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THE EFFECTS OF EXPOSURE DURATION AND DISTRUBUTED PRACTICE SCHEDULES UPON VISUAL INFORMATION PROCESSING

A Thesis Presented

By

Hal Bettencourt

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CONTENTS

CONTENTS(continued)

Abstract

There is experimental evidence which suggests that visual memory, like verbal memory, has several distinct stores: the sensory register (SR), short-term-store (STS) and long-term-store (LTS). Eventhough visual memory seems to share the above structural features with verbal memory, its control processes appear somewhat different. The differences are, perhaps best exemplified by the apparent lack of a visual rehearsal process like the one so crucial to and reliably observed in verbal memory (Shaffer and Shiffrin, 1972). This difference suggests the possibility of other important differences between the two memory modalities. Perhaps, distributed practice (DP) schedules would not improve learning in visual memory like these schedules reliably do in the verbal modality.

The present experiments were designed to examine the effects of these variables upon visual memory, and to describe the similarities and/or differences from the verbal modality, using Mooney figures (1960). The figures required the Ss to perceive and then to verbally describe (a) common object(s) embedded in the ambiguous backgrounds. The use of the Mooney figures prohibited, theoretically, any verbal descriptive behavior until Ss actually could "see" some coherent figure(s) in each slide; intuitively, this seems like an entirely visual process.

The subset of slides selected for experimental manipula-

tion were chosen because they were assumed to be "equally difficult" as a result of Experiment I. Experiment I estimated the difficulty of each ambiguous slide (to be used in Experiments II & III) by measuring the average time to correct solution for each of ten subjects. A "correct solution" occurred whenever S perceived and described the object(s) in each pictorial stimulus. Experiments II & III tested the effects of exposure duration, and distributed practice with either "blank time" or "filled" spacing intervals using the stimuli selected by Experiment I. The experimental results measured by percent "correct solutions" suggested that the most important variable for learning and retention in visual memory was total stimulus exposure time. The absence of a visual rehearsal process was suggested by the difference in performance between DP items with and without "blank time" spacing intervals. That is, DP scheduled items with "blank time" available for visual rehearsal produced worse performance (fewer correct solutions) than DP scheduled items with "visual-oral" interference task during the spacing interval. Apparently, DP learning schedules, like those used in Experiments II and III, do not facilitate the learning or memory processes in the visual modality.

LIST OF SAMPLE STIMULI IN APPENDIX A

LIST OF TABLES IN APPENDIX B

<u>Tables</u>:

LIST OF FIGURES IN

APPENDIX C

Graphic representations of Data from Experiments II, and III.

Figure

In both figures 1., and 2., the "learning-to-learn"curves appear relatively flat indicating that Ss were not learning how to solve new stimulus items with practice on previously presented stimuli.

INTRODUCTION

A Model of Human Memory:

A discussion of memory in which both verbal and non-verbal processes are compared is probably impossible unless a general model, or more properly, a framework is assumed. The model proposed by Atkinson and Shiffrin (1968) seems to capture most of the important assumptions shared by memory researchers today. However, the model is based upon emperical data obtained using stimuli that were easily verbally coded so that its application to non-verbal memory remains largely an unresolved problem. Therefore, Atkinson and Shiffrin's statements about visual memory described in their model must be read with caution.

The Model Described:

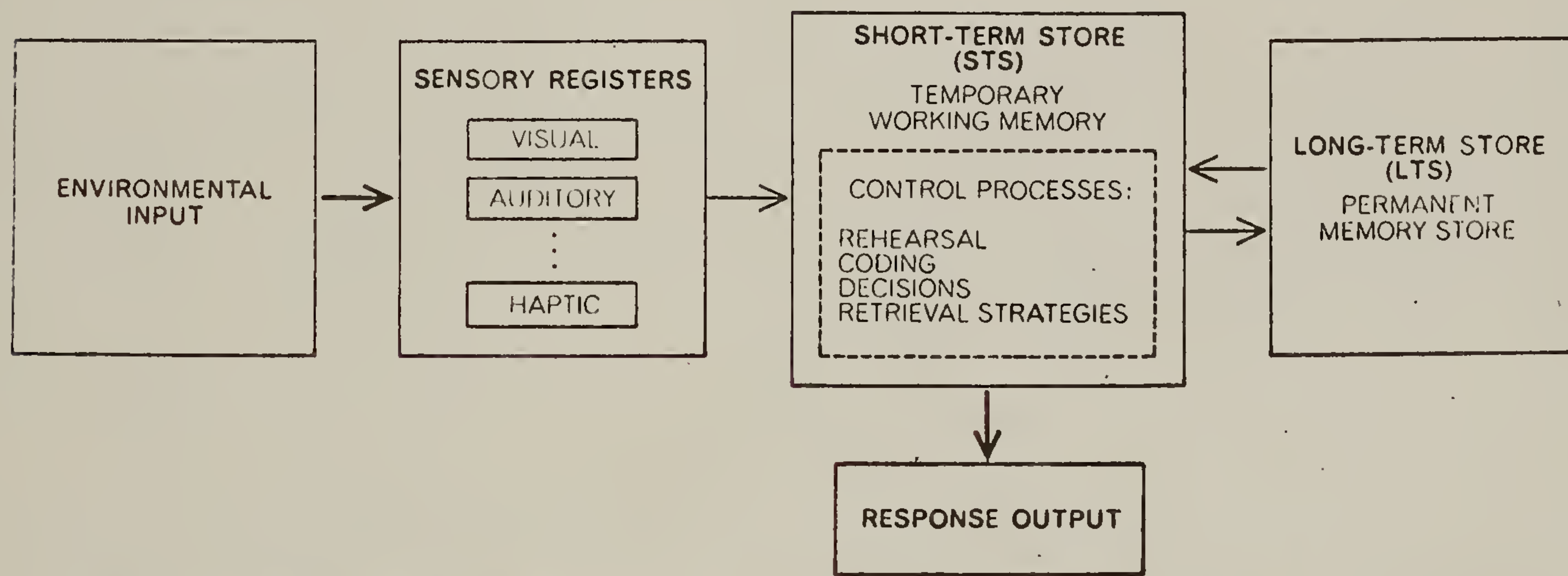
Atkinson and Shiffrin (1968, 1971) propose an information processing model for human memory which emphasizes the distinction between "structural features" and "control processes". The structural features are the permanent features of memory including "both the physical system and the built in processes that are unvarying and fixed from one situation to another" (p. 90, 1968). Examples of these permanent features are the Sensory Register (SR), Short-Term-Store (STS), and Long-Term-Store (LTS). "Control processes, on the other hand, are selected, constructed, and used at the option of the subject and may vary dramatically from one task to another even though superficially the tasks may appear very similar" (p. 90, 1968). Examples of these

control processes are coding procedures, rehearsal operations, and search strategies. (Both coding procedures and rehearsal operations will be described in detail in a later section of this thesis.)[1]

The basic features of the model are represented by the usual information processing flow diagram as a series of "black-boxes" interconnected by a series of arrows. The boxes symbolize the structural features of the model and the arrows the flow of information through the system, (refer to figure 1, taken from Atkinson and Shiffrin, 1971). As can be seen in the diagram information from the environment first enters the sensory registers. Then selected portions of information from the sensory registers are encoded into the STS. Once the selected information enters

Insert Figure 1 About Here

the STS, a series of processes and operations code the stimulus representations into "packages" for transfer to LTS. Information stored in LTS is available for later recall and utilization whenever necessary. Clearly, more has to be said about the details of the model in order to understand how control processes are seen to interact with the above structural features. The following paragraphs will describe the control processes, structural features and their interaction in more detail.



INFORMATION FLOW through the memory system is conceived of as beginning with the processing of environmental inputs in sensory registers (receptors plus internal elements) and entry into the short-term store (STS). While it remains there the information may be copied into the long-term store (LTS), and associated information that is in the long-term store may be activated and entered into the short-term store. If a triangle is seen, for example, the name "triangle" may be called up. Control processes in the short-term store affect these transfers into and out of the long-term store and govern learning, retrieval of information and forgetting.

DIAGRAM 1. A schematic representation of the Atkinson and Shiffrin (1971) model of human memory taken from Scientific American, Vol. 2, p 82-89, 1971

Structural Properties and the Rehearsal-Coding Processes:

Information entering the visual SR usually decays within a few hundred milliseconds (Sperling, 1960; Haber, 1964; MacWorthy, 1964) and is lost from the system unless attended to and recoded into STS. Likewise, information entering into the auditory SR decays and is lost in a similar fashion unless recoded (Crowder, 1963; Moray, 1970; Cohen, 1972). The problem here is that most of the experimental paradigms measure what happens to this information after it is recoded into the verbal portion of STS. Atkinson and Shiffrin choose to label this store the audio-verbal-linguistic store (a-v-l) because, "it is very difficult to separate the verbal and linguistic aspects from the auditory ones" (p. 100, 1968).[2]

The properties of the postulated a-v-l store are very different from those of the SR. Information entering the a-v-l store will decay in approximately 15 to 30 seconds unless the subject opts to employ a rehearsal strategy. While there is evidence that the SR has a very large capacity (usually the SR contains more information than the subject can report (Sperling, 1960), the a-v-l store seems to have a limited capacity, a span of about seven items (Miller, 1958). New information entering the system in excess of this limited capacity will "bump" old items out of STS and these items will be lost completely. Information transferred into LTS is shaped by the control processes of STS; the control process of primary importance to this information trans-

fer is that of rehearsal. To quote Atkinson and Shiffrin (1971), "One of the most important of these control processes is rehearsal. Through overt and covert repetition of information, rehearsal either increases the momentary strength of information in the short-term store or otherwise delays its loss. Rehearsal can be shown not only to maintain information in short-term storage but also to control transfer from the short-term store to the long-term one." (p. 4, 1971).[3]

However, the transfer of information to LTS also depends upon "coding". Coding refers to a class of control processes in which the information to be remembered is put into a context of additional, easily retrievable information, such as mnemonic phrases or sentences. Apparently, coding and rehearsal processes generally operate in conjunction with each other and must be considered interdependent. Rehearsal maintains the information in STS while the coding necessary for efficient storage and retrieval occurs. Once the coding operation has been completed, the coded information is then transferred to LTS.

Information transferred to LTS is stored permanently. The fact that information is stored permanently might cause some difficulty for the model because of insufficient storage capacity, consequently, Atkinson and Shiffrin assume the capacity of LTS to be infinite. The permanence of information in LTS is usually cited as a basis for determining the

location of information in the system. That is, if retention of the information shows decay (under certain conditions) over short periods of time, then transfer into LTS probably never occurred. (For additional information see Atkinson and Shiffrin, 1968, 1971).

In summary, the structural features of the model are: the SR, STS, and LTS. The SR is a very short duration, large capacity store used to hold information arriving from the environment for encoding. Additional encoding and re-coding processes usually occur in the postulated a-v-l mode of STS, although, other types of modalities in STS are also postulated. Information in STS is considered to be in the subject's "working memory"; consciousness. This storage area is also responsible for the transfer of information into and retrieval of information out of the permanent LTS.

Evidence for Localized Spatio-Visual Processing:

The Atkinson and Shiffrin (1968) assumption that verbal and visual information could be processed independently under certain conditions was partially varified by Gazzaniga in 1969. He reported emperical evidence suggesting that independent spatio-temporal (imagery) and verbal processing might actually occur. Furthermore, these operations seem to be localized in opposite hemispheres of the human brain. These emperical findings are important to the Atkinson and Shiffrin model because of the support these results provide for their assumption of independent visual and verbal stores. Gazzag-

aniga's research also serves as the transition into a review and discussion of the visual memory literature. More specifically, his research begins to answer the question, are there two distinct visual stores; visual STS and visual LTS?

Gazzaniga's Split Brain Experiments:

The human brain has two (left, right) hemispheres connected by the Corpus Callosum. The Corpus Callosum is responsible for the intergration of the operations of the two cerebral hemispheres in the normal intact brain. Furthermore, the right hemisphere has major responsibility for the motor movements of the left half of the body, particularly hand and arm motions. The left hemisphere, in a similar manner, is responsible for the same motor control of the right half of the body. Patients suffering from severe epilectic seizures often have surgical separation of the hemispheres by sectioning the Corpus Callosum. This remedial surgical operation does prove to be successful in preventing the reoccurrence of the seizures, however, there are some anomalies in psychological functioning. For example, Gazzaniga (1971) presents experimental findings obtained from Ss with surgically split brains which suggests verbal functions are located predominantly in one hemisphere, usually the left, while visual spatial functions seem to be located in the other hemisphere, usually the right.

The experiment of interest presented S with either a visual or tactile stimulus encode in the left or right hemi-

sphere only. When a stimulus (i.e., tactile would be an actual spoon while visual would be a picture of the object) was presented to the left hemisphere S could write or orally report a description of the stimulus. In contrast to this result, if the same information was presented to the right hemisphere, S could not describe the stimulus in either an oral or written manner. However, S could retrieve the object from a random collection of items or point to the correct pictorial representation embedded in a group of picture items. Furthermore, when S was asked to draw the stimulus (line drawing of a necker cube) previously presented to both hemispheres on alternate trials, the task was efficiently completed by the right hemisphere (i.e., the left hand), but not the left hemisphere (i.e., the right hand).

One implication of these studies argues for verbal processing predominating in the left hemisphere, although there is evidence that some simple verbal items are processed in the right hemisphere. However, the right hemisphere seems responsible for the majority of the recoding, retention, and reconstruction of higher order visual-spatial information.

The split brain experiments thus support the Atkinson and Shiffrin conceptualization of distinct stores for information other than verbal material. Clearly, these studies establish the localization, and therefore, the existence of a separate visual information store that extends temporally

beyond the 1 to 1.5 second limit of visual STS. It seems evident that the processes governing the control of information in one store (i.e., visual-spatial, or verbal) can be independent of the processes of the other. Gazzaniga's results do not, however, clearly establish exactly what visual processing is localized in the non-dominant hemisphere. His results only demonstrate the existence of independence between the visual and verbal memories at some level. The literature reviewed in the next section argues strongly for the existence of both a visual STS and a visual LTS.

