MEMORY SEARCH AND REHEARSAL

By

GARY FRANCIS MEUNIER

Bachelor of Arts
Butler University
Indianapolis, Indiana
1965

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1968

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
July, 1970

MEMORY SEARCH AND REHEARSAL

Thesis Approved:

Robert F. Stanners
Thesis Adviser

William W. Rambo

Robert J. Weber

[illegible] Cawan

David T. Hicks

D. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

I would like to express my appreciation to a number of people who have helped make this study possible: to Dr. Robert F. Stanners who gave generously of his time and knowledge as thesis adviser and committee chairman, his capabilities as a teacher, scientist, and friend are held in the highest regard; to Drs. Thaddeus M. Cowan, Robert J. Weber, William W. Rambo, and David L. Weeks who provided encouragement and gave many helpful criticisms in serving as committee members; and, finally, I would like to thank my wife, Jo Ann, who not only endured this project with an inordinate amount of patience and cheer, but contributed materially to its completion as well.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

THE PROBLEM

Introduction

The process of searching through a list to locate a defined target has recently received rather extensive experimental and theoretical investigation. This task may be construed in several ways, e.g., searching for the presence (or absence) of a target in a memorized (or external) list consisting of letters (or numbers), and so on. Many of the variables have been studied in detail and seem to hold considerable promise for the understanding of human cognitive functioning.

For example, it has been suggested that memory search may be an important component in the process of recall (James, 1890; Shiffrin and Atkinson, 1969; Shiffrin, 1970). A general statement of this notion is that in order to recognize or recall a previously presented item a subject must search the contents of his memory for some representation of that item. The accuracy and speed of his response would depend at least partially upon the mechanisms involved in this search.

Various investigators have shown that the speed and accuracy of memory search may be indicative of certain cognitive operations. For example, Briggs and Swanson (1969), utilizing a paired-associate task, had subjects search for specific responses from groups which contained differing numbers of responses. Their results indicated that search speed was a function of the size of the group examined. Other studies have reported similar results (e.g. Sternberg, 1969; Chase and Calfee, 1969). Weber and his associates (Weber, Cross and Carlton, 1968; Weber and Castleman, 1969; Weber and Blagowsky, 1970) have repeatedly demonstrated an approximate linear function between search time and the number of steps between a stimulus and the appropriate response in a memorized circular sequence of stimuli. Correct responses in these tasks are rule-defined as a specific number of "transformations" or steps away from the stimulus.

In a somewhat different vein, Yntema and Trask (1962) presented subjects with a long series of items taken from six different semantic categories. Occasionally the subject was asked to recall the most recent item from a given category. They found that the accuracy of the search for that item varied inversely with the time since it had been presented. Yntema and Trask hypothesized that each item carried a "time-tag" and that these tags must be scanned for the items within a given category.

Kennedy and Wilkes (1968) have demonstrated that the search process through a memorized sentence is sensitive to certain grammatical characteristics of the sentence. Subjects in their experiment were required to respond with the word from a memorized sentence which immediately followed a stimulus word provided by the experimenter. Reaction times to respond were significantly increased when the two words were separated by a constituent boundary (Chomsky, 1957).

The present study was an attempt to examine further the relationship between search and other memory processes. Specifically, modifications of a task first described by Sternberg (1963) were used to investigate the way in which memory search may vary in recall as opposed to recognition tasks, and as a function of the time allowed for processing the stimuli before responding.

Discussion of the Relevant Literature

Sternberg (1966, exp. II) has employed reaction time (RT) as an index of retrieval time in recognition memory experiments, and has proposed a theory of the process of retrieval. Ten single-digit numerals were used as stimuli in a fixed-set procedure. The numerals were divided into two subsets, each with membership known to the subject (S) before the experimental session began. Upon presentation of a numeral from the positive set (generally the smaller subset), the S was to react as rapidly as possible by moving a lever. The appropriate response to numerals in the complementary subset, called the negative set, was movement of a second lever. Size of the positive set was either 1, 2, or 4 items and was changed within-Ss. RT was the dependent variable.

Sternberg (1966) proposed that when the S is presented a digit from the positive set, a representation of the test stimulus is compared, successively, to a series of memory representations, one for each member of the positive set. Each comparison results in either a match or a mismatch. After the search has been completed a positive response is initiated if there has been a match, and a negative response otherwise. In terms of the theory, memory search is serial, since comparisons are made one at a time, and is exhaustive, since no response is made until there has been one comparison for each member of the positive set.

Consistent with the serial and successive aspects of the theory is the finding (e.g., Sternberg, 1969) that RT increases linearly with the size of the positive set, not only for positive responses but for negative responses as well. The proposition that search of the positive set is exhaustive gains support from the finding that average time per comparison, as evidenced by the slope of the function relating RT to positive set size, is the same for positive and negative responses.

A linear relationship between RT and the set size has also been reported in experiments utilizing a varied set procedure (Sternberg, 1966, exp. I). In this procedure digits were presented for 1.2 seconds and the last digit in the list was followed by a 2 second delay, a warning signal, and the probe. Lists varied according to length (from 1 to 6 digits) and items, both having been assigned randomly within Ss. Following each trial S attempted an ordered recall of the list.

Another test of Sternberg's theory is provided by the relationship between RT and serial position of the probed item. In a simple exhaustive search neither the order of search nor the serial position of the probed item should have an effect on average RT because all items are examined. The support given a serial-exhaustive theory by this relationship is weakened by the fact that at least one other type of search (one which starts at a random point and terminates upon a successful match) could produce similar data.

Two studies (DeRosa and Morin, 1970, exp. II; Sternberg, Knoll, and Nasto, 1969) have reported an analysis of within set RT which conforms to that required by the serial-exhaustive theory. Both studies used a fixed set procedure and reported a non-significant main effect of serial position.

Other investigators, however, have reported data not easily handled by this theory. Morin, DeRosa, and Stultz (1967) found a large difference in RT related to the serial position of the probed item. These experimenters presented lists of 4 single digits at a rate of .5 seconds per digit. A probe followed at the same interval. Composition of the lists varied across trials and recall was not required. When RT was plotted against serial position of the probe a small primacy effect and large recency effect were found. That is, reactions to the item in the first serial position were always faster than to the item in the second serial position, and the last presented item was identified as positive with much greater speed than numerals presented earlier. Strikingly similar results have been reported by Corballis (1967) with the same procedure as Morin, et al (1967) and a .6 second item presentation time.

Because these experiments have used only one positive set size it is impossible to make a complete test of predictions from the Sternberg model. A finding of differential RTs to varying serial positions of the positive set, however, seems difficult to reconcile with a serial-exhaustive theory.

