show effects of physical similarity on both physical and associational matches, support the visual recoding hypothesis of associational matches. For this reason acoustic similarity manipulation in Experiment I did not affect associational matches which are not acoustically based. This also suggests that Posner's use of the term "name" match is in fact a misnomer as is Taylor's use of "plan."

The results of Experiments I, II and III of the present research and earlier works are indicative of the following conclusions:

(1) A difference between associational and physical matches is found only for active memory probes. This indicates that in this

condition visually stored representations can be and are used in the memory comparison process.

(2) The slope difference between active and inactive memory functions is attributed to a serial retrieval of inactive items to the site of the comparison.

(3) The logical similarities between retrieval and recoding processes are supported by finding that the estimate of recoding time (associational - physical match) is approximately equal to the estimate to retrieval rate (inactive - active slope).

(4) The intercept difference between active and inactive memory functions (23 msec.) indicates the time to locate the inactive set prior to the retrieval or comparison operation.

(5) Associational matches do not involve acoustically represented names (Experiments II and III) but rather can be considered as recoded physical matches (i.e. given memory item 'A' and probe 'a'; recode 'A' to 'a' and compare 'a' with 'a').

APPENDIX

INSTRUCTIONS EXPERIMENT I

This experiment examines your ability to respond quickly and accurately to letters presented on the screen in front of you. You will be asked to memorize a fixed set of 1, 2 or 4 letters. These letters will be used throughout the entire session today. Here are your letters (show the subject his letters). Now, each trial will consist of 2 slides. The first slide will contain another set of 1, 2 or 4 letters. This set of letters is to be remembered until the second slide occurs 1 second later. On this slide only one letter will appear. This letter can (1) match a letter in the fixed set, (2) match a letter you just remembered or (3) match none of the memorized letters. Here is an illustration of the different possible matches (show the subject all possible types of matches). You are to indicate a "match" by pressing this (point) button and a "no match" by pressing this (point) button using your index fingers. These responses are to be made as rapidly and as accurately as possible.

The next trial starts with the presentation of another set of 1, 2 or 4 letters. The letter presented after this set is to be matched only with the just-presented set and the fixed set.

It is important to note that the fixed set of letters is to be well learned. You are NOT to rehearse it with the memory sets given on each trial but memorize it well enough so that rehearsal is not necessary. In fact, I will give you tomorrow's fixed set at the end of this session and you will be asked to recall it tomorrow before we start.

There will be about 75 trials today. Remember to respond as quickly as you can trying to be as accurate as possible. Wear these headphones to help block distracting sounds. Also, there will be a break in the noise which comes over them to act as a warning signal prior to each memory set.

Any questions?

INSTRUCTIONS EXPERIMENT III

This experiment examines your ability to respond quickly and accurately to slides presented on this screen (point). Each trial will consist of two slides. The first slide will contain two letters which you are to memorize. One second after this slide goes off the second slide will be presented. This slide will have just one letter on it. Your task is to determine whether the letter on the second slide matches either letter on the first slide. These types of matches are possible (show the subject all possible types of matches). You should indicate a match by pressing this (point) button with your right (left) index finger as quickly as possible. If no match occurs then press this (point) button with your left (right) index finger again, as quickly as possible.

Any questions? Remember, it is important that each response be made as quickly as possible without errors. Please wear the headphones during the experiment to help block distracting sounds. Also, there will be a break in the noise coming from the headphones to act as a warning signal prior to each memory set.