Visual Memory: Are There Two Distinct Stores?

The emperical data on localization of visual-spatial processing within a hemisphere was only tangentially helpful in beginning to answer the question of two distinct visual stores. Fortunately, there are several studies that suggest more strongly the existence of at least, a separate visual LTS. Although, it seems intuitively obvious that there is a visual or non-verbal LTS in memory (since we can recognize faces over a period of years), it is surprisingly difficult to establish that this type of memory is not dependent on verbal encoding. However, recognition of complex visual displays (i.e., typical photographs of scenery) is not, plausibly, totally dependent on verbal encoding and, hence has been the focus for work on visual memory.

There are several reasons why recognition performance

suggests the existence of a separate visual LTS. For example, it seems unlikely that Ss would depend entirely upon a verbal encoding strategy for recognition of large numbers of scenic pictures over long retention periods. This has been emperically documented by Nickerson (1965) who presented Ss with 600 meaningful pictorial stimuli in a continuous recognition experiment. Items were viewed for 5 seconds each with a second presentation at lags of 40, 80, 120, and 200 intervening pictorial stimuli. Ss responded to stimuli as "old" or "new" during the experimental session. The data show percent correct recognition for "old" items varies inversely with lag, the longer the lag the poorer performance (i.e., 97% to 87% correct).[4] However, average performance was better than 92% correct. Nickerson (1968) using an experimental paradigm similar to that just reported shows recognition memory for pictures (i.e., those of his first experiment) to be well above chance at delays of 360 days. Ss were given a continuous recognition task like that of experiment 1, but were tested for recognition memory of 50 of the original items, which were mixed with 50 new items at delays of 1, 7, 28, and 360 days. Performance ranged from 92% correct recognition on day 1 to 63% on day 360. Haber (1970) also reports excellent visual recognition performance for long retention intervals. He presented Ss with 2500 color slides (e.g., typically scenery) over a four day period and then tested recognition performance in a forced choice task. The average

overall performance was 90% correct recognition. However, these results are particularly relevant to a visual LTS explanation since items presented to S on the first day were recognized best. Clearly these experimental results suggests retention in visual LTS.[5]

A further suggestion of a separate visual LTS has been reported by Shepard (1967). More specifically, he shows that recognition performance for pictures is at least equal to and perhaps better than verbal memory for equal numbers of verbal stimuli. If pictorial stimuli were wholly dependent upon verbal description for correct recognition, then it would be unlikely that memory for pictures should exceed memory for the pictorial labels. Shepard presented groups of Ss with 600 stimulus slides and tested forced choice recognition performance immediately. The stimuli used in the three separate experiments were common nouns, short sentences, and meaningful color photographs. Results show visual recognition memory superior to verbal recognition memory for the stimuli he used. The recognition scores were 90%, 88%, and 98% correct for words, short sentences, and pictures respectively. (Furthermore, longer term visual recognition for the picture was greater than 90% at delays of seven days.) However, it must be concluded that Shepard's comparisons are only suggestive since there was no independent measure of whether the stimuli used in the different groups were equated for difficulty.

A third indication that these recognition memory studies exemplify visual LTS is related to storage capacity. It seems unlikely that Ss could retain as many as 200 to 2500 pictures in a limited capacity visual STS for any period of time. It also seems unlikely that Ss could efficiently verbally encode descriptions of so many pictures quickly enough to have the very high recognition scores reported (Nickerson, 1965, 1968; Shepard, 1967; Haber, 1970), although, verbal encoding is probably partially responsible for the overall high performance.

In summary, the evidence presented is highly suggestive of a visual LTS. However, it is difficult to assess the amount of verbal encoding and facilitation in the several tasks. In every case the pictorial stimuli used were selected to contain salient features that could be easily verbally encoded. Other investigators have attempted to manipulate verbal codability in their pictorial stimuli in an effort to estimate the verbal component in memory for pictures.

One variable that one would intuitively think has an important role in visual memory is stimulus familiarity (i.e., the amount of experience the S has had with the stimuli). However, familiarity might affect visual memory in a nonvisual way. An example of the problem of determining whether familiarity operates in a visual or verbal mode is an experiment by Goldstein and Chance (1970). In their experiment the stimulus classes were pictures of faces, inkblots, or snow-

flakes presented to separate groups of _S_s for 2 or 3 seconds each. Results show a large familiarity effect: recognition for schematic faces, inkblots, and snowflakes was 71%, 47%, and 34% respectively. However, the better performance for the more familiar schematic face could have been caused by verbal encoding. For example, it might be considerably easier for _S_s to pick out a salient feature in the picture if the picture is that of a very familiar item (i.e., faces). Consequently, this salient feature could be labelled quickly, whereas, this might not be true for unfamiliar items. Unfamiliar items would take more time to encode since unfamiliar _S_s would have to remember more irrelevant, less important information than familiar _S_s would. This has been exemplified by Mooney (1960) who has shown recognition performance for complex, meaningless visual configurations to be at chance level at lags of 15 items (delayed recognition for 15 seconds). These results are a dramatic illustration of the effect of familiarity on visual memory similar to the Goldstein and Chance inkblots and, perhaps, the snowflake conditions.

Another variable, like familiarity, that might account for the observed decline in recognition performance in the studies discussed is "complexity". Complexity will be defined as the length of the verbal description necessary to _uniquely_ describe any stimulus (this concept seems slightly confounded with familiarity, yet the two are not the same).

Items uniquely described in a few words would be "low complex" while those requiring long descriptions would be "high complex". It seems obvious that Mooney's meaningless figures, and Goldstein and Chance's inkblots and snowflakes would all be considered high complex. Thus recognition performance would be expected to decrease if verbal memory were responsible for retention or if visual complexity (which seems to correlate with the concept of verbal complexity) somehow reduced Ss ability to visually retain all the information in any slide. Several psychologists have tried to use a concept much like complexity to demonstrate the dependence of visual recognition memory upon verbal codability.

Wyant et al. (1972) define the concept of "similarity" as the length of the verbal statement necessary to uniquely distinguish between any two pictorial slides (similiarity is related to complexity since the more complex the two slides are, the more difficult to discriminate by a simple verbal description if the slides look alike). For example, if the verbal statement is lengthly, then the items are very similar and vice versa. Thus, items quite dissimilar could be remembered by a simple verbal code. The author's intent here was to vary the verbal and pictorial similarity of the stimulus items. Wyant et al. hypothesize, "if memory for pictures is based upon pictorial storage, visual similarity between targets and distractors in recognition tests should reduce recognition accuracy. If recognition for pictures is

mediated by verbal coding, recognition should decline as the verbal code assigned to the target becomes less efficient at distinguishing it from distractors" (p. 152). In otherwords, when old and new pictures are selected for recognition tests on the basis of both their visual similarity and the similarity of a verbal description of them, the verbal description is more important.

Wyant et al. found that the higher the rated verbal discriminability of the differences between each pair of old and new pictures, the better the recognition accuracy. This implies that Ss were using a verbal code to remember the pictures. However, when viewing time was short (three rather than ten seconds) there was an effect of rated similarity between stimulus pairs. Presumably, the longer the exposure duration, the more opportunity Ss had to verbally encode pictorial differences.[6]

These last few studies suggest that the type of stimulus material is very important to visual recognition performance. Familiar, meaningful, low complexity items will be recognized easily. Unfortunately, it is not clear whether recognition is dependent upon a strong visual or verbal memory component, perhaps both. Thus the question of verbal mediation of pictorial representation in memory remains an open issue.

Another variable manipulated in each of the experiments discussed has been exposure duration. The importance of this variable to visual memory will be made apparent in the following discussion on the existence of visual STS.

Visual STS:

Visual STS has been investigated infrequently in the past because of the difficulty of either eliminating or measuring the degree of verbal mediation. If one could isolate visual STS, the first questions that one would like answered about visual STS are, (a) its temporal duration if material is not attended to, and (b) whether there is a rehearsal process which can both extend the duration of the short-term trace and also facilitate formation of a long-term trace(i.e., properties like those of the verbal medium).

Perhaps the most unambiguous demonstration of visual short-term memory has been given by Posner, Boies, Eichelman, and Taylor (1969), and Posner and Keele (1967). Posner et al. used reaction time (RT) to infer the existence of a visual store. In a simultaneous matching task, Ss were able to say "same" to a physically identical (PI) pair (i.e., AA) about 80 msec. faster than to a name identity (NI) pair (i.e, Aa) when instructed to indicate whether the two letters had the same name. The faster time for the PI pair is interpreted as resulting from a faster comparison in a visual store. However, if the letters are presented sequentially, the advantage of PI pairs over NI pairs decreases exponentially with the advantage disappearing for ISI's of 2-3 seconds. Posner interprets this decrease as a decay in visual store. However, one should be cautious (as Posner points out) in interpreting 2-3 seconds as the decay time of the visual trace, since all that one knows

is that by 2-3 seconds the physical trace has decayed to the point that the PI comparison is no faster than the NI comparison.

Posner argues that the PI match is faster than the NI match because Ss can "visually rehearse" the stimulus (e.g., A) in memory while waiting for the probe letter. Emperical verification for this hypothesis is shown in his PI match data for pure lists: RT (430 msec. at zero seconds probe delay) increases only slightly (10 msec.) when the probe letter is delayed for 1 second. If RT had increased, this would have been an indication of visual trace decay, or a lack of visual rehearsal. This, in fact, was the case for the PI match mixed list condition: RT increased approximately 70 msec. for the same 1 second probe letter delay. These results do seem to suggest a visual rehearsal process, however, rehearsal here is not the same processes that Atkinson and Shiffrin describe as rehearsal in verbal STS. To quote Posner (1967), "the term rehearsal, rather than being restricted to those cases where the process is verbal, is appropriate whenever it is shown that S's ability to retain information requires central processing capacity (CPC)." More simply, it appears as if Ss can hold information in visual STS if they actively invest their attention in doing so, while a lack of attention leads to information loss.

One criticism of Posner's interpretation of his experiments is that the decaying store is simply the sensory

register and not a functionally distinct visual STS. Droost and Turvey (1971) present experimental evidence to refute any such criticism of Posner's research. Droost and Turvey required Ss to perform a verbal identification of elements of a briefly exposed visual display (similar to Sperling's original experiments demonstrating iconic storage) while performing a secondary memory task simultaneously. If retention in iconic store is independent of CPC, then recall from iconic store should be unaffected by simultaneously retaining information in verbal STS. Furthermore, the information being held in verbal STS should be recalled accurately. The results show the experimental group's delayed (up to 700 msec.) recall (from iconic store) for any of the three tone cued rows of the 3x5 letter array was equal to that of controls, even though, the experimental group was asked to retain and recall a CVC (presented prior to the array) immediately after their partial report. This means that there was no differential effects upon recall from iconic store caused by the secondary memory task. Thus, Posner has shown that retention in visual STS depends upon CPC, while, Droost and Turvey have demonstrated that retention in iconic store does not depend upon CPC. Therefore, it can be concluded that iconic memory and the visual memory identified by Posner reflect different representations of visual information.

At this point it appears safe to accept Posner's data

as evidence for a visual STS. However, his estimate of a 2-3 second decay time seems intuitively much too short to be adaptive for human memory. Therefore, the following questions must be asked, (a) is there evidence for a slower rate of decay than 2-3 seconds and if so, (b) then what are the conditions that affect the rate of visual decay (for example, type of stimulus material or, task and exposure duration)? If decay rate can be shown to vary with experimental conditions, then a third question must be asked, how does rehearsal affect decay rate? To be more specific, (c) can "visual rehearsal" help to encode information into visual LTS or does rehearsal simply maintain the visual short term trace?

Several studies will be reported in answering questions (a) and (b) which have found different (usually longer) decay times using different procedures. Unfortunately, differences in experimental procedures between studies make them hard to compare. The general results of these experiments show decay times to be longer if the stimuli are "simpler" and/or if the Ss are allowed longer exposure times for encoding. Caution is urged in interpreting some of the experimental results since a verbal encoding hypothesis can not be completely ruled out. For example, Posner and Konick (1966), and Posner (1967) show that visual-location information (position of a dot on a line) can be accurately maintained in memory up to 20 seconds

even while Ss perform a secondary task (reading visually presented letters aloud). However, if the task becomes more difficult (adding numbers) then performance deteriorates rapidly. This rapid deterioration could be easily explained by disruption of a verbally encoded trace for the dot locations, as well as the visual trace decay hypothesis offered.

Three recent studies attempted to eliminate any possibility for verbal encoding by using fast exposure durations and/or selecting visual stimuli difficult to verbally describe. All three papers criticize Posner et al. (1969) for confounding the decay of visual trace with the development of the name code for his letter stimuli. That is, the visual trace was assumed to decay more slowly when a verbal code was not easily available for rehearsal in verbal memory.

The first study reported by Phillips and Baddeley (1971) found trace decay (for a 5x5 matrix array of filled or unfilled squares) as long as 9 seconds when the arrays were exposed only 500 msec. Mitchell (1972) criticized Phillips and Baddeley for using stimuli much too complex to allow proper coding in visual STS because of the short exposure duration. He used simpler stimuli (Gibson figures) exposed 30 or 40 msec. and found visual trace decay lasting at least 6.0 seconds (70% correct recognition). To decrease the possibility of verbal encoding effects in his data, Mitchell analyzed only those Gibson figures that Ss had not provided a name for during the experiment. A third study reported by

Cermak (1972) appears to have come closest to examining visual encoding and trace decay. Because his data show an exponential decay function that approaches a stable asymptotic level of performance the experiment will be explained in detail.