A stronger test of the model is provided by Morin, DeRosa, and Ulm (1967). These investigators used sets of 3, 4, 5, and 6 items in a procedure similar to that of Morin, DeRosa, and Stultz (1967). They reported not only a curvilinear relationship between RT and serial position, but a significant quadratic compoent to the function relating RT to positive set size. The obvious disagreement of these results with predictions from the serial-exhaustive model strongly suggests the need for further theoretical and experimental research.

A Proposed Model and Explanation

One possible explanation of these conflicting results may be provided by a model of memory recently proposed by Waugh and Norman (1965). According to this model items pass from a memory store of limited capacity (primary memory) to a second, more stable store of virtually unlimited capacity (secondary memory). Items are maintained in primary memory (PM) and encoded into secondary memory (SM) by rehearsal. Material which is not encoded in SM is lost rather quickly when rehearsal is stopped. One interesting feature of this model is that the contents of the two storages are not mutually exclusive; that is, the probability that an item is recalled is dependent upon the probability it is in PM plus the probability it is in SM. Hence, the contents of a list of items may be retrieved from either PM or SM or both in a typical recall experiment.

Recent experimental results (Stanners and Meunier, 1969; Stanners, Meunier, and Headley, 1969) have been interpreted as favorable to the Waugh and Norman model. These studies provided information on the rehearsal aspect of the model, i.e., they strongly suggest a rehearsal process that is more efficient for materials which reflect the hypothesized auditory aspects of primary memory (Sperling and Speelman, 1970).

One implication of the Waugh and Norman model is that procedural differences among certain of the experiments designed to test Sternberg's theory may account for the disparate results. In Sternberg's varied set procedure each digit was presented for 1.2 seconds and the list was followed by a warning signal and 2 second delay before the probe appeared. Estimated implicit speech rates of 3 to 4 items per second (Landauer, 1962; Weber and Bach, 1969) would indicate that sufficient time was allowed in this procedure for rehearsal. In the Morin, et al. (1967) and Corballis (1967) experiments much less time was allowed for rehearsal. Item duration time in these experiments was a maximum of .6 seconds and the probe was separated from the last list item by an interval of less than .5 seconds.

Another interesting procedural difference between these two sets of studies is the nature of the task required <u>after</u> <u>S</u> has made his decision. Subjects in the Morin, et al. and Corballis experiments were not required to maintain the items after they had responded to the probe. Because of the relatively fast inter-trial interval (4 seconds) <u>S</u>s were, in fact, encouraged to forget the items in order to minimize proactive interference effects on following lists. Forgetting seemed to be facilitated by the fact that in no instance did the number of items to be remembered exceed the estimated capacity of short-term memory (Miller, 1956), and, hence, encoding into SM was not required. Thus, Ss in these experiments did not seem required, nor, due to the relatively fast rate of presentation, were they allowed substantial opportunity to encode items into SM.

By presenting the set of positive items only once (at the beginning of each block of trials) Sternberg's fixed set procedure (Sternberg, 1967; DeRosa and Morin, 1970, exp. II) would seem to require the encoding of some relatively stable representation of the items. In the varied set procedure (Sternberg, 1966, exp. I) Ss were encouraged to maintain the items in memory following their decision by the requirement of an ordered recall of each list. The necessity to maintain a fairly stable memory representation of the items and the similarity of the results suggest that Ss in both the varied set and fixed set procedures were encoding list items into SM.

Additional evidence for the importance of the task which follows the recognition response is provided by the varied set procedure of Sternberg (e.g., 1966, exp. I) and a study reported by Kennedy and Hamilton (1969). The Kennedy and Hamilton experiment found strong recency effects in the curve relating RT to serial position of positive probes. Subjects in each study were allowed almost equal rehearsal time (1 second vs. 1.2 seconds) and differed only in that Sternberg required a recall after each trial and Kennedy and Hamilton did not. The different results from these experiments suggest that the presence or absence of a recall task following the decision determined how the rehearsal time was utilized. One possible interpretation of these results is that only Sternberg's Ss were using the rehearsal time to encode the list items into SM.

The notion that Ss exercise some "control" over the use of rehearsal has been advocated by Atkinson and Shiffrin (1967) and given empirical support by Mechanic (1962). Briefly, Mechanic had Ss pronounce and rate the degree of phonetic similarity of pairs of items in an incidental learning task. In contrast with the results of previous studies (e.g., Postman and Stark, 1956) recall of incidental items increased with practice. One interpretation of this result is that Ss typically do not rehearse incidental items. By requiring a pronounciation of all items, however, Mechanic forced his Ss to rehearse incidental items and recall improved with the additional rehearsal.

A notion of subject control of encoding has been utilized in a recent attempt to explain the relationship between recognition and recall tasks (Martin, 1968). Martin has suggested that items are encoded differently depending upon the nature of the task; Ss must encode only one of many possible representations of a trigram stimulus in recognition tasks, but must store an integrated form capable of being reproduced in its entirety in recall tasks. Thus, slower learning, when measured by written recall, should result from the necessity to encode and store the complete stimulus item. And, due to the greater amount of "information" stored for recall, these items should suffer more from the processes which serve to produce forgetting. Certain experimental evidence (e.g., Martin, 1967) support these suggestions.

Thus, in sum, the model of memory proposed by Waugh and Norman (1965) does seem to offer some possibility of explaining differing results obtained from memory search experiments. Specifically, rehearsal, as affected by the temporal characteristics and task demands of the experiment, would seem to have a crucial effect on memory search. Although the reason these search effects are produced is not known, one possibility is that they may be a result of searching different memory stores. That is, appropriate experimental manipulations may force Ss to search either PM or SM. The data would suggest, in this case, that the search process is different in the two memory stores.

Another explanation of these effects has been recently offered by Sternberg, et al. (1969). These authors suggested that memory search (at least for the situations reviewed here) may be a process unique to PM. Different results would be produced, according to this notion, when part of the material is in SM and must be transferred to PM in order to be searched.

The present study was an attempt to experimentally examine certain temporal and task variables in regard to their effects on memory search. Specifically, conditions of the experiment were designed so as to allow manipulation of both the opportunity for rehearsal as well as the necessity for rehearsal. It was hoped that performance differences produced by these factors would appear in interaction with the presence or absence of a requirement to recall the list. Implications of the results for a serial-exhaustive search theory (e.g., Sternberg, 1966) were suggested and interpretation of the results was aided by consideration of the Waugh and Norman (1965) model.

CHAPTER II

METHOD

Subjects

Ninety-six right handed students from the Introductory Psychology sections at Oklahoma State University served as Ss. An equal number of male and female students served in each condition of the experiment. All Ss were given extra credit points as an inducement to participate.