Table 4

Average Reaction Times (msec.) including both
Correct and Incorrect Responses in Experiment I

When Inactive =		1	2	4
Physical				
Active =	1	439	454	469
	2	466	497	510
	4	538	558	578
Assoc.				
Active =	1	470	475	492
	2	498	521	531
	4	572	577	583
When Active =		1	2	4
Physical				
Inactive =	1	480	489	547
	2	549	561	610
	4	613	644	664
Assoc.				
Inactive =	1	476	500	548
	2	558	579	623
	4	629	644	683

Table 5

Analysis of Variance of the Reaction Time Data-Experiment I

Source	df	MS	F	p
Mean	1	169.5585		
Subjects (S)	23	2.4265		
Acoustic Similarity (A)	1	0.0132	0.34	> .10
Memory System (F)	1	0.6323	45.27	< .01
Type of Match (C)	1	0.0365	41.80	< .01
Memory Load (M)	2	1.2681	73.13	< .01
S X A	23	0.8860		
S X F	23	0.3213		
A X F	1	0.0033	1.27	> .10
S X C	23	0.0201		
A X C	1	0.0000	0.00	> .10
F X C	1	0.0050	10.72	< .01
S X M	46	0.3988		
A X M	2	0.0030	0.28	> .10
F X M	2	0.0464	3.63	< .05
C X M	2	0.0004	0.25	> .10
S X A X F	23	0.0595		
S X A X C	23	0.0168		
S X F X C	23	0.0107		
A X F X C	1	0.0000	0.00	> .10
S X A X M	46	0.2491		
S X F X M	46	0.2943		
A X F X M	2	0.0033	0.41	> .10
S X C X M	46	0.0357		
A X C X M	2	0.0014	0.86	> .10
F X C X M	2	0.0007	1.04	> .10
S X A X F X C	23	0.0133		
S X A X F X M	46	0.1889		
S X A X C X M	46	0.0384		
S X F X C X M	46	0.0156		
A X F X C X M	2	0.0011	0.68	> .10
S X A X F X C X M	46	0.0383		

Table 6

Analysis of Variance of the Relative Errors-Experiment I

Source	df	MS	F	p
Mean	1	30.8000	182.03	
Memory System (F)	1	0.0425	0.31	> .10
Acoustic Similarity (A)	1	0.2987	2.96	> .05
Type of Match (C)	1	0.2460	3.78	< .05
Memory Load (M)	2	17.8881	151.35	< .01
Subjects (S)	23	3.8917		
F X A	1	0.0034	0.03	> .10
F X C	1	0.0054	0.09	> .10
A X C	1	0.0011	0.02	> .10
F X M	2	0.4633	2.62	> .05
A X M	2	0.1505	0.93	> .10
C X M	2	0.1543	1.62	> .10
F X S	23	3.1515		
A X S	23	2.3212		
C X S	23	1.4973		
M X S	46	2.7184		
F X A X C	1	0.0995	1.05	> .10
F X A X M	2	0.0562	0.37	> .10
F X C X M	2	0.1352	1.09	> .10
A X C X M	2	0.1028	0.69	> .10
F X A X S	23	2.6781		
F X C X S	23	1.3189		
A X C X S	23	1.6681		
F X M X S	46	4.0637		
A X M X S	46	3.7305		
C X M X S	46	2.1966		
F X A X C X M	2	0.2094	1.25	> .10
F X A X C X S	23	2.1809		
F X A X M X S	46	3.4854		
F X C X M X S	46	2.8405		
A X C X M X S	46	3.4150		
F X A X C X M X S	46	3.8570		

Table 7
Average Ratings of Visual Similarity

Visually Similar		Visually Neutral	
letters	ave. rating	letters	ave. rating
GD	4.94	AY	3.17
BQ	3.54	AM	3.65
BD	6.13	HY	2.63
GQ	4.67	AH	4.71
QD	7.10	YM	3.94
BG	5.04	HM	4.79
bg	4.79	ym	1.58
gd	4.63	ay	1.54
gq	8.21	am	3.08
qd	5.42	ah	2.25
bq	5.67	hm	4.65
bd	7.42	hy	2.77
Average	5.63		3.23

Table 8
 Analysis of Variance of the Positive Reaction
 Time Data for Experiment III