Cermak used a "same-different" recognition task to measure retention of free form nonsense figures at exposure duration of 5 seconds each. The figures were simple closed amorphous line drawings matched along several dimensions to increase the difficulty of discrimination. Difference between items were subtle and difficult to encode in any verbal manner. The probe stimuli were selected in a random order as either "same" or "different". When the probe was classified as different, it was one of the "adjacent figures". Here, "adjacent figure" means that the general shape of the stimulus and the probe were the same, but differed on some minor features. Probe presentations were delay, that is, probes appeared at retention intervals of 1.5, 4.0, 12.0, or 20.0 seconds. Ss had no previous knowledge of the probe stimulus to appear on any trial. This further reduced the likelihood of verbal mediation during encoding. Retention intervals were unfilled and Ss were given no special instructions.

Results in this study were measured in percent correct recognition which ranged from 78% correct at 1.5 seconds to 66% correct at 20 seconds delay. The visual decay function

was negatively accelerating showing the greatest decay between 1.5 to 4.0 seconds (78% to 70% correct recognition). The function seemed to approach asymptotic performance at a point beyond the 12 second retention period (66% correct recognition at 12 seconds).

Even though verbal mediation or encoding cannot be ruled out in any of the three studies, it appears unlikely in Cermak's data. The important information to be gained from his study is (1) a slow decay rate, and (2) demonstrated asymptotic performance. These results seem similar to the characteristics of verbal STS reported by Atkinson and Shiffrin. However, it is impossible to determine whether exposure duration, type of stimuli, the experimental paradigm, or some combination of all three of these is responsible for the data Cermak obtained. Only two other studies have found decay rates slower than 20 seconds (Kroll et al., 1970, and Warington and Shallice, 1972). Both articles report presenting letter stimuli either visually or aurally and comparing the retention over time. In both of these experiments, the visual presentation always provided better performance than aurally presented stimulus lists when an aural interference task was used to disrupt verbal encoding. These authors feel their results further suggest the existence of a visual STS.

The discrepancies between the decay rates above suggest the possibility that the decay rate of visual STS is somewhat

under the control of Ss, because of some sort of "visual rehearsal" process. They may be able to visually rehearse (i.e., maintain) their visual memory traces if they allot CPC. For example, Posner, Boies, Eichelman, and Taylor (1969) found that RT does not become slower for physical matches of letters if all the letters are upper case (i.e., there are never any pure name matches). They interpret this finding as evidence that the visual trace can be maintained if the task demands make it worth the Ss effort. Although several authors (Posner and Konick, 1966; Phillips and Baddeley, 1971; Mitchell, 1972; Cermak, 1972) speculate that a visual rehearsal process (like Posner's CPC hypothesis) influences the rate of visual trace decay, none attempted to subtantiate their speculations emperically. This is unfortunate since sound emperical evidence would begin to answer the important question (c, above), can visual rehearsal help to encode information into visual LTS or does rehearsal simply maintain the visual short term trace? Shaffer and Shiffrin (1972) report emperical evidence suggesting that rehearsal might be responsible for maintaining a visual trace in visual STS but it is probably not responsible for visual information transfer into visual LTS. The only variable found to affect visual trace decay and retention of visual information in visual LTS was exposure duration. Because of this important finding, this study will be reviewed in detail.

Shaffer and Shiffrin used a picture recognition task with stimulus exposure durations of 0.2, 0.5, 1.0, 2.0, or 4.0 seconds. The exposure durations were orthogonally combined with between-slide durations of 1.0, 2.0. or 4.0 seconds for all Ss. Each S was given special instructions to "remember" or "think about each slide exactly as it appears" (visual rehearsal) during the blank ISIs. Recognition of the stimulus items was tested in a random order with the exception of the last four items presented. Confidence rating were recorded for each correct recognition of an old or new item.

The data show that average confidence ratings (Ss were more sure they were correct in their judgments) increased markedly as a function of stimulus exposure but were unaffected by the length of the associated blank times. Shaffer and Shiffrin argue convincingly for a lack of a visual rehearsal process analogous to that of verbal rehearsal (e.g., no effect of blank time on performance). They also suggest visual STS to be a single store (no independent iconic store) because increasing the blank intervals between stimuli did not lead to better performance. Better performance would be expected if additional encoding or other transfer to visual long-term memory had occurred during the blank time, at least, for the processing of complex visual stimuli. To quote Shaffer and Shiffrin, "it is a more parsimoneous view that there is just a single short-term visual memory. This

short-term visual memory would decay quickly when the information content of the visual field was high, and more slowly when the information content was greatly reduced" (p. 295).

Certainly the notions of visual rehearsal having no verbal analogue and variable decay rates being due to stimulus complexity seem reasonable in light of the studies reviewed above. However, the notion of a single store is in direct contradiction to the Droost and Turvey results. At best, it should be concluded that the two visual stores (iconic store and visual STS) are likely, but with control processes different from their verbal counterparts. Retention of visual information does seem dependent in a direct way upon exposure duration and stimulus complexity. Exposure duration in visual memory experiments should not be confused with total rehearsal time in verbal memory experiments. _S_s in verbal memory experiments (word stimuli) might spend the extended stimulus exposure duration covertly rehearsing that stimulus item or another already presented, or _S_s might really be attending to the actual stimulus but only for a fraction of the total exposure duration. When using non-verbally codable stimuli (e.g., like Mooney's, 1960), _S_s must necessarily continue to attend to each stimulus for as long as it appears.

In summary, the following statements seem to be accurate for visual memory:

1. visual long-term memory capacity and efficiency

are at least equal to and perhaps superior to verbal memory.

2. visual memory is a composite of several distinct stores: the sensory register, visual STS, and visual LTS.

3. decay of trace in visual STS seems dependent upon the type of stimuli (i.e., complexity), length of stimulus exposure, and the type of experimental task, but primarily upon exposure duration.

4. rehearsal (CPC) in visual STS might be possible, but only for simple stimuli (e.g., letters) at very short delays. However, an alternative explanation is that rehearsal of complex pictorial stimuli uses the Ss total CPC. If Ss have no available CPC to invest in the operations of encoding and transfer of information to visual LTS, then the visual information, even though being "rehearsed", never has the opportunity to build up a long-term memory trace. Consequently, when visual rehearsal becomes impossible, that information is completely lost from memory.

5. visual stimuli that contain meaningful, coherent figures appear to be remembered better in visual memory than those stimuli that lack these properties (e.g., Mooney figures). However, the better performance usually observed for pictures containing meaningful coherent figures might be a function of some verbal mediational component of memory.

6. in general, the literature reviewed in this section suggests that visual memory is a multiple storage medium that may occasionally function separately from verbal memory.

However, the fact that the two types of memory usually interact does not indicate that visual and verbal memory stores have the same control processes.

Massed and Distributed Practice in Verbal Memory:

The differential performance produced using massed and distributed practice schedules is not new to verbal investigators. Distributed practice (DP) schedules generally yield better performance than massed practice (MP) schedules for a variety of conditions in several different paradigms (Melton, 1970; Underwood, 1970; Bjork, 1970; and Pollatsek, 1969). This result is commonly referred to as the "DP effect". Waugh (1970) reports the only exception to this general emperical rule, that is, she shows no differential performance between the two schedules.

Waugh's rejection of the well documented evidence in support of the MP vs. DP distinction is based primarily upon her acceptance of the Total Time Law (TTL) to explain her experimental results. Even though total stimulus exposure time may explain her lack of a DP effect in her data, it appears unlikely that TTL can be used to explain the DP effect achieved in many different paradigms. Waugh's further criticism of the DP effect as being caused by differential rehearsal strategies by Ss also seems unlikely. Pollatsek (1969) using a modified Brown-Peterson paradigm which prevents overt rehearsal and makes covert rehearsal negligible, shows consistent, highly replicable, DP effects. In view of

the many studies reporting consistent DP effects and the Pollatsek data, Waugh's findings must be considered exceptional, but not detrimental to the literature on MP vs. DP in verbal memory. Perhaps the best summary of the effect of DP are presented by Bjork (1970).

"1. In general, performance is significantly better following spaced repetition (DP) of an item than performance following massed repetition (MP) of an item. 2., however, there is an interaction: if performance is measured after very short retention intervals, it is better to have massed repetitions. 3., and, there is a limit to the improvement in the performance with spacing: as the interval between two repetitions of an item is increased, performance improves to a point and then declines." (This is what Bjork lables the "strength paradox". However, this effect seems only true for paired-associate paradigms and is not universally found there. In free-recall and the Peterson and Peterson paradigms, the effect does not decline, although it levels off, (personal communication, A. W. Pollatsek)). One point that is not clear from the Bjork summary is the effect of increased repetitions within the MP vs. DP paradigm. A fourth point quoted from Melton (1970) based upon Underwood's (1970) emperical evidence should be added. In particular, Melton says, "a DP schedule always produces better recall than MP and more so the greater the frequency of presentations."

Since DP schedules produce superior performance to MP schedules in short-term memory, and since the effect is very consistent and highly replicable under a variety of conditions and paradigms, the superiority of DP appears to be a basic law of verbal learning. Because visual memory appears to have many properties, trace decay, high recognition capabilities, multiple stores, similar to that of verbal memory (except for an efficient rehearsal process) it seems reasonable to ask the question of whether DP produces better performance than MP in visual memory. If the DP effect (superior performance to MP schedules) is due solely to some rehearsal process as Waugh (1970) postulates, then MP performance would be expected to be equal to that of DP because there is no rehearsal in visual STS than can lead to coding in visual LTS (Shaffer and Shiffrin, 1972). However, if a DP effect is obtained then it could be argued that the effect is dependent upon some more interesting memory process besides covert rehearsal, as so many authors argue (Melton, 1970; Underwood, 1970; Bjork, 1970; Pollatsek, 1969). Of course, it should be added that, if no DP effect is obtained, then it could also be that the DP effect is peculiar to verbal memory alone. It would then still be a matter of some debate whether the verbal effect is due to covert rehearsal.

The only way in which a visual memory experiment can add significantly to our knowledge about the relation between visual and verbal storage, however, is to ensure that the Ss

will not adopt a verbal rehearsal and/or some verbal mediational process while performing the visual task. One method that would ensure the absence of verbal rehearsal and/or verbal mediational processes is to use visual stimuli that prohibit any verbal behavior. For example, the ambiguous stimuli developed by Mooney (1960) (much like those of Leeper, 1935) are ideal for the purposes just described. These figures make it unlikely that the S attaches meaningful verbal labels until closure occurs and the actual figure can be seen by S within each picture (refer to examples in Appendix A).

In the present experiments the S's task was to "learn to see" the display as a coherent figure. Thus, if correct perception or construction of the figure preceeds the verbal labelling process, the learning process is a completely visual one. Therefore, it was assumed that Ss would be unable to use verbal processes until they perceive the figure. (This property enabled us to use "number of correct responses" as our dependent variable. That is, items were deemed correct only when Ss provided the appropriate lable for a figure in a specific display). However, it is possible that Ss are using a verbal hypothesis testing strategy (generating a verbal category label, i.e., "face", then looking to see if the appropriate features, i.e., eyes or nose, were in the display) to solve the picture items. If this is the case, a verbal interference task can be introduced to insure only visual processing.

Spaced practice (MP vs. DP), although very important and interesting, was not to be the only variable examined. Stimulus exposure duration, visual rehearsal and number of stimulus repetitions were experimentally manipulated. Before describing the three experiments, several hypotheses will be presented.

Hypotheses:

Given the general constructs of the paradigm, what should the observed data be expected to show?

I. a. If rehearsal is responsible for the DP effect, as Waugh (1970) argues then learning of the pictorial stimulus items should be equal for both distributed and massed practice. This prediction would be based upon the absence of a covert rehearsal process in visual STS (Shaffer and Shiffrin, 1972).

I. b. It could be that the total time of stimulus exposure is the most important variable and furthermore, any disruption of processing (e.g., a MP or DP schedule) would produce poorer performance than one single long exposure.

I. c. If performance improves with increasing lags between stimulus items, then the improvement must be due to some other process besides covert rehearsal. It could be that distributed practice is dependent in some way upon the decay characteristics of the information store (verbal STS or visual STS).

II. Assuming that duration of stimulus exposure and number

of stimulus repetitions are the two critical variables which increase Ss overall performance, then performance should increase in a direct proportion to the total exposure time and/or the number of stimulus repetitions. This follows directly from Shaffer and Shiffrin (1972) and Melton (1970).

III. a. If Ss are generating verbal hypotheses to mediate a solution to the pictorial stimuli, then adding a verbal interference task should decrease verbal behavior. If the solution depends primarily upon such verbal behavior, then performance should decline if the verbal interference task is difficult enough. However, if the items are actually being solved in a predominently visual manner, then performance should remain, at best, the same.

III. b. If information processing up to the correct solution is purely visual, then performance on the interference trials should be approximately equal to performance during the blank trials (this assumes verbal behavior to be unnecessary during blank times).

III. c. If the solution of the pictorial items is really due to purely visual processing then the addition of a visual interference task should be more disruptive (i.e., performance should decline) to performance than either the verbal interference or the blank time (in that order).

The prediction in part III., c., is to be run as a fourth experiment to follow those reported in this thesis. This is a result of several difficulties encountered in

operationalizing the experiment (e.g., defining a visual interference task that would be suitable to the paradigm). In general, the prediction (I, thru III. b.) stated for the three experiments already run, were developed from the literature reviewed under, "A model of human memory", "Visual memory", "Are there two distinct stores", and "Massed and distributed practice in verbal memory", in this thesis.

Experiment I

Prior to running the experiments necessary to test the hypothesis listed above, some method of determining the difficulty of the stimulus materials seemed appropriate. It was reasoned that using stimuli of approximately the same average time-to-solution (e.g., to correctly label the stimulus item) by Ss would be equally difficult and would reduce unreliability in the main experiments. Furthermore, determining the average time-to-solution for each slide would be necessary to select the proper exposure durations to be used in the later experiments. Experiment I was designed to determine the average difficulty of each slide, to select those slides to be used in Experiments II and III, and to establish the appropriate stimulus exposure durations for the MP vs. DP schedules.