Materials and Equipment

Stimuli were randomly composed lists of single digits between 1 and 8 inclusive. Forty lists of 4 and 5 items each, and forty-eight 3 item lists were constructed with certain restrictions. No digit was repeated within a list and all digits were used approximately the same number of times at each serial position. An equal number of positive and negative probes appeared at each set size and each serial position was probed equally often within each set of lists. In accord with DeRosa and Morin's finding (1970, exp. I) that sequential lists of numbers lead to a different type of processing strategy, care was taken to avoid ascending and descending series of digits.

Digits were presented at a height of 2.54 cm. by an Industrial Electronics model 693 projector programmed by a Computer Mechanisms model 18 tape reader and three Hunter timers. RT was measured to the nearest .001 second by a Hunter Kloukkounter.

Design

The general design for this experiment was a 2x2x2x2x3 factorial. Item duration (.25 or 1.00 seconds), interval between the last list item and the probe (.25 or 4.00 seconds), and post-recognition task (recall of the list or a rating of S's confidence in his decision) were manipulated orthogonally between Ss. Each of these 8 between-Ss treatment combinations contained 12 Ss. Size of the positive set (3, 4, or 5 items) and probe type (positive or negative) were manipulated within Ss.

Item presentation time was varied in accordance with Aaronson's (1967) suggestion that Ss may rehearse during presentation of a list. An additional manipulation of rehearsal time was provided by varying the delay between the last list item and the probe. It was thought that by lengthening item duration an opportunity for rehearsal would be provided; by introducing a delay before the probe a rehearsal process would be required. The literature review would suggest that only certain Ss (those required to recall) would utilize the rehearsal time provided by a lengthened item duration. It was expected, however, that all Ss would rehearse when forced to retain the list items for some seconds before the probe appeared.

Three different list lengths were utilized in order to provide a strong test of Sternberg's theory. By using 3 set sizes predictions concerning the relationship between RT and serial position as well as between RT and size of the positive set could be examined (cf: Sternberg, 1969 for a discussion). Similarly, the use of positive and negative probes allows still another test of the serial-exhaustive search theory.

Procedure

Subjects were tested individually and were assigned to treatment conditions randomly upon arrival in the laboratory. The random assignment of Ss to conditions was restricted to the extent that no treatment condition was filled a second time until all other conditions had been filled at least once.

Subjects were seated at a small desk and viewed stimulus items from a distance of approximately 2 ft. A 3 ft. by 3 ft. sheet of plywood was affixed to the side of the desk opposite S and served both as a mounting for the projector and as a mask of the remaining equipment and the experimenter (E). A toggle-type switch mounted into the top of the desk served as the lever for S's decision response. The switch had a 2-in. handle and a very light spring loading for ease of operation. Direction of lever movement was balanced across the Ss. Lights were dimmed in the lab room during testing to insure accurate perception of the digits.

Each S viewed a list presented at a duration of either .25 or 1.00 seconds per item which was followed by an interval of either .25 or 4.00 seconds before the probe. A constant interval of .25 seconds was maintained between list items. A buzzer accompanied onset of the probe. RT was the elapsed time between probe onset and movement of the lever. Direction of lever movement indicated S's decision as to whether or not the probe was one of the list items. One-half (48) of the Ss attempted written recall of the list following lever movement, the other one-half rated the degree of confidence they had in their decision. The confidence rating task was actually used as a "filler" in order to provide an intertrial task which was roughly equivalent to that required of the recall Ss in terms of time requirements.

Subjects required to recall were provided a booklet of answer sheets with space marked on each for the appropriate number of items. Ordered recall was not specified. Confidence ratings were also made on individual sheets from a booklet provided by E. Ratings varied from 1 to 5 with a 1 indicating very high confidence and a 5 very low confidence in the correctness of the decision. Intermediate levels of confidence were associated with those numbers between 1 and 5.

A 15-second intertrial interval was maintained between the lever movement and a verbal signal of "Ready" by E indicating the next trial was about to begin. Each S received all lists in blocks corresponding to list size. Order of presentation of the blocks was randomized across Ss and a 1 minute rest period was allowed between blocks. Three practice trials preceeded each new set of trials.

CHAPTER III

RESULTS

Separate analyses-of-variance were performed on the data in an attempt to examine the search process between and within sets of varying size. Individual observations for the analyses were the mean RT of a given S in a given subcondition. Incorrect decisions accounted for approximately 9% of the lever movement responses and were not considered in the analyses. In order to provide for possible violations of assumptions underlying the analyses, F tests on within-Ss factors were calculated with the conservative procedure recommended by Greenhouse and Geiser (1958). The .05 level was adopted as the minimum required for statistical significance.

Analysis of Between-Set RT

An analysis-of-variance was performed on the data with each of the following factors at 2 levels: item duration (I), delay between the last item and the probe (D), S's task following lever movement (R), and nature of the probe (P). Size of the positive set (S) was varied across the 3 levels previously mentioned. Both P and S were treated as within Ss-factors. The results of this analysis are presented as Table I.

Main effects of set size and probe type, as well as the SxIxDxR interaction, all reached statistical significance. The significant S and P main effects are depicted as Figures 1 and 2 respectively. Examination of these figures indicates that RT increased with size of the positive set (the linear component of this function accounted for 99.8% of the variance) and was longer

TABLE I

ANALYSIS-OF-VARIANCE OF BETWEEN SET DATA

Source	df	SS	MS	F
Between-Ss	95	13.474		
I	1	.242	.242	1.692
D	1	.002	.002	<1
R	1	.110	.110	<1
ID	1	.197	.197	1.378
IR	1	.007	.007	<1
DR	1	.042	.042	<1
IDR	1	.271	.271	1.895
Error	88	12.603	.143	
Within-Ss	480	5.157		
P	1	.067	.067	13.400**
IP	1	.002	.002	<1
DP	1	.014	.014	2.800
RP	1	.005	.005	1.000
IDP	1	.007	.007	1.400
IRP	1	.001	.001	<1
DRP	1	.001	.001	<1
IDRP	1	.003	.003	<1
PxSs within gps.	88	.468	.005	
S	2	1.077	.539	89.833**
IS	2	.019	.009	1.500
DS	2	.022	.011	1.833
RS	2	.027	.014	2.333
IDS	2	.010	.005	<1
IRS	2	.030	.015	2.500
DRS	2	.009	.005	<1
IDRS	2	.051	.026	4.33*
SxSs in gps.	176	1.203	.006	
PS	2	.001	.001	<1
IPS	2	.002	.001	<1
DPS	2	.003	.002	<1
RPS	2	.002	.001	<1
IDPS	2	.007	.004	<1
IRPS	2	.000	.000	<1
DRPS	2	.000	.000	<1
IDRPS	2	.004	.002	<1
PSxSs in gps.	176	2.122	.012	

NOTE: * indicates $p<.05$ and ** indicates $p<.01$.