Source	df	MS	F	p
Mean	1	47.6599	783.76	
Visual Similarity (V)	1	0.1890	41.74	< .01
Subjects (S)	23	1.3986		
Days (D)	1	0.0134	3.94	< .05
Type of Match (C)	1	0.0397	112.84	< .01
V X S	23	0.1042		
V X D	1	0.0000	0.00	> .10
S X D	23	0.0782		
V X C	1	0.0011	1.98	> .10
S X C	23	0.0081		
D X C	1	0.0002	0.49	> .10
V X S X D	23	0.0300		
V X S X C	23	0.0125		
V X D X C	1	0.0001	0.29	> .10
S X D X C	23	0.0110		
V X S X D X C	23	0.0088		

Table 9
 Analysis of Variance of the Negative Reaction
 Time Data From Experiment III

Source	df	MS	F	p
Mean	1	32.1988	891.77	
Visual Similarity (V)	1	0.1646	33.43	< .01
Subjects (S)	23	0.8304		
Days (D)	1	0.0073	3.20	> .05
V X S	23	0.1132		
V X D	1	0.0002	0.18	> .10
S X D	23	0.0522		
V X S X D	23	0.0251		

Table 10

Analysis of Variance of the Relative Errors-Experiment III

Source	df	MS	F	p
Mean	1	1831.0090	171.37	
Visual Similarity (V)	1	27.5521	4.82	< .05
Subjects (S)	23	245.7513		
Days (D)	1	12.8676	1.70	> .10
Type of Match (C)	1	128.5006	29.21	< .01
V X S	23	131.4420		
V X D	1	7.0658	1.59	> .10
S X D	23	174.1169		
V X C	1	0.2442	0.05	> .10
S X C	23	101.1729		
D X C	1	4.9830	1.15	> .10
V X S X D	23	101.9209		
V X S X C	23	118.3279		
V X D X C	1	2.1680	0.33	> .10
S X D X C	23	100.0863		
V X S X D X C	23	148.8766		

Table 11

Median Reaction Times for each Subject -
Active Memory, Acoustically Similar

Subject Number	Physical			Associational		
	<u>M = 1</u>	<u>M = 2</u>	<u>M = 4</u>	<u>M = 1</u>	<u>M = 2</u>	<u>M = 4</u>
1	0.548	0.594	0.568	0.610	0.617	0.621
2	0.623	0.714	0.848	0.621	0.774	0.986
3	0.455	0.492	0.519	0.467	0.493	0.503
4	0.513	0.504	0.520	0.520	0.607	0.592
5	0.538	0.653	0.668	0.578	0.610	0.714
6	0.456	0.495	0.678	0.423	0.554	0.588
7	0.477	0.495	0.553	0.503	0.528	0.502
8	0.354	0.424	0.450	0.408	0.420	0.494
9	0.367	0.399	0.456	0.386	0.462	0.443
10	0.499	0.579	0.682	0.513	0.648	0.585
11	0.388	0.413	0.464	0.412	0.452	0.498
12	0.457	0.518	0.517	0.510	0.577	0.574
13	0.400	0.450	0.537	0.421	0.458	0.576
14	0.471	0.479	0.537	0.471	0.490	0.592
15	0.510	0.545	0.531	0.478	0.546	0.592
16	0.455	0.514	0.636	0.487	0.519	0.687
17	0.375	0.418	0.520	0.409	0.432	0.452
18	0.443	0.439	0.489	0.465	0.502	0.530
19	0.343	0.367	0.423	0.345	0.393	0.434
20	0.376	0.407	0.442	0.421	0.416	0.432
21	0.443	0.442	0.517	0.443	0.487	0.533
22	0.358	0.398	0.453	0.379	0.387	0.511
23	0.465	0.465	0.543	0.464	0.472	0.587
24	0.394	0.422	0.465	0.402	0.417	0.496