Method

Materials & Equipment: Stimulus materials were slides of ambiguous pictures (see Appendix A) constructed by Mooney, (1962) for diagnosing clinical patients with closure problems. These slides were of two types; (a) "fragmented" - slides composed of angular black and white areas out of which a coherent figure could be seen, (b) "figure-ground" - slides composed of flowing, smooth contoured, black and white areas from which Ss could also perceive a coherent figure. However, Ss usually had to determine which portion

of the slide (black or white area) would compose the major portion of the coherent figure pictured.

Each of the 48 slides were projected onto a 3 x 3 foot rectangular screen approximately five feet from the Kodak carousel (   ) random access projector. Slide selection, exposure duration, and data collection were done by "digital-bit" apparatus constructed in the laboratory. Slides were changed by a voice key connected to the digital-bit apparatus only when Ss responded aloud. Reaction time (RT) was recorded for each slide in tenths of a second. E recorded the slide number and the verbal response by each subject for later analysis.

Procedure and design: Each S in the experiment read instructions explaining the procedure they should follow. They were specifically asked to "respond only when they were sure that they could correctly identify each slide," and "to speak loudly into the microphone before them because the sound of their voice would change each slide in the sequence". Ss were also told "to take as much time as they needed to identify any slide". Each Ss was given an opportunity to question E about the instructions to be sure S fully understood the task prior to the beginning of the experiment. The digital-bit apparatus selected the slide to be shown in a random order by reading slide sequence numbers from a paper tape generated by a Hewlett-Packard (2114A) computer. Each slide was shown exactly once to each of the 10 Ss during the

experiment. Ss were run separately in a closed, soundproof, experimental chamber.

Subjects: Ss were selected on a "first-come" basis, from the University of Massachusetts graduate and undergraduate student body, in answer to an add posted throughout the campus. Each Ss participating in the experiment was paid $1.75 when he/she completed the task.

Results: The slide numbers, correct solutions (e.g., name for the pictured figure), the average time-to-solution, and the slide type (fragmented or figure ground) are recorded in Table 1. However, only those slides used as stimuli in Experiments II & III are reported with the appropriate data (examples of these slides are shown in Appendix A).

Insert Table 1 About Here

Discussion

The slides listed in the table were selected for Experiments II & III because the average time-to-solution was between 4 to 12 seconds each. Slides that were consistently solved in less than 4 seconds or more than 12 were assumed to be too easy or too difficult to be for further use. An additional criterion for selection of the two sets of experimental slides was to have equal numbers of "fragmented" and "figure-ground" picture types (9 each) represented in the design of Experiments II and III. The two sets of experimental slides were also selected to include several name

categories; for example, "animals", "human faces and figures" and "common objects". The two groups of slides reported in the results section are the most homogeneous possible based upon the time-to-solution criterion while also being the most heterogeneous possible when the criterion for selection was "stimulus category".

Experiment II

This experiment was designed to examine the effects of spaced practice (i.e., MP vs. DP), exposure duration and number of stimulus presentation trials, upon visual memory. The spacing (0, 1.5, or 4.5 seconds) of the visual stimulus presentations were factorially varied with exposure duration (0.2 or 0.4 seconds), and each slide was shown for 6 trials. Unfortunately, exposure duration was in error in this experiment by 0.2 seconds for each stimulus exposure because of the time required by the digital-bit apparatus to read commands from the paper tape. However, this constant temporal error affected only the very brief exposure duration as usual here in Experiment II, whereas, the usual long exposure duration of Experiment I would be unaffected.

Method

Materials & Equipment: The stimulus materials used in this experiment and the apparatus were exactly those used in Experiment I. However, two additional "instructional" slides ("READY" and "RECALL") and one "blank" (non-transparent) slide per stimulus slide were required to operationalize the exper-

imental paradigm. Therefore, the total number of slides used in this experiment was 72: 18 ambiguous stimulus slides, 18 "READY" slides, 18 "RECALL" slides and 18 blank slides. Each of these slides (except blanks) subtended a visual angle of 11.4^{o} in the vertical plane and 15.2^{o} in the horizontal plane (visual angles are identical to those of Experiment I). These large visual angles minimized any difficulty that might have been caused by Ss being unable to see crucial details within each pictured slide.

Procedure and design: Ss were provided type written instructions to read prior to the experiment and were encouraged to question E when any statement was not completely understood. Sample stimuli were also presented to Ss and described by E to be sure that each S was familiar with the type of verbal description necessary for a correct response. Furthermore, Ss were told to note that, "each experimental trial sequence (therefore, each new slide) would begin with the word, READY".

Design: The three spacing intervals (0, 1.5, and 4.5 second blank periods between slides) were factorially varied with the two exposure durations (0.2, and 0.4 seconds) yielding six separate experimental conditions. These conditions were blocked with the three different stimuli per condition presented sequentially. Therefore, there were a total of 18 different slides; three slides per experimental condition. Within each condition, each slide was repeated for six sequential trials. A typical sequence with spaced (S) stimulus

exposures (E) began with "READY" (R) and had six "RECALL" (r) periods, one for each trial. Therefore, a typical spaced slide condition could be represented as: $RE_1SE_2r_i$; $E_1SE_2r_2$; ... $E_1SE_2r_6$. Similarily, a massed experimental sequence could be represented as: $RE_1E_2r_1$; $E_1E_2r_2$; ... $E_1E_2r_6$. In the massed exposure sequence the slides remained on the screen uninterrupted for twice the time of a single exposure in a spaced sequence. That is, the total exposure time in the massed condition was exactly equal to the sum of the two exposures in the spaced condition.

The presentation orders for the six experimental conditions were randomly selected so that each of the first six *S*s saw a different ordering. Even though the next six *S*s saw the same presentation order of experimental conditions, the slides themselves within each condition had been changed. Both the slide position and the six experimental conditions were balanced in this design.

Procedure: *S*s sat in an experimental chamber approximately 5 feet from the viewing screen (each slide viewed on the screen covered a 16" by 12" rectangular area). Each slide viewed by *S*s subtended a visual angle with 11.2° vertical and 15.2° horizontal arch. They read type-written instructions and were encouraged to question *E* about any statement not completely understood. Each *S* was specifically instructed by *E* to respond only when "RECALL" appeared on the screen and to "try to hold a visual image of the slide

just seen in visual memory during the blank spacing intervals. Presumably, these instructions would insure that Ss at least attempted to "visually rehearse" whenever possible. During the experiment E recorded Ss verbal responses for later analysis.

Subjects: Twelve Ss were randomly selected from the University of Massachusetts student population in a manner identical to that of Experiment I. Ss were paid $1.75 for the one hour of experimental participation.

Results: An analysis of variance on the data showed that the number of trials (1 to 6) was the only significant main effect, $F(5,55) = 50.41$, $p < .001$, indicating that Ss solved more items the greater the number of trials available to observe each stimulus. However, this seems to be a paradoxical result since, (a) exposure duration had no effect, yet number of trials did, and (b) an analysis of percent correct responses by slide position (1 to 18) for trials 1 and 6, shows no "learning-to-learn." That is, Ss made many more correct responses to stimuli on trial 6 of a given problem than on trial 1 of the same problem, but learned nothing new about how to solve new items over the experimental session. This result can be seen in Figures 2 as a "flat" graphic function: percent correct solution across slide positions is approximately equal.

Insert Figures 2 About Here

The Figure (Fragmented X Figure-ground) X exposure duration X trials interaction was the only interaction significant $F(5,55) = 2.653$, $p < .05$, but this result is difficult to interpret, since after the experiment was completed it was discovered that each exposure duration was inflated by either 0.2 or 0.4 seconds. For example, a single presentation of 0.4 seconds was actually 0.6 seconds. In addition, a single massed exposure should have been equal to two shorter spaced exposures, a comparison which could no longer be made (i.e., two spaced 0.2 second exposures did not equal a single 0.4 second exposure, but actually totalled 0.8 seconds). This problem was caused by a defect in the paper tape reading apparatus. Therefore, it becomes difficult to compare the effects of exposure duration between the different experimental conditions (see data, Table 2). Furthermore, the tape

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Insert Table 2 About Here

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reader was found to make occasional errors in reading the exposure durations as being exactly the same from trial to trial (i.e., instead of reading 0.2 seconds, it would read the actual exposure as something less than 0.2 seconds and then add the additional constant of 0.2 seconds).

The Exposure X Figure type data seemed to indicate that "Figure-ground" (F/G) slides were solved more easily than "Fragmented" (FRAG) types. However, this difference was not supported by the main effect for slide type which

was nonsignificant, $F(1,11) = 11.17$, $p < 0.10$.

Discussion

The malfunctioning of the experimental apparatus make discussion of the experimental results difficult. For example, the fact that increase exposure duration did not increase performance seems counterintuitive and contrary to the Shaffer and Shiffrin (1972) results reported earlier. Furthermore, the fact that two spaced presentations of 0.4 seconds each produced no better performance than did one 0.4 second exposure over six trials seems unusual. That is, twice as many presentations of the same duration should produce more learning. Related to this finding was the fact that even though spacing within a particular trial failed to facilitate performance, "spaced" practice across different trials for a particular stimulus did help.

One hypothesis that might explain these curious results is Ss might fixate on an incorrect solution (see something in a slide other than what was actually there) within a trial and somehow, the appearance of the word "RECALL" would help to disrupt incorrect memories of the stimulus item. Consequently, there would be more correct solutions over trials. However, this hypothesis presents a paradox, since the "learning-to-learn" curves suggest Ss did not learn any new processes to aid solution of later items (exemplified by a flat learning-to-learn curve).

In order to explain these experimental findings and resolve the difficulties produced by the faulty digital-bit apparatus, a third experiment was designed. Experiment III was run by a PDP-8/I computer which made some changes in the research paradigm. For example, a visual-verbal interference task (read a two digit number aloud, and then classify, as above or below 50, and odd or even), was introduced between spaced presentations for two of the four distributed practice conditions. If this task caused performance to increase over the massed items and the control spaced items (blank time between the spaced items), then the observed increases in performance over trials could have been caused by the descriptive effect of the word "RECALL" on memory the stimulus items between trials. That is, the word "RECALL" and the number classification task probably disrupts memory in a similar manner that somehow facilitates solution of the ambiguous stimulus across trials.

Experiment III

Part I, Experiment III was essentially a replication of Experiment II. Since the main effects of exposure duration and distributed practice produced unexpected and counterintuitive results, it seemed advisable to see whether they were reproducable before making any sweeping conclusions. In addition to the variables studied in Experiment II, another was introduced, the nature of the spacing interval. The interval was either blank, as in Experiment II, or it was filled by a "visual-oral" number classification task. The Ss performed the task between the first and second stimulus presentation on half of the DP trials. It was assumed that this task would help determine the cause of increased performance (correct solutions) with "spacing" between trials in the absence of a similar effect within each trial for the DP conditions. The addition of this task, and the possible unreliability of the digital-bit apparatus required Experiment III to be run and controlled by a PDP-8I computer.

Part II of Experiment III was added to test the effects of exposure duration, distributed practice and "visual-oral" interference upon long-term recognition memory for the original 18 pictorial stimulus items. Experiment II suggested that these variables were not important to visual short-term memory, however, no attempt was made to measure these effects upon visual long-term memory. The effect these variables had upon visual long-term memory were tested by a 40 item (18 - original "old" stimulus items and 22 similar "new" items) "old-new" recognition test administered to each S approxi-

mately 20 minutes after the completion of Part I of Experiment III. Ss were not told of the recognition test prior to Part I of Experiment III.

Method

Materials & Equipment: The pictorial stimulus materials used in Part I of Experiment III were identical to those used in Experiment II, with the exception of two(refer to Table 1, Experiment I) which were replaced because they were too difficult to be used with such short exposure durations (Ss never solved these items during Experiment II). These slides subtended a visual angle of 10.6° in the vertical plane and 15.2° in the horizontal plane (similar to Experiment II, 11.4° vertical and 15.2° horizontal). The addition of the "visual-oral" number classification task required the use of two alpha-numeric nixie tubes which subtended a visual angle of approximately 1.2° on both the vertical and horizontal planes. The classification task required Ss to read aloud a randomly selected two digit number (from 1 to 99) displayed by the nixie-tubes during the blank interval for half the DP scheduled conditions. Then, Ss had to respond with "high" or "low" and "odd" or "even" depending on whether or not the displayed number was greater or less than 50 and divisible evenly by two or not. For example, 51 would be classified as "high-odd" while 48 would be "low-even". The number 50 never appeared. Also, the number classification task was designed to allow Ss just enough time for accurate completion

during the blank spacing interval (4.5 seconds) between DP items.

The actual operation of Part I, Experiment III was controlled by a PDP-8I computer programmed to operate a Kodak carousel slide projector for all experimental conditions and to operate the random number nixie-tube display when appropriate. The use of the computer minimized the possibility of temporal errors in stimulus exposure or spacing duration (± 0.0001 second error).

Procedure: Ss were provided with typewritten instructions similar to those of Experiment II. The instructions, in general, differed only by the addition of two short paragraphs explaining the visual-oral classification task. Each S was encouraged to question E about any ambiguous statement(s) before and after the pretraining session on the classification task. To further reduce experimental unreliability, Ss were told prior to each trial during the experiment whether or not the classification task would occur.

Design: Part I, Experiment III: The two spacing intervals (0 and 4.5 seconds) were orthogonally combined with exposure duration (0.3 and 0.6 seconds), then the DP trials (4.5 seconds spacing) were divided into two conditions: "blank time", or "visual-oral" classification task between spaced items. This design produced six experimental conditions: two MP conditions (0.3, 0.6 seconds

exposure), two DP "blank" conditions (0.3, 0.6 second exposure) and two DP task conditions (0.3, 0.6 second exposure). Therefore, a typical MP condition (six trials) could be symbolically represented as in Experiment II, R $E_1E_2r_1$; $E_1E_2r_2$;... $E_1E_2r_6$ (R = READY, r = RECALL, E = exposure duration). However, the DP conditions must be represented in a slightly different manner. That is, the spacing between slides will be represented as either "blank" (S_B) or containing the "visual-oral-task" (S_T). Consequently, a typical DP "blank" six trial sequence and "visual-oral-task" six trial sequence could be represented as, R $E_1S_BE_2r_1$; ... R $E_1S_BE_2r_6$, and R $E_1S_TE_2r_1$;... R $E_1S_TE_2r_6$ respectively.