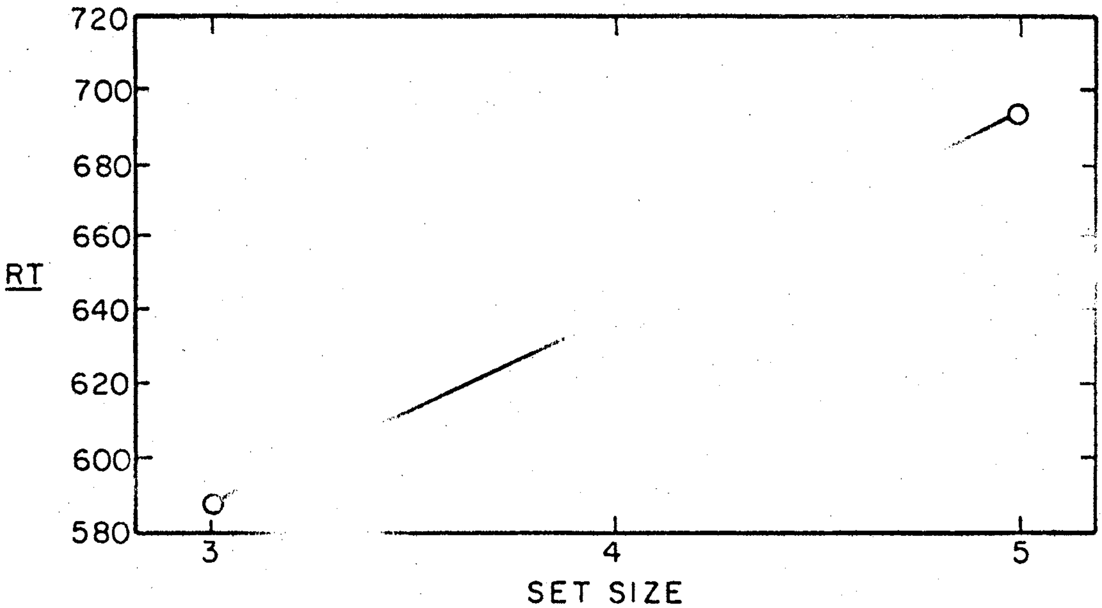

Figure 1. Mean RT of the Data Collapsed on All Variables But Set Size

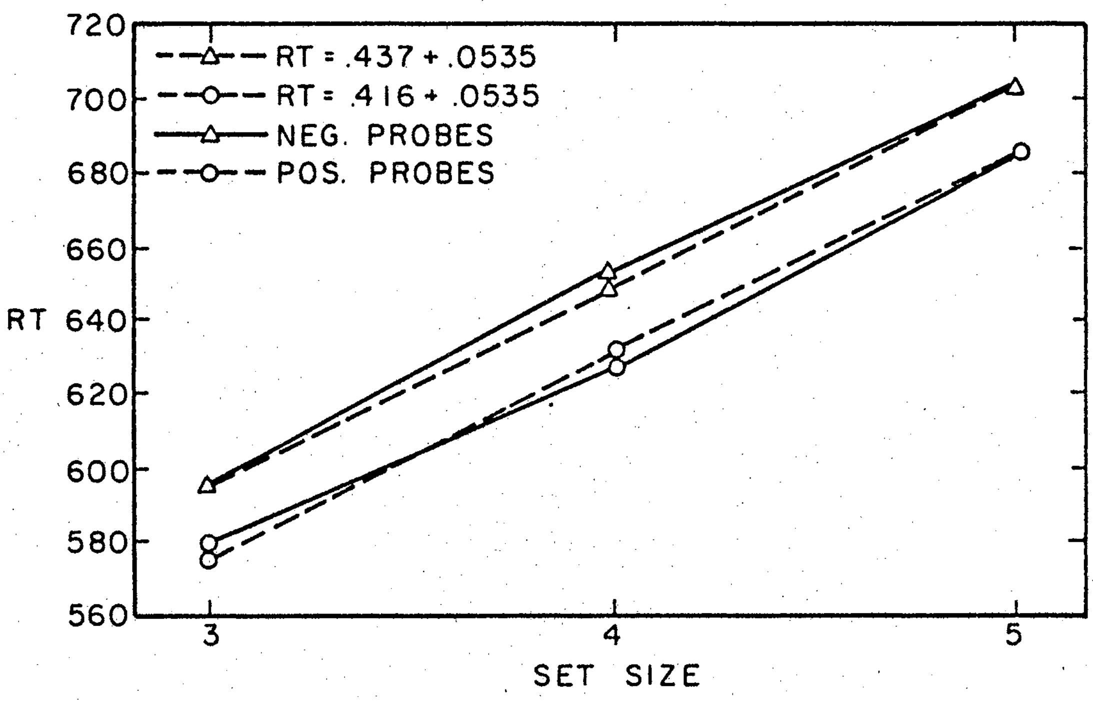

Figure 2. Positive and Negative Probes Plotted at Each Set Size

for negative than for positive probes. Both of these results would seem compatible with a notion of exhaustive search if it could be demonstrated that the longer RTs to negative probes were produced by some aspect of the task other than search.

One way of separating search time from other components of the recognition task is to plot regression equations for response times against set size. The rate of search can be derived from the slop of the regression line; all other components of the task (e.g., encoding of the probe stimulus) are reflected in the Y-intercept of the line. Regression equations and lines for positive and negative probes (also presented in Fig. 2) clearly indicate that search rates were identical in the two situations. Average search rate in both situations was about 19 digits/second. Because the slopes were equal a statistical test of their difference was deemed unnecessary. Thus, the significant effect of P in the above analysis would seem to be caused by some element(s) of the task other than search. This result is similar to that reported by Sternberg (1969).

In order to examine the SxIxDxR interaction the data were collapsed over probe type and plotted separately for each level of R. Inspection of these data (Figures 3 and 4) suggests that the nature of the post-decision task had a strong effect on the pattern of the RT curves. RT is consistently slower with longer item durations for the recall data (Fig. 3). In the confidence rating data, however, there seems to be an interaction between item duration and delay; RT was fastest for those conditions where rehearsal time was either minimized (.25-.25) or maximized (1.00-4.00). Presentation of the means and standard errors of these data collapsed over set size (Table II) illustrates this point.