Median Reaction Times for each Subject -
Inactive Memory, Acoustically Similar

Subject Number	Physical			Associational		
	<u>M = 1</u>	<u>M = 2</u>	<u>M = 4</u>	<u>M = 1</u>	<u>M = 2</u>	<u>M = 4</u>
1	0.566	0.500	0.590	0.575	0.534	0.607
2	0.533	0.675	0.689	0.581	0.766	0.731
3	0.495	0.526	0.545	0.514	0.559	0.527
4	0.471	0.560	0.566	0.461	0.589	0.572
5	0.653	0.661	0.918	0.639	0.702	1.050
6	0.593	0.638	0.877	0.590	0.634	0.864
7	0.510	0.585	0.737	0.497	0.573	0.693
8	0.515	0.518	0.521	0.523	0.492	0.546
9	0.403	0.428	0.527	0.371	0.482	0.505
10	0.498	0.647	0.587	0.501	0.637	0.669
11	0.435	0.545	0.542	0.423	0.552	0.529
12	0.518	0.632	0.549	0.539	0.601	0.625
13	0.472	0.623	0.783	0.503	0.650	0.771
14	0.550	0.543	0.613	0.524	0.562	0.601
15	0.515	0.700	0.777	0.547	0.709	0.723
16	0.578	0.636	0.783	0.603	0.642	0.803
17	0.455	0.523	0.533	0.494	0.587	0.493
18	0.493	0.589	0.580	0.536	0.623	0.568
19	0.439	0.484	0.523	0.437	0.483	0.507
20	0.456	0.527	0.488	0.441	0.551	0.496
21	0.493	0.555	0.593	0.454	0.542	0.619
22	0.455	0.490	0.511	0.437	0.529	0.508
23	0.513	0.524	0.719	0.513	0.542	0.688
24	0.497	0.565	0.565	0.519	0.567	0.580

Median Reaction Times for each Subject -
Active Memory, Acoustically Neutral

<u>Subject Number</u>	<u>Physical</u>			<u>Associational</u>		
	<u>M = 1</u>	<u>M = 2</u>	<u>M = 4</u>	<u>M = 1</u>	<u>M = 2</u>	<u>M = 4</u>
1	0.444	0.470	0.481	0.475	0.488	0.538
2	0.578	0.577	0.615	0.584	0.651	0.670
3	0.593	0.628	0.674	0.668	0.742	0.696
4	0.579	0.673	0.628	0.580	0.586	0.662
5	0.468	0.490	0.527	0.478	0.532	0.529
6	0.375	0.427	0.543	0.391	0.454	0.553
7	0.544	0.611	0.593	0.554	0.602	0.623
8	0.405	0.448	0.604	0.422	0.463	0.612
9	0.377	0.429	0.453	0.387	0.461	0.448
10	0.457	0.464	0.460	0.499	0.474	0.534
11	0.397	0.428	0.471	0.457	0.439	0.489
12	0.528	0.498	0.577	0.555	0.536	0.616
13	0.379	0.475	0.641	0.409	0.498	0.550
14	0.461	0.491	0.535	0.465	0.477	0.600
15	0.614	0.674	0.723	0.710	0.662	0.701
16	0.458	0.504	0.746	0.485	0.530	0.639
17	0.382	0.418	0.492	0.431	0.511	0.554
18	0.395	0.452	0.554	0.413	0.459	0.574
19	0.342	0.369	0.474	0.371	0.385	0.457
20	0.392	0.437	0.422	0.428	0.431	0.410
21	0.403	0.422	0.516	0.435	0.458	0.533
22	0.370	0.393	0.524	0.415	0.420	0.513
23	0.646	0.648	0.667	0.672	0.669	0.772
24	0.465	0.475	0.509	0.477	0.478	0.509