Each of the six experimental conditions were presented in a random sequence identical to that of Experiment II, i.e., each of the first six subjects observed a different ordering of the conditions. The slide positions of the individual stimuli were changed after the 6th, 12th, and 18th subject had been run. Therefore, every subject in the actual experiment observed a different sequence of conditions or the same sequence with different slide orderings.

Part II, Experiment III: The delayed recognition test simply required Ss to write down the page number and brief description of each of the forty, 3 x 5 inch ambiguous pictures randomly ordered in a test booklet. Ss were also required to indicate which of the pictures were "old" (just seen in Part I, Experiment III) or "new" (never seen before).

The recognition task was self-paced by each S and averaged approximately 6 seconds per picture. Observation time was short because Ss had been instructed "not to spend a long time on the recognition task, but to proceed rapidly and not to be concerned if they were unable to correctly label any of the slides".

Procedure: The procedure for Part I of Experiment III was identical to that of Experiment II. However, Part II of Experiment III was self-paced and required a written response to each of 40 stimulus items. The items (18- original pictures from Part I and 22 distractors similar to the original eighteen items) were presented in random order in a bound booklet. Ss were given instructions for the recognition task after a 15 minute procedural-question-answer period administered at the completion of Part I. The instructions were brief and therefore, the recognition task began approximately 20 minutes after Part I of Experiment III had ended.

Subjects: Ss were selected and paid exactly as those which participated in Experiment II. None of the 24 Ss used in Experiment III had participated in either Experiments I or II.

Results: Part I, Experiment III: An analysis of variance on the data from Part I revealed several significant main effects and no significant interaction effects. The

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Insert Table 5 About Here

Trials main effect, which replicated the results of Experiment II, was highly significant, $F(5,115) = 120.68$, $p < .001$, indicating that Ss solved more items the greater the number of trials (1 to 6) available to observe each stimulus. However, this result does not seem as paradoxical as it did for Experiment II. More specifically, Ss here continued to show no "learning-to-learn" effect (the likelihood of solution did not increase with practice for slide one to eighteen), but, the exposure duration main effect was significant, $F(1,23) = 11.29$, $p < .01$. This result suggests that Ss were more likely to solve a particular item the longer the stimulus exposure duration. Consequently, it seems likely

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Insert Figures 2 - 4 About Here

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that the observed increase in performance with increasing number of trials could be partially explained by exposure duration. Unfortunately, this explanation was not supported by a significant Trials X Exposure duration interaction. An additional, less interesting but significant main effect was slide type (Figure ground vs. Fragmented, refer to Figure 1), $F(1,23) = 5.93$, $p < .05$. This result suggests that Ss found the "figure-ground" slides easier to solve (form a visually coherent figure within each slide) than the fragmented types. However, the fact that "figure-ground" slides appeared easier to solve did not interact with any other variables (i.e., Trials, exposure duration, scheduled

practice or type of spacing interval).

To summarize briefly, what we have labeled the "paradoxical" effect of increased performance with increasing trials (spacing between trials) has been replicated. The increased performance with "spacing" between trials seemed "paradoxical" in Experiment II because both the exposure duration and scheduled spaced practice within a trial had no appreciable effect on performance. Even though longer exposure durations significantly increased performance in Experiment III, one would expect that the learning rate as well as the level of performance would be greater for the longer exposure duration, and thus, produce a significant Trials X Exposure Duration interaction. However, the apparent equality of learning rates for the two exposure conditions in Experiment III suggests that increased exposure duration may not be the sole cause of the Trials effect.

Unfortunately, differences in probability of a correct response may not be the proper index of learning rate. (A more detailed discussion of this point will be presented later in the General Discussion section.) However, the possibility remains that exposure duration will not adequately explain the Trials effect, and an alternative explanation for the learning with "spacing" between trials will be needed. For example, if the paradoxical effect were somehow caused by disruption of Ss memory between trials then the DP trials with the "visual-oral" task should have significant improved

performance. This hypothesis deserves further experimental verification since performance did improve slightly for conditions with the "visual-oral" task. Perhaps, a more demanding visual task would produce the desired results.

Part II, Experiment III: The results of the recognition memory experiment indicated that Ss correctly recognized 90% of the 18-original stimulus items as "old". Furthermore, a conditional analyses of the recognition data revealed several interesting facts dependent upon MP vs. DP scheduled learning, and wehther or not Ss correctly labelled items during Part I of Experiment III. For example, Ss were significantly better at correctly recognizing an old item as "old" given that it was correctly labelled by trial 6, than if it was not correctly labelled, $\chi^2_{(1)} = 6.4$, $p < .05$. Recognition performance for non-labelled slides (85.2%), although not as good as that for labelled items, was much better than the "false alarm" rate, or chance performance (7%). In addition, S correctly recognized old items as "old" much better given that the original learning occurred on a MP schedule (93.7% correct) rather than a DP schedule (88.6%), $\chi^2_{(1)} = 2.93$, $p < .08$.

Insert Table 4

These experimental findings suggest that (a), stimulus items are better retained (recognized) in visual memory when they form a coherent, familiar, representation and/or the

stimulus item can be easily labelled (perhaps a verbal cue to verify correct recognition), and (b), MP or continuous exposure of these ambiguous stimulus items seemingly produces better recognition than DP schedules for visual items.

Discussion

Part I, Experiment III: The results of Part I, Experiment III replicated an earlier experimental finding (i.e., trial main effect, Experiment II) that correct solutions to the ambiguous pictorial stimuli depended upon increasing numbers of observation trials. However, the present results only suggests that this effect might be partially caused by total length of continuous stimulus exposure duration. The validity of this hypothetical explanation is suggested by the significant exposure duration main effect and the fact that total exposure duration must increase as the number of trials increase. Unfortunately, the significant trials main effect remains paradoxical because it is unlikely that exposure duration is wholly responsible for the increased performance as suggested by the lack of a significant Trials X Exposure Duration interaction. Also, Ss seemed to be unable to benefit from extended practice at solving the stimulus items (i.e., no "learning-to-learn effect").

The experimental results observed and reported do agree however, with results reported by Shaffer and Shiffrin (1972). They demonstrated that exposure duration was the most important psychological variable for retention of the scenic

stimulus slides used in their experiment. Furthermore, Shaffer and Shiffrin argued that visual rehearsal of their stimuli was impossible because performance following blank rehearsal periods did not increase Ss ability to recognize the stimulus items from distractors. This result is further supported by our data showing poorer performance when Ss were provided blank time to visually rehearse between stimulus presentations. This does not mean that visual rehearsal is impossible, as Shaffer and Shiffrin point out, but that visual rehearsal might only be possible for very simple, familiar stimuli like those (i.e, AA) used by Posner et al. (1969). In addition to the important effects of exposure duration upon visual memory and the lack of a visual rehearsal process analogous to that found in verbal memory, our data also suggest that the highly replicable DP effects found in verbal memory may be unique to the verbal medium.

Part II, Experiment III: The results of our recognition experiment also seem harmonious with recent experimental evidence (Wiseman and Neisser, 1972; Freedman and Haber, 1973 as reported by Haber, 1973) for recognition memory for Mooney figures similar to those used in Experiment III. Wiseman and Neisser,and, Freedman and Haber, provide similar hypothesis suggesting that ambiguous pictorial stimuli (i.e., faces) would be correctly recognized as "old" more frequently when the old items had been seen as coherent figures than when no coherent representation could be perceived by Ss.

Their results, like those reported in Part II of Experiment III, confirm their hypothesis. That is, old items that were correctly labelled ("seen as coherent figures") were more frequently recognized as "old" items than those not labelled ("not seen as coherent figures") when the old items were presented randomly within a similar group of distractor items. These findings seems to suggest that visual memory is more efficient when pictures are seen as meaningful, familiar objects and/or pictured items have an easily accessible verbal label to aid the visual memory component.

General Discussion

Is exposure duration important? The length of the stimulus exposure duration seems to be crucial to visual information processing. That is, the longer the exposure duration, the greater the amount of visual information processed and available in visual-short-term-memory to interact with visual-long-term-memory. If Ss rely upon this short-term processing to "search" visual-long-term-memory for familiar "cues" to correctly identify visual stimuli (e.g., Mooney figures), then continuous exposure would be essential in the absence of a visual rehearsal process (for complex stimuli). The present experimental results suggested that exposure duration was the sole relevant variable for learning and that no significant visual rehearsal process exists. Thus these findings agree with those of Shaffer and Shiffrin (1972). That is, significant improvements in performance were observed in Experiment III with increasing exposure duration, while "blank time" following or between stimulus presentations did not affect performance and if anything, was of less help than an interval filled with a distrating task (in the present experiments).

The effects of exposure duration were also apparent in the recognition data of Part II, Experiment III. Ambiguous pictorial stimuli presented under MP schedules (longer exposures) were correctly recognized (93.7%) more often than items presented under DP schedules (88.4%). Even though improved recognition performance with increased exposure

duration was frequently suggested in several experiments reviewed earlier in this thesis (Phillips & Baddeley, 1971; Mitchell, 1972; Cermak, 1972), more experiments like Shaffer and Shiffrin's and ours were needed, to demonstrate the reliability and generality of the exposure duration effect upon visual memory. Because this effect seems highly reliable, it suggests a general law for visual information processing: increasing continuous exposure duration assures increased learning and/or retention in visual memory (for non verbal stimuli). Obviously, this general law depends upon the absence of an efficient visual rehearsal process as many studies suggest, nevertheless, there might be other alternatives to no visual rehearsal?

Is visual rehearsal really impossible? The absence of a visual rehearsal process was suggested by the lack of improved performance by subjects when they were provided "blank time" for rehearsal between stimulus presentations. For example, on DP trials where rehearsal was possible (51% correct on trial #6) performance was no better than on MP trials (55.5% correct on trial #6) where rehearsal was impossible. This result is consistent with the Shaffer and Shiffrin study reported earlier, although these authors suggest that visual rehearsal may be possible for very simple stimuli (i.e., letters). Furthermore, if transfer and storage of information into visual long-term-memory depends upon "active processing" of the pictorial item, then the

picture would have to be physically visable in order for long-term encoding to occur. Stimulus "offset" would be synonomous with stopping the visual information processing if visual rehearsal is really impossible. Other processing, probably verbal, would then predominate.

The absence of a visual rehearsal process is not the only alternative. Suppose visually complex stimuli (i.e., Mooney figures) can be rehearsed during "blank times", but the difficult, ambiguous character of these figures requires "total" CPC from each S for rehearsal to occur. Suppose, also that transfer to visual long-term-store also requires CPC, but since the rehearsal requires "total" capacity, transfer does not occur. Consequently, rehearsal may occur for complex visual stimuli, although its occurrance prohibits other information processing. Unfortunately, the experimental data available does not allow a choice between the two alternatives. It seems nonadaptive, however, to be able to maintain a visual trace in short-term-memory without being able to develop some lasting representation in visual long-term-memory. Therefore, a lack of a visual rehearsal process for complex stimuli is more appealing.

Learning schedules are for the "verbs"! DP schedules for visual material produced results (Experiments II & III) contrary to those usually observed in the verbal medium. That is, DP schedules produce significant increases in learning and retention over MP schedules, in verbal memory,

but have little effect upon the visual medium. There are two simple reasons why this might be true: (1) the DP effect may be <u>unique</u> to or dependent upon processes (i.e., rehearsal) <u>unique</u> to verbal memory, or (2) DP may be effective in the visual modality, but the experimental conditions used in Experiments II & III were not appropriate to produce large differences in performance.

Hypothesis one clearly suggests that the more parsimonious theories of human memory - memory may be composed of several different modalities, however, the control process in the several modalities are identical or perhaps, a single memory with common processes - seems erroneous. That is, human memory has multiple phases (stores) in several modalities (i.e., visual or verbal) which are dependent upon some common processes (as exemplified by transfer between stores) although, each modality probably has unique, independent, qualities.

Hypothesis two, on the other hand, suggests something a bit different. Hypothesis two is strengthened by the likelihood that the DP effect in verbal memory is not dependent upon rehearsal (Melton, 1970; Underwood, 1970; Pollatsek, 1969; Bjork, 1970; Bjork and Allen, 1970). For example, Pollatsek produced strong DP effects even though the interference task between stimulus presentations was extremely difficult and practically assured the absence of any verbal rehearsal. The interfering task used in Experiment III was,

perhaps, much too simple to produce a DP effect for visual material. This explanation seems reasonable since DP schedules with the "visual-oral" task increased performance nearly 5% compared to DP schedules with "blank time" between presentations. Furthermore, there was the "between" trials DP effect (i.e., the trials main effect) that could not be easily explained completely by exposure duration. In addition, Hintzman and Rogers (1973) report a DP effect for judged frequency of appearance of common, scenic color slides. However, this experiment could be critized for using stimuli that might be easily verbally encoded.

In summary, it appears as if the question of whether or not a DP effect can be <u>reliably</u> produced in visual memory must await further experimental analysis. Although, stimuli like Mooney figures which prohibit verbal retention prior to solution seem to suggest hypothesis one to be more accurate.

<u>Did Ss really learn?</u> The data from Experiments II & III indicate that <u>S</u>s learned to perform efficiently in each of the experimental conditions, i.e., to attend and respond as instructed to the ambiguous pictorial stimuli. However, <u>S</u>s did not learn any new visual processes that facilitated solution of additional stimuli. More specifically, practice at solving the Mooney figures did not help, an unusual effect observed as a "flat" learning-to-learn functions in both Experiments II and III. It could be that picure recognition is an ability that requires little or no learning, as Hochberg

and Brooks (1962) suggest, although the efficiency of the recognition process might increase with familiarity. In other words, after Ss have correctly solved a Mooney figure, latter solutions for the same item will be faster, although, this experience or practice will not help solve additional, new items.