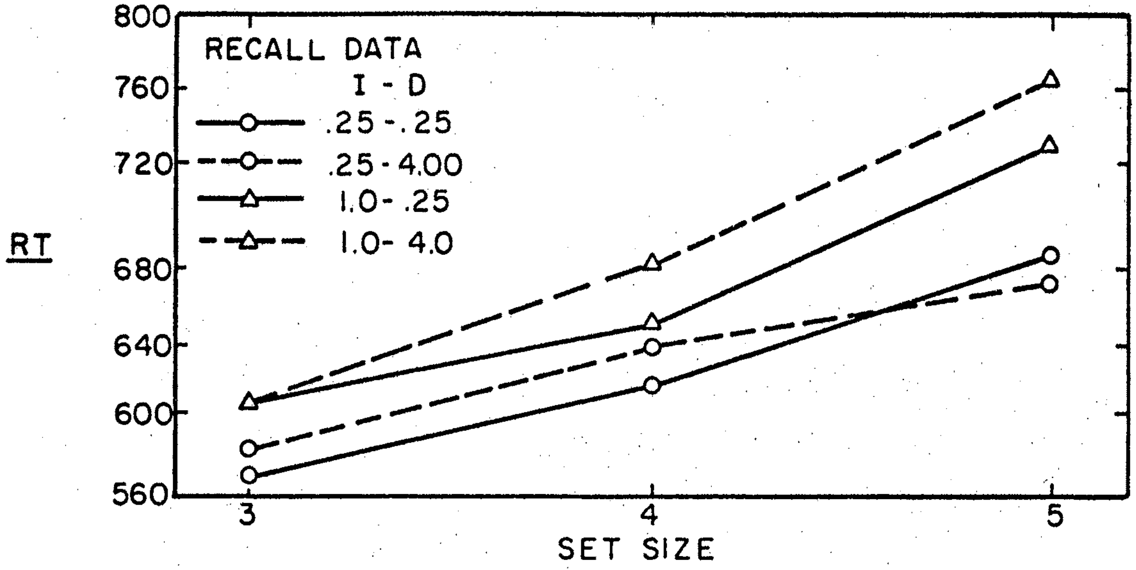

Figure 3. Mean Recall RT for Each ID Treatment Combination at Each Set Size

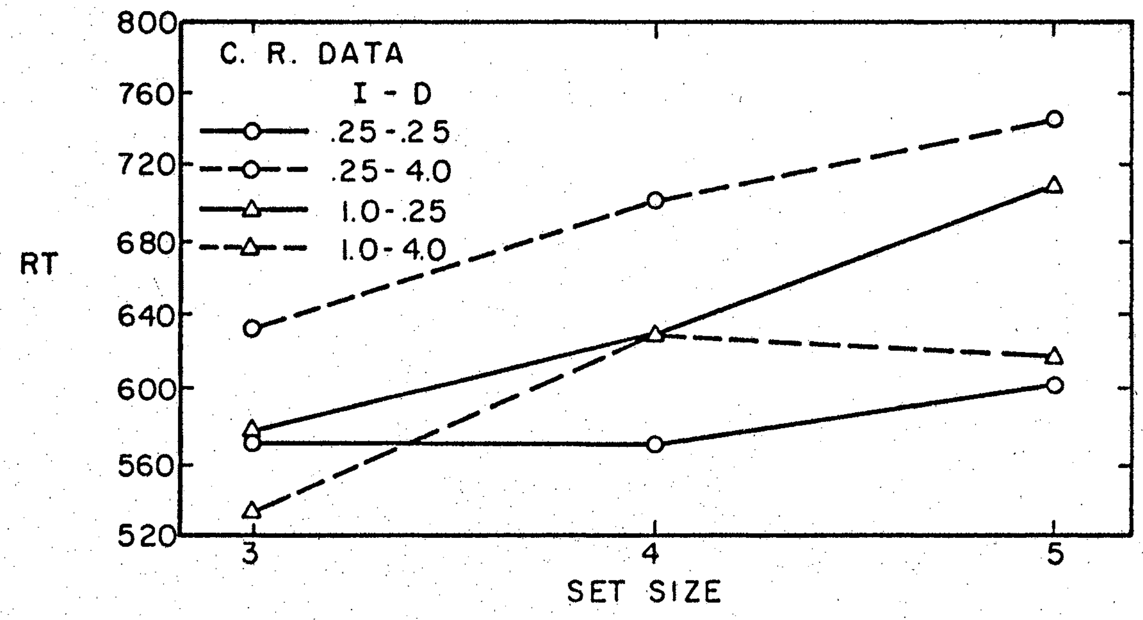

Figure 4. Mean Confidence Rating RT for Each ID Treatment Combination at Each Set Size

TABLE II

MEAN CONFIDENCE RATING RTs COLLAPSED OVER SET SIZE AND PROBE

Times	.25-.25	.25-4.00	1.00-.25	1.00-4.00
MEAN (m. sec.)	578	687	638	592
SE (m sec.)	4	6	7	4

Statistical verification of these results was provided by a significant IXD interaction in the analysis of the confidence rating data (Table III). A similar analysis of the recall data yielded a large but non-significant ($F_{(1.44)}$ = 4.00, $p < .07$) IxS interaction (Table IV).

Analysis of Within-Set RT

Separate analyses were also performed on the data at each set size. Serial position (SP) of the positive probes was an additional factor in these analyses and negative probes were, of course, excluded from consideration.

Set Size 3

The main effect of serial position as well as the DxRxSP interaction was significant in the over-all analysis of set size 3 data (Table V). To examine this interaction, subanalyses were performed at each level of R with the data collapsed over levels of I. Inspection of Table VI reveals a significant effect of SP and of the DxSP interaction in the recall data. The DxSP interaction is plotted as the left panel in Figure 5. A rather pronounced

TABLE III

ANALYSIS-OF-VARIANCE OF CONFIDENCE RATING DATA
COLLAPSED OVER PROBES

Source	df	SS	MS	F
Between-Ss	47	2.560		
I	1	.035	.035	<1
D	1	.012	.012	<1
ID	1	.218	.218	4.192*
Error	44	2.295	.052	
Within-Ss	96	.988		
S	2	.183	.091	11.375**
IS	2	.020	.010	1.250
DS	2	.015	.008	1.000
IDS	2	.034	.017	2.125
Error	88	.736	.008	

NOTE: *indicates $p < .05$ and ** indicates $p < .01$.

TABLE IV

ANALYSIS-OF-VARIANCE OF RECALL DATA COLLAPSED OVER PROBES

Source	df	SS	MS	F
Between-Ss	47	4.810		
I	1	.083	.083	<1
D	1	.007	.007	<1
ID	1	.001	.001	<1
Error	44	4.719	.107	
Within-Ss	96	.457		
$\bar{S}$	2	.351	.176	176.000**
IS	2	.007	.004	4.000
DS	2	.003	.002	2.000
IDS	2	.005	.003	3.000
Error	88	.091	.001	

NOTE: *indicates $p < .05$ and ** indicates $p < .01$.