Median Reaction Times for each Subject -
Inactive Memory, Acoustically Neutral

Subject Number	Physical			Associational		
	<u>M = 1</u>	<u>M = 2</u>	<u>M = 4</u>	<u>M = 1</u>	<u>M = 2</u>	<u>M = 4</u>
1	0.449	0.524	0.515	0.463	0.526	0.516
2	0.534	0.635	0.634	0.552	0.684	0.706
3	0.440	1.009	0.752	0.447	1.061	0.683
4	0.524	0.707	0.546	0.482	0.651	0.563
5	0.476	0.567	0.687	0.512	0.585	0.651
6	0.566	0.572	0.636	0.566	0.548	0.660
7	0.522	0.588	0.848	0.540	0.541	0.904
8	0.508	0.525	0.664	0.531	0.562	0.685
9	0.412	0.406	0.545	0.458	0.474	0.508
10	0.487	0.492	0.519	0.500	0.512	0.551
11	0.498	0.520	0.608	0.488	0.545	0.618
12	0.508	0.472	0.681	0.459	0.496	0.731
13	0.546	0.626	0.731	0.613	0.652	0.793
14	0.545	0.552	0.530	0.525	0.567	0.607
15	0.661	0.714	0.772	0.613	0.705	0.888
16	0.574	0.597	0.714	0.599	0.617	0.684
17	0.480	0.522	0.529	0.512	0.513	0.571
18	0.547	0.581	0.647	0.558	0.567	0.654
19	0.387	0.481	0.544	0.399	0.473	0.513
20	0.407	0.444	0.532	0.458	0.465	0.533
21	0.476	0.562	0.598	0.451	0.553	0.520
22	0.453	0.525	0.528	0.446	0.495	0.514
23	0.563	0.670	0.967	0.582	0.640	1.036
24	0.484	0.492	0.669	0.471	0.526	0.691

Table 12

Median Match Reaction Times for each Subject
for each Condition in Experiment III

Subject Number	Day 1		Day 2	
	Physical	Associational	Physical	Associational
Visually Similar				
1	0.833	0.750	0.722	0.753
2	0.576	0.592	0.553	0.601
3	0.518	0.501	0.472	0.487
4	0.429	0.434	0.481	0.528
5	0.587	0.632	0.612	0.620
6	0.483	0.507	0.471	0.560
7	0.385	0.432	0.392	0.409
8	0.397	0.404	0.400	0.446
9	0.454	0.460	0.419	0.478
10	0.721	0.851	0.570	0.595
11	0.483	0.484	0.422	0.453
12	0.661	0.688	0.644	0.703
13	0.516	0.556	0.506	0.548
14	0.407	0.471	0.422	0.500
15	0.517	0.548	0.498	0.512
16	0.392	0.446	0.372	0.411
17	0.436	0.451	0.456	0.493
18	0.482	0.516	0.512	0.504
19	0.764	0.816	0.677	0.690
20	0.443	0.494	0.453	0.466
21	0.530	0.660	0.556	0.599
22	0.453	0.472	0.446	0.426
23	0.466	0.488	0.461	0.528
24	0.615	0.611	0.547	0.646

Subject Number	Day 1		Day 2	
	Physical	Associational	Physical	Associational
<hr/> Visually Neutral				
1	0.650	0.703	0.606	0.638
2	0.545	0.535	0.577	0.579
3	0.443	0.489	0.416	0.474
4	0.377	0.406	0.374	0.413
5	0.517	0.536	0.491	0.497
6	0.411	0.427	0.413	0.436
7	0.392	0.423	0.369	0.394
8	0.330	0.346	0.349	0.363
9	0.397	0.396	0.406	0.426
10	0.543	0.550	0.463	0.451
11	0.394	0.425	0.376	0.411
12	0.538	0.541	0.568	0.609
13	0.511	0.515	0.504	0.532
14	0.362	0.404	0.360	0.386
15	0.536	0.502	0.438	0.447
16	0.391	0.432	0.358	0.399
17	0.399	0.420	0.401	0.445
18	0.500	0.525	0.403	0.437
19	0.565	0.598	0.516	0.538
20	0.407	0.438	0.432	0.472
21	0.547	0.621	0.483	0.508
22	0.370	0.408	0.433	0.475
23	0.451	0.489	0.461	0.447
24	0.548	0.565	0.506	0.516

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