The trials "paradox" exposed: The increased performance observed with an increasing number of trials has been previously described as "paradoxical" since a "spacing" effect between trials occurred without a comparable effect due to scheduled spacing within trials. The data analysis also failed to find a Trials X Exposure Duration interaction which suggested that exposure duration was not solely responsible for the Trials main effect. Although the failure to achieve a scheduled DP effect will not be discussed further, an additional quantitative modeling analysis of the exposure duration main effect will be described. Eventhough, there are usually problems with assessing "goodness-of-fit", a simple model postulating that learning was simply a function of exposure duration did account well for the dramatically improved performance over trials.

The general model used to predict the experimental data was generated from the notion of "all-or-none" learning. That is, on any trial S either learns and therefore, responds with a correct solution to a stimulus item, or S remains in the unlearned state and responds incorrectly. In the all-or-none

model the probability of an error response, $P(E_j)$, on any trial is some probability, $(1-a)^j$, where 1-a is the probability of an error on trial 1 and j is the trial number. Consequently, the probability of a correct response, $P(C_j)$, on any trial can be represented as, $P(C_j) = 1-P(E_j) = 1-(1-a)^j$. The form of the learning curve depends upon two additional assumptions about the learning process: (1), once a correct response has been made S never returns to the error state (all-or-none learning), (2) the probability of learning on any trial given S was in the unlearned state on the previous trial is a constant, $P(C_{n+1}/E_n) = a$. This implies that the probability of an error on each succeeding trial (j) is an exponential function of trial number, $P(E_j) = (1-a)^j$.

The goodness-of-fit of the predicted data to the observed data was measured by a log likelihood ratio statistic which approximates the chi-squared (χ^2) distribution (Restle and Greeno, 1970, pp. 317). For example, if the log likelihood ratio between the predicted and observed data points is small - the χ^2 will not approach significance - the assumptions of the specific quantitative model describing the particular learning method by Ss would be accepted as accurate. Two variations of the general model were used, the second predicted the observed data of Part I, Experiment III nearly perfectly. All parameter estimates used to predict the experimental data were generated using a Stepit subroutine package developed by J. P. Chandler (1965), on the University of Massachusetts

time-sharing computer system.

Model I: This model assumed that two independent parameters would describe the learning process responsible for the observed data. In particular, the probability of learning, a, on any trial would be an independent function of exposure duration, either 0.3 seconds or 0.6 seconds. In addition, the model assumed that each stimulus item used in Experiment III could be solved by Ss if a large number of trials were provided. Consequently, performance would be expected to approach an asymptote of 100% correct solutions as the number of trials increased toward infinity.

Unfortunately, model I provided a somewhat inadequate description of the learning process since the chi-square produced by the log likelihood criterion was nearly significant, $\chi^2_{(10)} = 16.33$, $.05 < P < .10$. This result suggested a sizable descrepancy between the observed data and the theory: either the learning rates for the two exposure durations were not constant over trials or asymptotic performance was not perfect. A closer comparison of the predicted and observed

Insert Figure 3 About Here

data, as graphed in Figure 3, clearly shows that the learning rate in the 0.6 second condition ($a_{0.6} = .158$) is not constant over trials. That is, while the predicted data for the 0.3 second condition closely approximates the observed data, the predicted data for the 0.6 second condition clearly underestimates

learning on the early trials (1 and 2) and dramatically overestimates the same learning process on later trials (5 and 6). Thus, the descrepancy between theory and data appears to be both sizable and systematic.

The overprediction of trial 6 data suggests that some of the stimuli used were too difficult for Ss to solve: asymptotic performance may be less than 100% correct solution. Therefore, it appears that both assumptions made for Model I present an inappropriate description of the learning process observed in Part I, Experiment III.

Model II: The assumptions of Model I were altered resulting in a model whose predicted learning curves were nearly identical to the observed data. It was assumed that the learning rate for the 0.6 second condition was equal to the learning rate produced by two successive independent 0.3 second exposures. That is, the probability of an incorrect response on trial n is equal to (1-a). For the 0.6 second exposure, the possibility of an error on trial 1 is: $P(E_{0.6})_1 = P(E_{0.3})_1{}^2 = (1-a)^2$. Similarly, the probability of correct on trial 1 for the 0.6 second condition can be represented as, $P(C_{0.6}) = 1-P(E_{0.3})^2 = 1-(1-a)^2$. Furthermore, asymptotic performance, A, for both stimulus exposure duration conditions was allowed to assume a value of less than one. Therefore, the functions describing the theoretical learning over trials, j, in Model II would be:

$$P(C_j) = A(1-(1-a)^k)$$

$$\text{where } k = \begin{cases} 2j \text{ for 0.6 second exposures and } j = 1 \text{ to } 6 \\ j \text{ for 0.3 second exposures and } j = 1 \text{ to } 6 \end{cases}$$

The two parameters, a and A, used in Model II were estimated to be .118 and .625 respectively. These parameters predicted theoretical functions nearly identical to those observed in Part I, Experiment III, as indicated by the log likelihood ratio, $\chi^2_{(10)} = 3.87$, $.95 < P < .975$. Therefore, it appears that the trials main effect can be totally explained

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Insert Figure 4 About Here

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as a systematic increase in learning rate due to the total exposure time or viewing time per stimulus slide. The failure of the longer, 0.6 second exposure durations to produce twice the learning, or correct number of solutions, was attributed to asymptotic performance being less than perfect: below 100% correct solution. These results further support the Shaffer and Shiffrin (1972) conclusions that learning in visual memory is dependent primarily upon exposure duration.

Why does "blank time" between DP scheduled slides reduce performance?: If it is assumed that visual information is "processed" in visual short-term-store only while the actual stimulus is visable (no visual rehearsal), then several different events might explain the reduced performance for blank time DP trials. For example, if a correct solution to an

ambiguous pictorial slide depends upon a search of visual long-term-store for the familiar attributes of the object(s) before perception occurs, then slides would be more likely to be solved as search time increased. Therefore, it seems likely that MP schedules which produce the longest continuous exposures should also provide the longest, most efficient search process (i.e., more correct solutions) than DP schedules with "blank time" intervals.

A reasonable explanation of superior MP performance over "blank time" DP scheduled performance has been described. But, why should "blank time" DP performance be worse than performance under DP schedules where the spacing interval is filled with a distracting task? It might be that the "blank time" separating DP items causes a disruption of the visual search process as soon as the stimulus slide disappears. What results is a rapid transfer of possibly "meaningful visual information" into a much less efficient verbal code. The verbal code is then used to continue to search, but, the search is probably no longer visual. That is, the verbal code is used to search for what might be the appropriate conceptual attributes to provide a correct solution. Consequently, prior to the second exposure S has perhaps developed some verbal expectation (probably incorrect) about what the pictorial object(s) should be. That is, S has created some conceptual expectation in short-term-memory which actually inhibits the pictorial reorganization processes from occurring. This has been referred

to as a "functional fixation" on an incorrect solution. This incorrect and "functionally fixed" representation becomes incorporated into visual long-term-memory along with appropriate verbal labels and descriptions. Unfortunately, once on incorrect solution is made by Ss, it becomes very difficult for them to correct themselves even when told of their error. Therefore, "blank time" in DP schedules is detrimental to performance when identifying ambiguous Mooney figures.

On the other hand, when Ss must perform a "visual-oral" classification task during the visual "blank time" performance actually increases. The task tends to discourage the development of verbal descriptions of the visual display in verbal short-term-memory and also disrupts any memory trace in visual long-term-memory. Therefore, each successive presentation is more like the first exposure of an item, "unbiased" by erroneous information. This means that the visual search process is less likely to become "fixated" on some incorrect solution, and more apt to locate the proper visual attributes to correctly perceive a pictorial item. Therefore, performance in the "visual-oral" task conditions would be expected to be better than DP conditions with "blank time" spacing intervals.

What research should be done?: Since the data show increased performance; non- significant, with the addition of a "visual-oral" task to the DP scheduled items, and additional experiment should be conducted. A more difficult, visual search task (e.g., perhaps a "same-different" judgment

of maze-like figures) and a difficult verbal shadowing task (e.g., shadow a list of aurally presented numbers) should be used between multiple exposures of ambiguous stimuli in DP schedules. These results could be compared with "blank interval" results to determine whether or not the interval between spaced items is used for primarily visual or verbal processing. It could be that a DP effect in visual memory, like verbal memory, would be more apparent when a difficult, purely visual interference task was used in place of the "blank time" spacing interval.

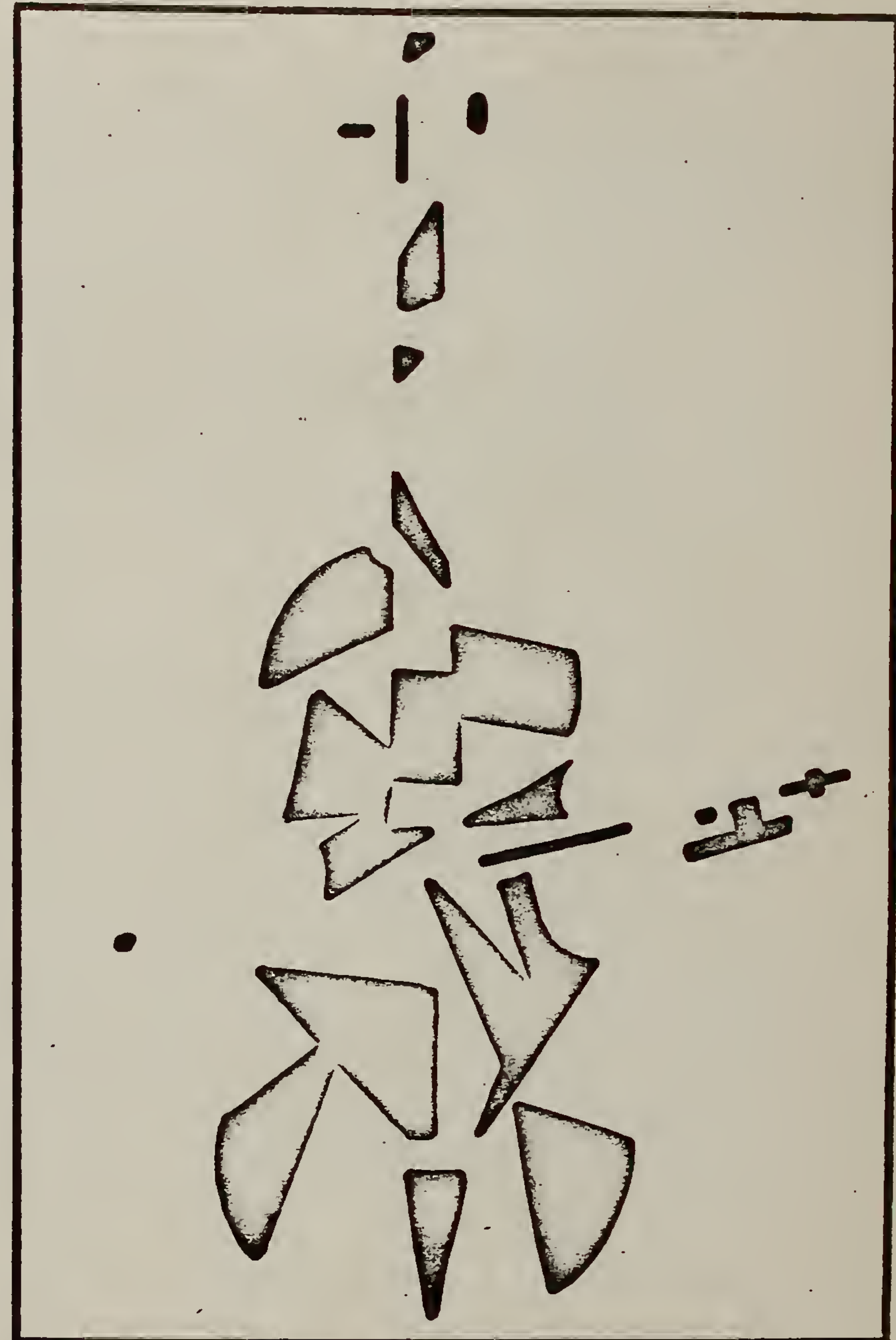
Summary

At best, the data simply show that exposure duration is a crucial psychological factor for visual information processing. Visual rehearsal, on the other hand, seems to be very inefficient for the stimuli used in Experiments II & III. This result seems consistent with other experimental evidence reviewed (Shaffer & Shiffrin) using complex visual stimuli. Distributed practice does not seem to facilitate learning or recognition of the Mooney figures. However, other evidence (Hintzman & Rogers) and inconsistencies in our data suggest that more accurate conclusions require further experimental analysis. Finally, Ss found solutions to the visual stimuli of Experiments II & III easier as the number of trials (exposures) increased, although, multiple exposures within trials were of questionable value: a result difficult to interpret. The dramatically increased performance over trials was attri-

buted solely to exposure duration within the framework of an all-or-none learning model, which assumed that the asymptote of learning was less than 100%.