TABLE V

ANALYSIS-OF-VARIANCE OF SET SIZE 3

Source	df	SS	MS	F
Between-Ss	95	6.218		
I	1	.055	.055	<1
D	1	.072	.072	1.075
R	1	.022	.022	<1
ID	1	.081	.081	1.209
IR	1	.009	.009	<1
DR	1	.031	.031	<1
IDR	1	.034	.034	<1
Error	88	5.914	.067	
Within-Ss	192	.918		
SP	2	.065	.032	8.000**
IxSP	2	.002	.001	<1
DxSP	2	.024	.012	3.000
RxSP	2	.012	.006	1.500
IxDxSP	2	.006	.003	<1
IxRxSP	2	.020	.010	2.500
DxRxSP	2	.044	.022	5.500**
IxDxRxSP	2	.005	.003	<1
Error	176	.740	.004	

NOTE: * indicates $p < .05$ and ** indicates $p < .01$.

TABLE VI

ANALYSIS-OF-VARIANCE OF RECALL DATA: SET SIZE 3
COLLAPSED ON ITEM DURATIONS

Source	df	SS	MS	F
Between-Ss	47	3.418		
D	1	.004	.004	<1
Error	46	3.414	.074	
Within-Ss	96	.449		
SP	2	.050	.025	6.25**
DxSP	2	.062	.031	7.75**
Error	92	.337	.004	

NOTE: * indicates $p<.05$ and ** indicates $p<.01$.

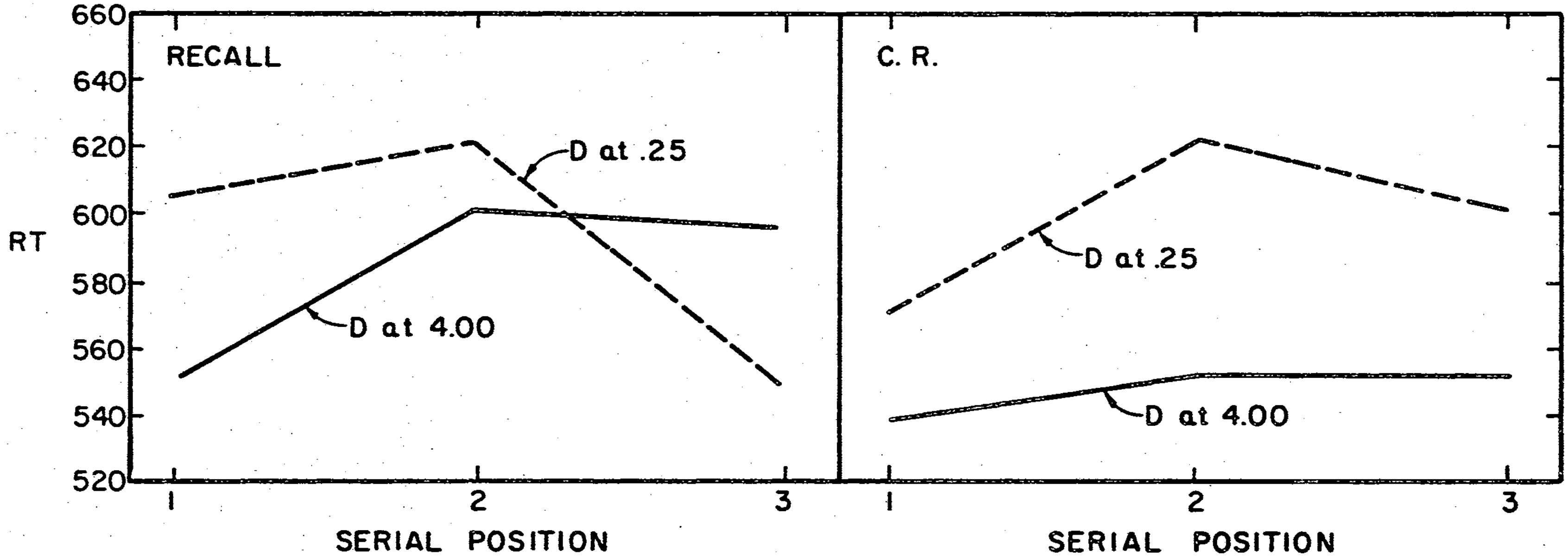

Figure 5. Relationship of Recall and Confidence Rating Data at Each Level of Delay to Serial Positions in Set Size 3

recency effect is displayed with data at the .25 level of D: a strong primacy effect is evident at the 4.00 level of D These data suggest that one effect of forcing a period of rehearsal before the probe is to shift the general pattern of the serial position curve. With the very short delay, fastest RTs occurred to the last serial item; with a longer delay fastest responding was to the first serial item. A theoretical interpretation of these results will be presented later in this paper.

No significant effects were found in the comparable analysis of the confidence rating data (Table VII). With the data plotted at the levels of D and SP (right panel of Fig. 5) a tendency towards a serial position curbe does appear but is not detected by the analysis.

TABLE VII

ANALYSIS-OF-VARIANCE OF CONFIDENCE RATING DATA: SET SIZE 3; COLLAPSED ON ITEM DURATIONS

Source	df	SS	MS	F
Between-Ss	47	2.800		
D	1	.100	.100	1.695
Error	46	2.700	.059	
Within-Ss	96	.469		
SP	2	.025	.013	2.600
DxSP	2	.007	.003	<1
Error	92	.437	.005	

NOTE: * indicates $p < .05$ and ** indicates $p < .01$.

Set Size 4

Statistical analysis of these data did not produce results comparable to those for set size 3. Only the SP main effect reached significance (Table VIII). For ease of comparing results across the various set sizes, these data are illustrated in the same way as the set size 3 data (Fig. 6).

TABLE VIII

ANALYSIS-OF-VARIANCE OF SET SIZE 4

Source	df	SS	MS	F
Between-Ss	95	10.971		
I	1	.303	.303	2.589
D	1	.004	.004	<1
R	1	.021	.021	<1
ID	1	.114	.114	<1
IR	1	.025	.025	<1
DR	1	.046	.046	<1
IDR	1	.083	.083	<1
Error	88	10.375	.117	
Within-Ss	288	2.090		
SP	3	.326	.109	18.167**
IxSP	3	.004	.001	<1
DxSP	3	.058	.019	3.170
RxSP	3	.002	.001	<1
IxDxSP	3	.017	.006	1.000
IxRxSP	3	.016	.005	<1
DxRxSP	3	.028	.009	1.500
IxDxRxSP	3	.025	.008	1.334
Error	264	1.614	.006	

NOTE: * indicates $p < .05$ and ** indicates $p < .01$.