APPENDIX A

Sample Stimuli (used in Experiment I, II, and III)



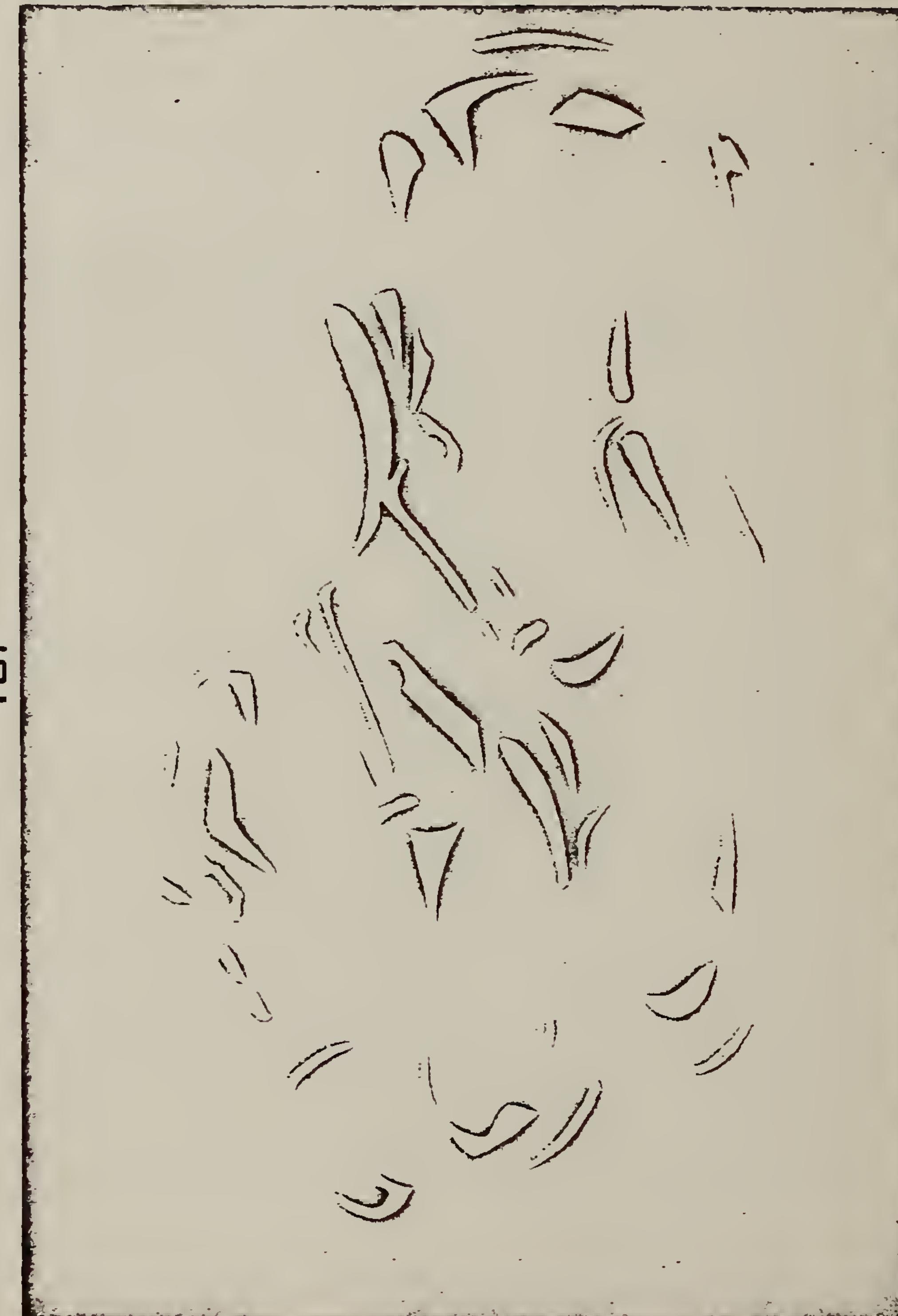
SAMPLE STIMULI--FRAGMENTED TYPE

"Man Playing a Piano"

"Cello" or "Violin"

TOP

TOP



SAMPLE STIMULI--FIGURE/GROUND TYPE

"Man's Face"

"Three Shoes"

APPENDIX B

Tables:

Table 1

Results of Experiment I

Slide Name	Number	Type	Experiment II average time to solution in seconds	Experiment III average time to solution in seconds
Reclining Human	33	FRAG**	8.6	N/A*
Logger with pole	35	F/G***	N/A	11.1
Man's face	30	F/G	5.0	5.0
Couple dancing	21	FRAG	6.5	6.5
Ship or ocean liner	9	FRAG	5.5	5.5
Pig or cow	15	FRAG	8.8	8.8
Dogs head(profile)	27	F/G	7.4	7.4
Man riding a bike	7	FRAG	4.0	4.0
Man playing piano	4	FRAG	4.7	4.7
Three shoes	8	F/G	7.0	7.0
A girl	32	FRAG	6.3	6.3
Woman's face	3	F/G	6.1	6.1
Cello	18	FRAG	11.2	11.2
Dogs face("front")	40	F/G	5.9	5.9
Woman walking	29	FRAG	7.6	7.6
Train or locomotive	14	F/G	10.8	10.8
Teapot	13	FRAG	10.6	N/A
Sailboat	6	FRAG	N/A	6.4
Four tomatoes	38	F/G	9.2	9.2
Mother & child	19	F/G	4.7	4.7

*N/A means this slide was not used in this experiment.

FRAG** - Fragmented slides.

F/G*** - Figure ground slides.

Table 2a

Summary Data for Main Effect of Trials

Trial Number					
1	2	3	4	5	6
23.82*	37.94	47.97	51.34	53.40	54.53

*Cell values are percent correct solution collapsed over all other independent variables (exposure, and spacing) The main effects of trials was significant, F(5,55) = 50.41, p .001.

Table 2b

Summary Data for Experiment II

Exposure:0.2 seconds

Spacing in Seconds	Trials 1	2	3	4	5	6
0.0	26.91**	39.33	47.58	49.62	55.79	55.79
1.5	16.54	35.16	41.37	51.70	55.83	59.95
4.5	20.75	39.33	51.66	53.70	53.70	55.75

Exposure:0.4 seconds

Spacing in Seconds	1	2	3	4	5	6
0.0	31.08**	35.20	47.58	51.66	51.66	55.79
1.5	29.00	41.37	51.70	55.83	55.83	55.83
4.5	18.66	37.25	45.54	45.54	47.48	43.45

** Cell values are percent correct solution

Figure type x Exposure Duration

	Exposure 0.3 sec	0.6 sec
Figure-ground	34.8%	48.0%
Fragmented	27.1%	38.9%

Table 5

Data From Part I Experiment III

Summary of Main Effects

Trials

	Trial Number					
	1	2	3	4	5	6
Percent Correct solutions	16.21	28.95	34.63	41.85	48.56	53.03

Exposure Duration

	Stimulus Exposure	
	0.3 seconds	0.6 seconds
Percent Correct solutions	30.97	43.45

Stimulus Type

	Figure-Ground (F/G)	Fragmented (Frag)
Percent Correct solutions	44.42	33.00

Learning Schedule (MP vs. DP)

	Schedule Type		
	MP	DP	DP
	zero spacing interval	blank spacing interval	task filled interval
Percent Correct solutions	38.05	34.22	39.35

Table 3 continued

Summary Data Part I Experiment III

Exposure X Stimulus Type X Trials

Exposure Duration	1	2	3	4	5	6
Figure-ground slides						
0.3 seconds	14.50*	24.16	29.68	37.25	49.63	53.76
0.6 seconds	26.22	37.25	47.56	51.68	59.91	65.40
Fragmented slides						
0.3 seconds	6.23*	20.66	23.44	34.44	36.57	41.34
0.6 seconds	17.91	33.75	37.86	44.05	48.18	51.63

*cell values are percent correct solution

Learning Schedule X Stimulus Type X Trials

Learning Schedule	1	2	3	4	5	6
Figure-ground						
MP(zero interval)	22.77	28.97	38.27	46.50	60.93	64.04
DP(blank interval)	12.43	26.95	35.22	38.33	47.60	53.77
DP(task interval)	25.87	36.18	42.37	48.56	55.79	60.93
Fragmented						
MP(zero interval)	13.43	25.88	30.98	37.18	42.33	43.37
DP(blank interval)	9.33	26.88	32.04	39.25	42.35	46.50
DP(task interval)	13.45	26.88	28.93	41.31	42.35	49.60

Table 4a

Summary Data From Part II Experiment III

Recognition Memory

Item Category on Part I Experiment III

	Response: Old	Response: New
Old	Hit 90%	Error 10%
New*	False Alarm 7%	Correct Rejection 93%

*"New" here means that these items were not seen during Experiment III

Table 4b

Recognition Data Conditional Upon Whether Stimulus Was solved in Part I

Item Category on Part I Experiment III

	Response: Old	Response: New
Correct solution of old item on or before trial #6	94.8*	6.2
Old item not solved before trial #6	85.2	14.8

*All values are conditional probabilities (i.e., P(responded old on recognition test/item was correctly solved on or before trial #6 Part I)) recorded in percent correct

APPENDIX C

Graphic representations of Data from Experiments II, and III.

<u>Figure</u>

In both figures 1., and 2., the "learning-to-learn"curves appear relatively flat indicating that <u>Ss</u> were not learning how to solve new stimulus items with practice on previously presented stimuli.

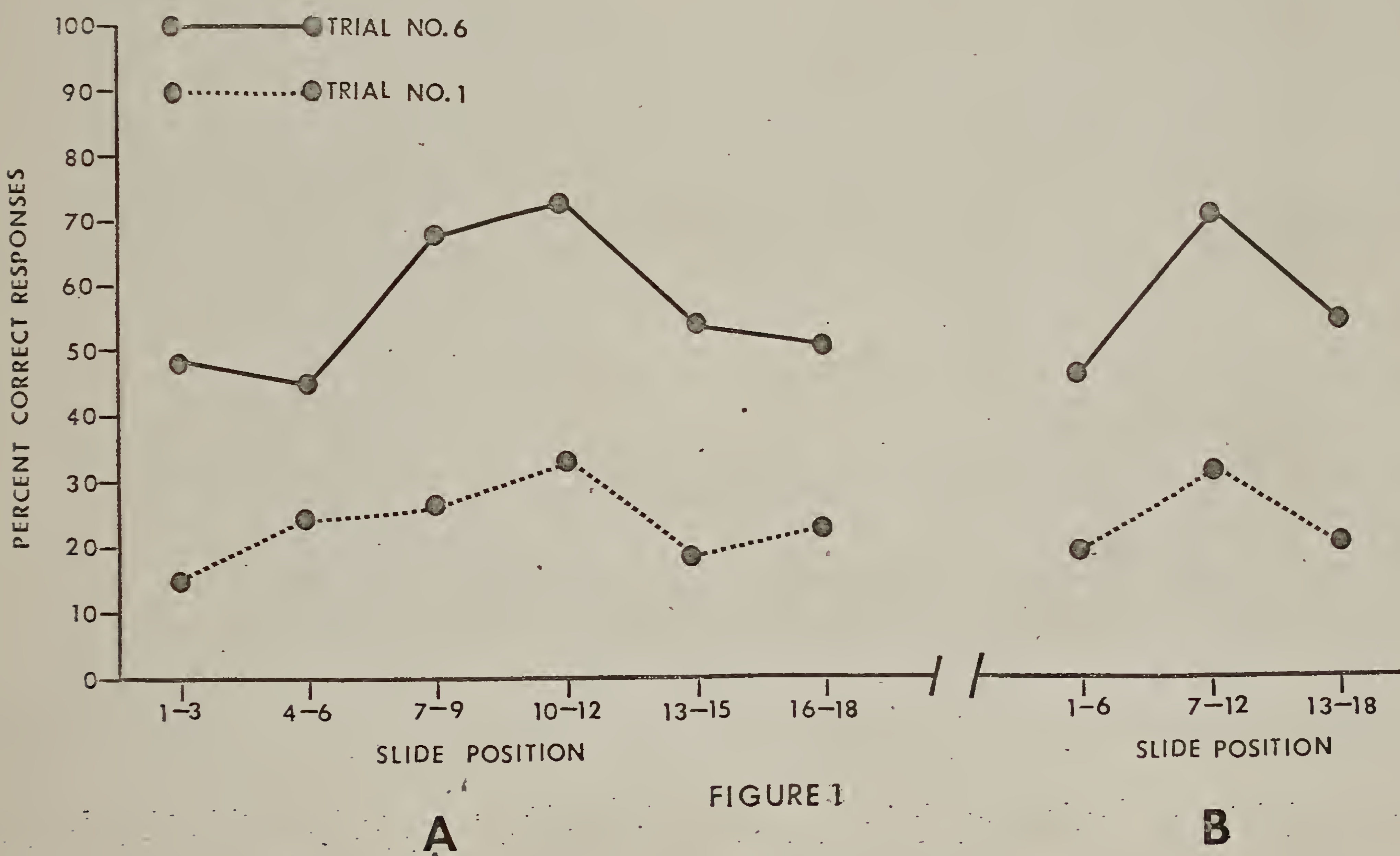
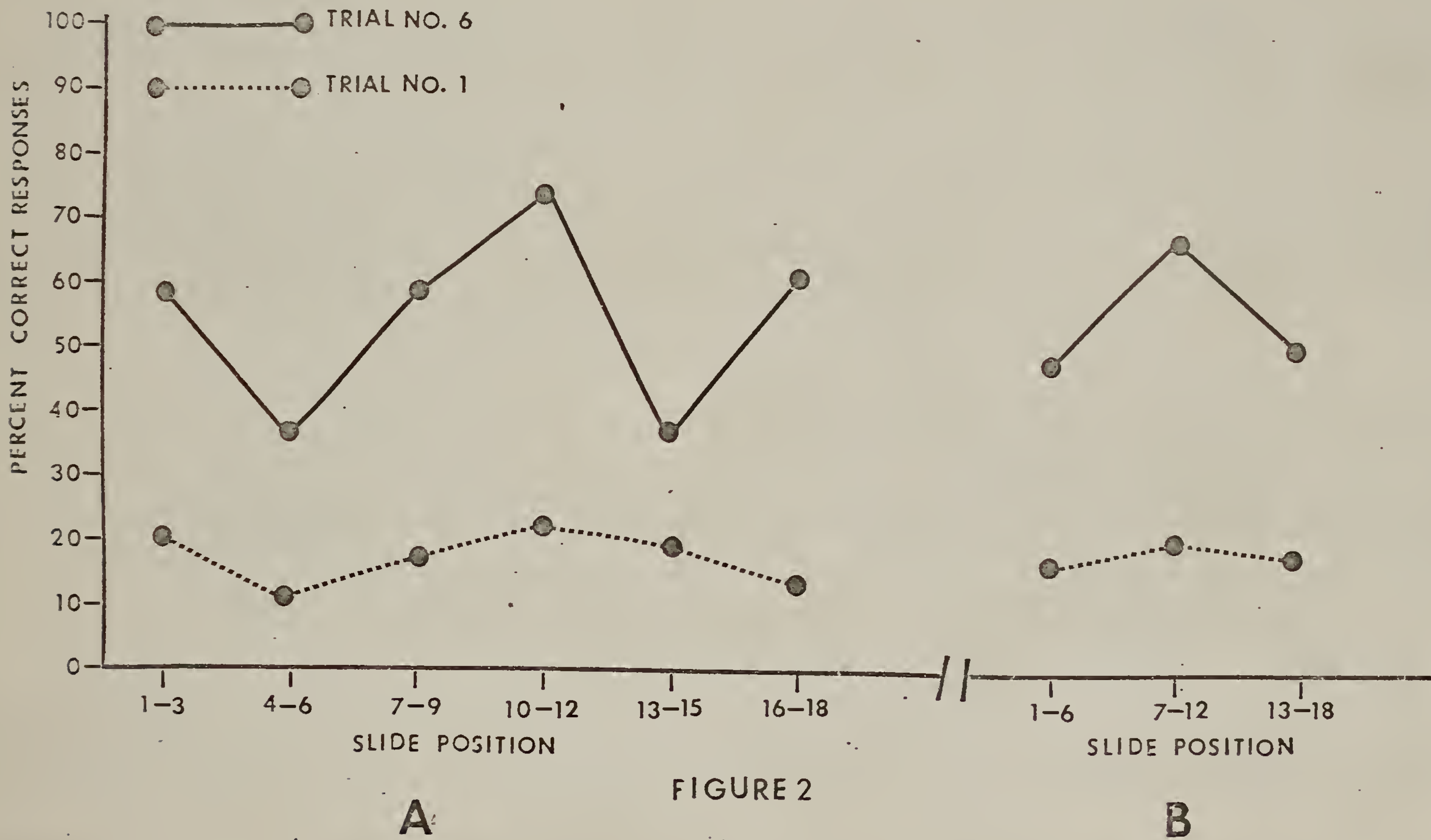