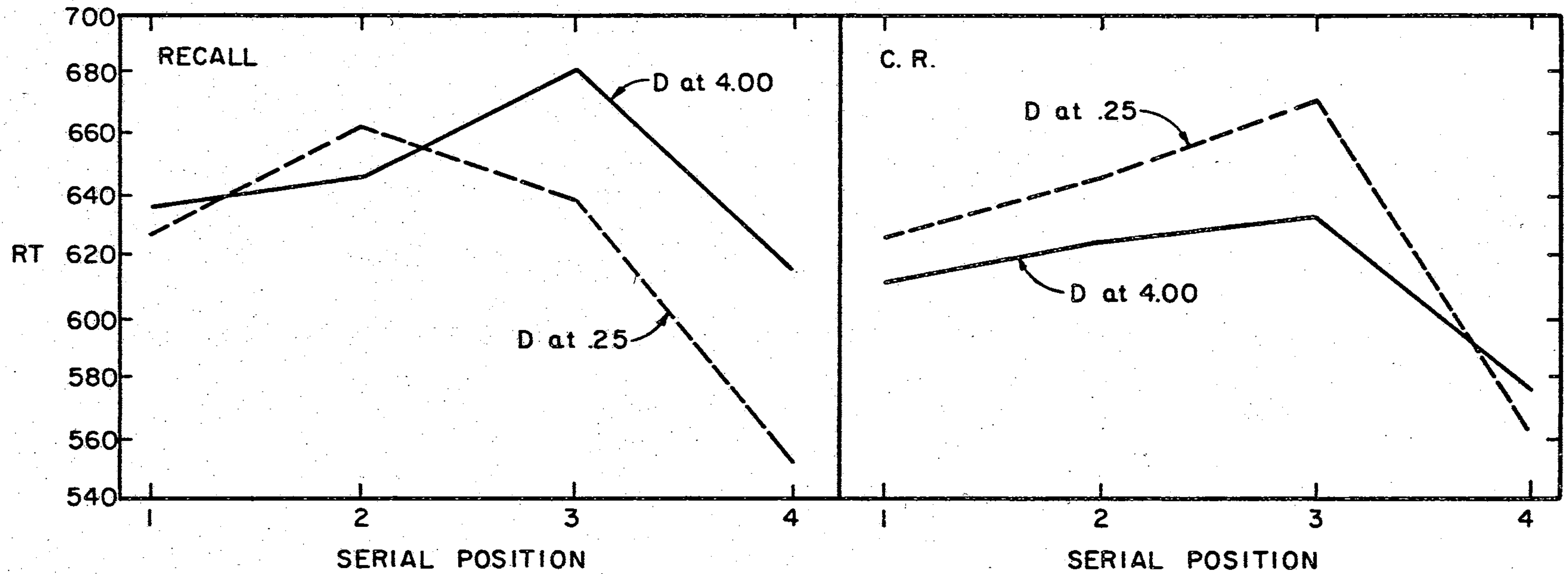

Figure 6. Relationship of Recall and Confidence Rating Data at Each Level of Delay to Serial Positions in Set Size 4

Inspection of this figure indicates a strong recency effect for all the curves. This effect appears to be reduced at the long delay period but the statistical analysis did not strongly support this suggestion. The DxSP interaction attained a level of approximately .08.

Set Size 5

As in the preceeding analysis, the main effect of serial position was the only effect to reach significance in the analysis of set size 5 data (Table IX). These data are plotted in the same way as those for set sizes 3 and 4 (Fig. 7).

As with the set size 4 data, these curves exhibit a strong tendency for recency effects.

Other Within-Set Comparisons

One of the objectives of this study was to determine the effect of rehearsal on the memory search process. The ambiguity of the results so far suggests that another approach to this question is needed. One such approach would be to test the extreme conditions of rehearsal, i.e., the .25-.25 conditions and the 1.00-4.00 conditions, for any systematic effects on RT. These conditions are plotted as Figure 8.

This figure demonstrates that, in general, the RT curves tend to be flattest when over-all rehearsal time is maximized (the 1.00-4.00 curves) and most bowed when rehearsal time is minimized (the .25-.25 curves). In order to test these extreme conditions a series of analyses were performed with recall method (R), and total rehearsal time (T) as between Ss factors, and serial position (SP) as a within Ss factor.

Analysis of the set size 3 data revealed a significant main effect of SP and of the TxRxSP interaction (Table X). Inspection of Figure 8 reveals rela-

TABLE IX

ANALYSIS-OF-VARIANCE OF SET SIZE 5

Source	df	SS	MS	F
Between-Ss	95	19.827		
I	1	.243	.243	1.146
D	1	.033	.033	<1
R	1	.134	.134	<1
ID	1	.644	.644	3.038
IR	1	.017	.017	<1
DR	1	.005	.005	<1
IDR	1	.099	.099	<1
Error	88	18.652	.212	
Within-Ss	384	3.421		
SP	4	.285	.071	8.875**
IxSP	4	.005	.001	<1
DxSP	4	.063	.013	1.625
RxSP	4	.023	.006	<1
IxDxSP	4	.001	.000	<1
IxRxSP	4	.020	.005	<1
DxRxSP	4	.041	.010	1.250
IxDxRxSP	4	.111	.0278	3.475
Error	352	2.872	.008	

NOTE: ** indicates p<.01.