PERCENT CORRECT RESPONSES
100
90
80
70
60
50
40
30
20
10
0
TRIAL NO. 6
TRIAL NO. 1
1–3
4–6
7–9
10–12
13–15
16–18
SLIDE POSITION
A
1–6
7–12
13–18
SLIDE POSITION
B

FIGURE 1



PERCENT CORRECT RESPONSES
100
90
80
70
60
50
40
30
20
10
0
TRIAL NO. 6
TRIAL NO. 1
1–3
4–6
7–9
10–12
13–15
16–18
SLIDE POSITION
A
1–6
7–12
13–18
SLIDE POSITION
B

FIGURE 2

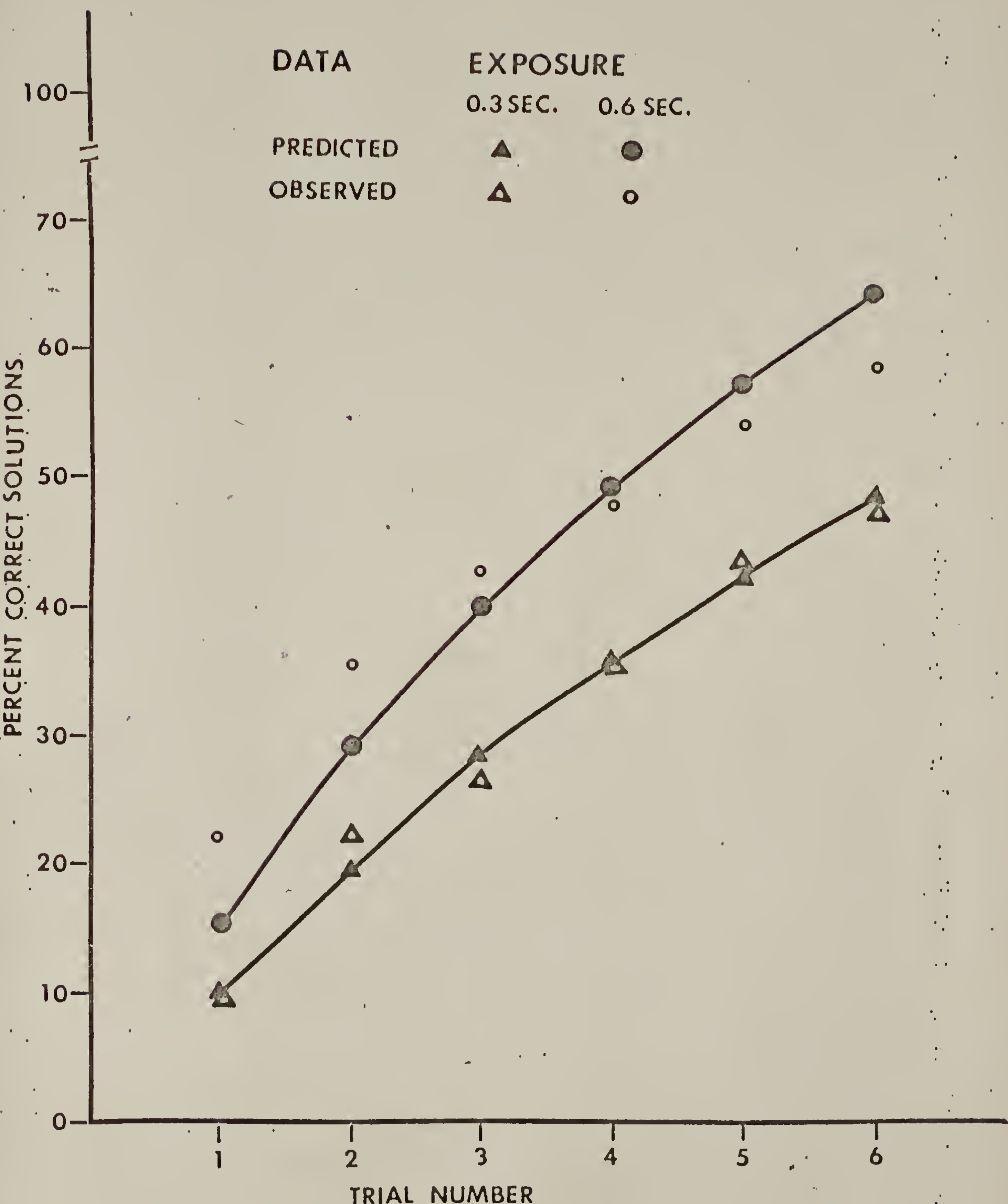
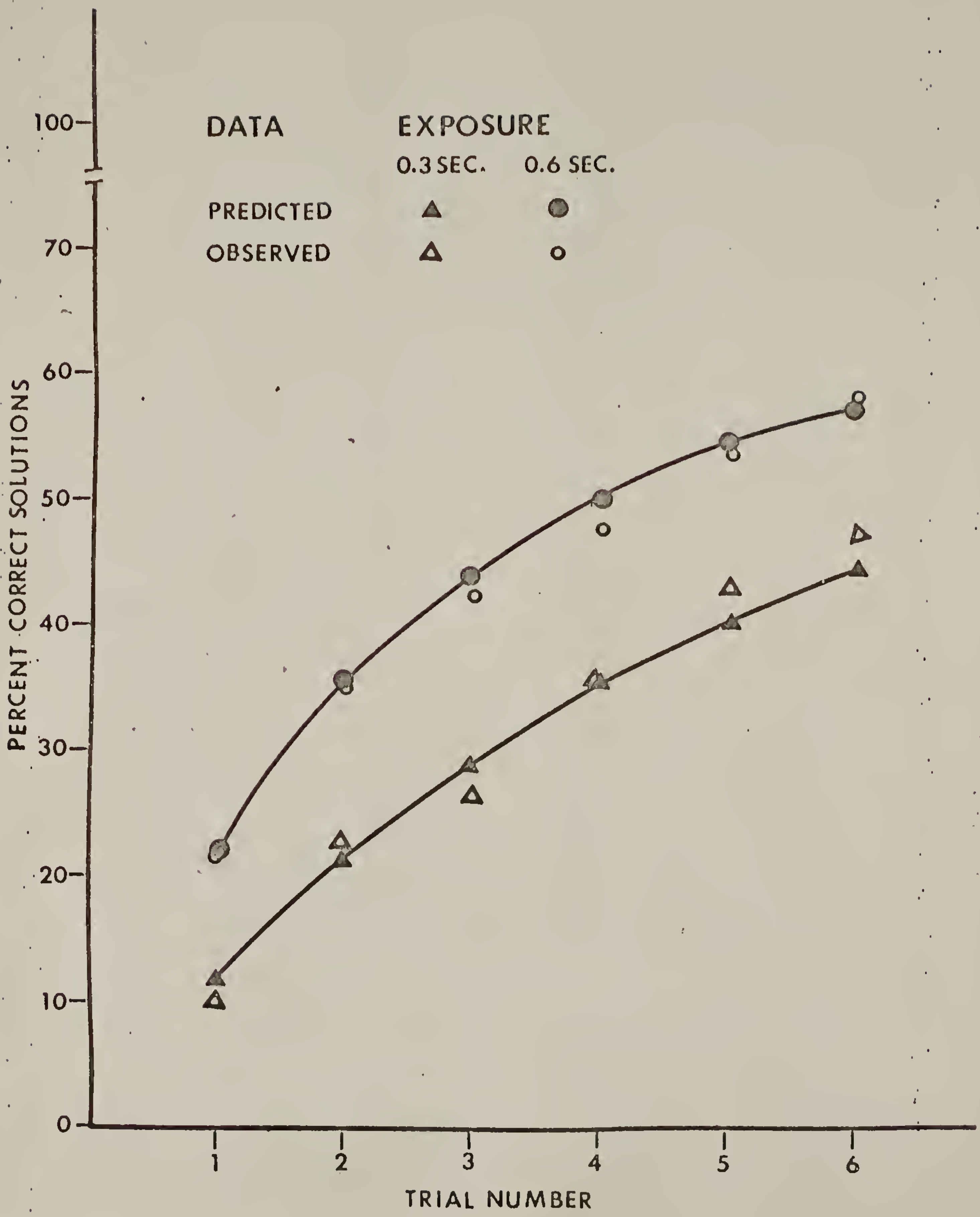

DATA
EXPOSURE
0.3 SEC.
0.6 SEC.
PREDICTED
OBSERVED
PERCENT CORRECT SOLUTIONS
100
70
60
50
40
30
20
10
0
1
2
3
4
5
6
TRIAL NUMBER

FIGURE 3



DATA
EXPOSURE
0.3 SEC.
0.6 SEC.
PREDICTED
OBSERVED
PERCENT CORRECT SOLUTIONS
100
70
60
50
40
30
20
10
0
1
2
3
4
5
6
TRIAL NUMBER

FIGURE 4

Footnotes

[1]Perhaps a good analogy in thinking of the Atkinson and Shiffrin system of memory is to think of a computer. The hard wiring and the actual physical apparatus of the computer hardware itself would be like the "permanent features" of the model. The control processes, however, are more like the programmed instructions that are necessary for the computer to function (software). Just as the information entering a computer is transformed and acted upon by its control processes, so is that of the human information processor.

[2]A distinction must be introduced here to help clarify the difference between the postulated theoretical stores, (STS, LTS) and their operational counterparts as presented in the experimental literature. Since it becomes an impossible task to separate out completely the interaction of short term storage and long term storage in human subjects during experimentation, new categorical labels had to be developed. Short Term Memory (STM) would be the subject's operational "working" memory and is postulated to combine processes from the theoretical STS and LTS. In general, when E discusses STM, he is discussing data collected from experiments designed to measure memory within certain temporal limits (retention of stimuli up to 30 seconds). For example, data from a STM experiment might show a decrement in performance (decay of trace) to some asymptotic level

(steady level of performance) between zero and 30 seconds retention. The rapidly decreasing portion of the function would be ascribed to information loss from STS, while the asymptote would be postulated to be due to LTS.

[3]Even though the process of rehearsal seems well-defined when referring to information in the a-v-l mode, difficulties arise when this concept is applied to visual memory. It seems unreasonable to think that a visual image could be repeated covertly in memory in a manner like that of verbal rehearsal. Consequently, if rehearsal is the process responsible for the transfer of information between STS and LTS, then any emperical evidence questioning the existence of a visual rehearsal process also questions the existence of separate visual store. In fact, Shaffer and Shiffrin (1972) report just such emperical evidence. They argue that a visual rehearsal process analogous to that of the a-v-l mode does not exist. Furthermore, the existence of visual STS is tentative, although, visual LTS must exist as exemplified by the results of recognition experiments (this emperical data is reviewed in this paper under "Visual memory: one store or two").

[4]It will be wasy to substantiate the existence of the LTS by considering recognition of visual materials. However, establishing conclusions derived from experiments dealing with recall as the dependent variable must be con-

sidered with caution. This is obvious since familiar objects presented pictorially are likely to be recoded immediately into verbal STS, from which they are necessarily recalled. This is not to say that the visual trace does not exist or facilitate in the recall process, but it does mean that any attempt to consider the control processes operational in this context must necessarily be confounded with those of the verbal medium. This criticism will be brought to bear in several of the studies reviewed below.

[5]There is some difficulty here in making a determination of store represented. Traditionally, memory theorists argue for decay in STS. However, the temporal characteristics of decay in visual short-term memory generally exceed the 20 to 30 seconds decay time of STS. Since a recent experiment argues convincingly for no visual rehearsal analogous to that of the verbal medium, it seems reasonable to argue that these items could not be held indefinitely in some type of rehearsal buffer. Consequently, the problem is the obvious decay over time as exhibited by the data, which appears to be a LTM phenomenon.

[6]One criticism of this study is that the rated measures of verbal and visual similarity might be highly correlated. If this were true than Wyant et al. may have been measuring two different aspects of visual memory. This seems especially true for what they called "difficult to describe verbally"

items. The difference in performance between the ten and three second exposure was only 8%.

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