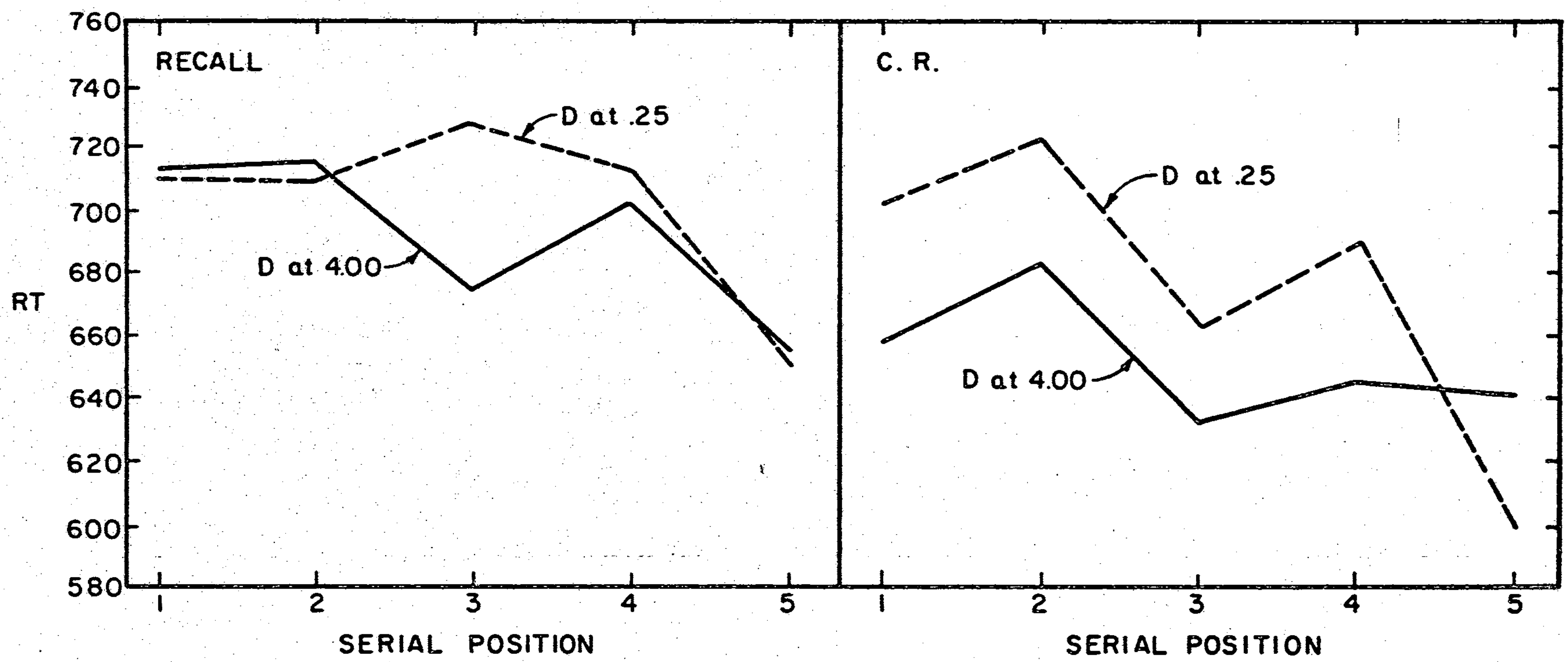

Figure 7. Relationship of Recall and Confidence Rating Data at Each Level of Delay to Serial Positions in Set Size 5

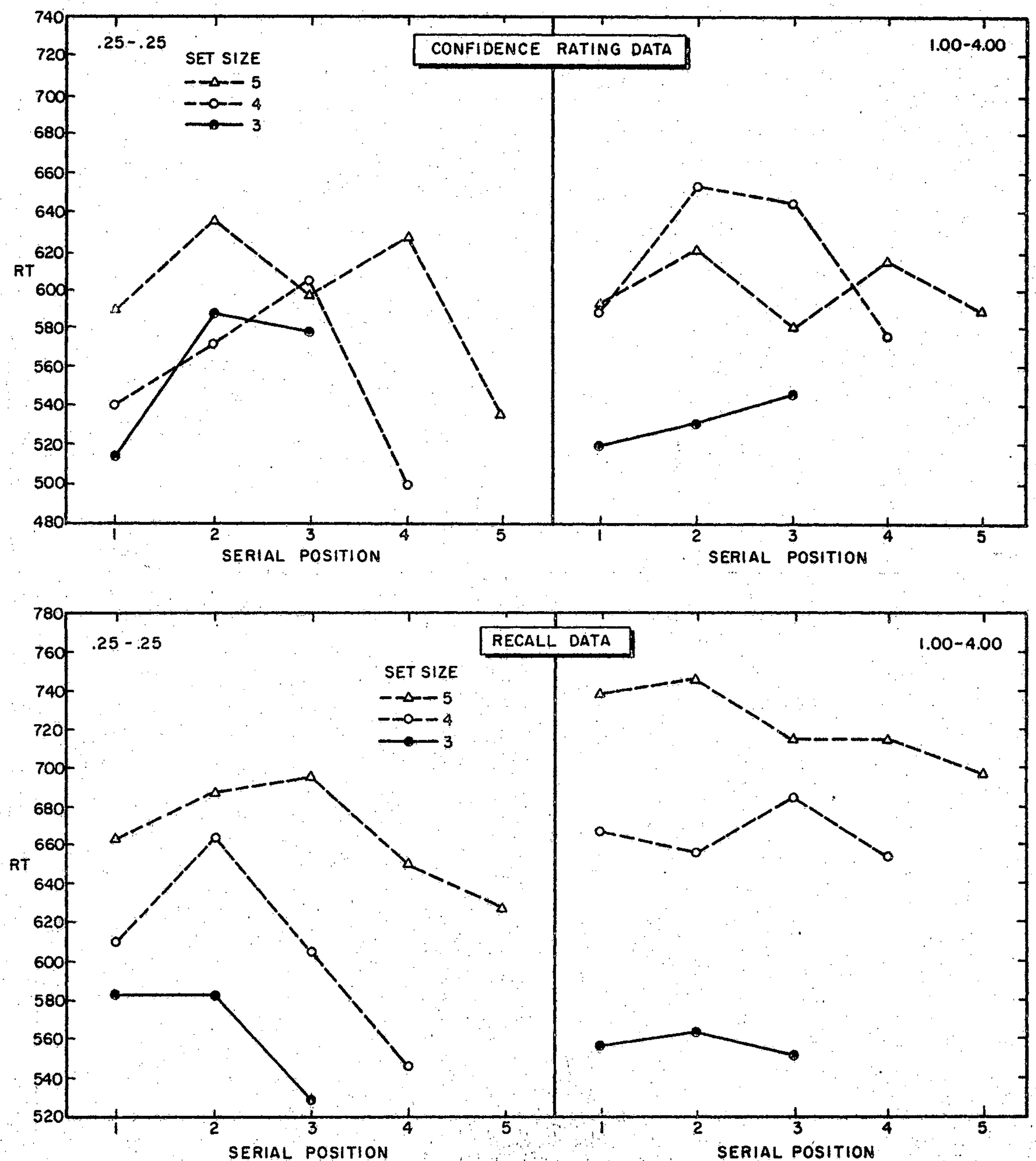

Figure 8. RT at Each Serial Position for Recall and Confidence Rating Subjects at the .25-.25 and 1.00-4.00 Levels

TABLE X

ANALYSIS-OF-VARIANCE OF SET SIZE 3 DATA AT .25-.25 AND 1.0-4.0 LEVELS

Source	df	SS	MS	F
Between-Ss	47	2.726		
T	1	.001	.001	<1
R	1	.055	.055	<1
TxR	1	.038	.038	<1
Error	44	2.632	.059	
Within-Ss	96	.509		
SP	2	.041	.022	4.50**
TxSP	2	.007	.004	<1
RxSP	2	.012	.006	1.200
TxRxSP	2	.041	.022	4.50**
Error	88	.408	.005	

NOTE: ** indicates $p < .01$.

tively flat curves for the 1.00-4.00 condition and different shape serial position curves for the .25-.25 conditions. Subanalyses on the data at each level of the T variable confirmed these observations: A significant RxSP interaction emerged only in the data with a .25-.25 presentation time. These subanalyses are presented as Tables XI and XII. This significant interaction reflects the strong recency effect in the recall curve as opposed to the primacy effect in the confidence rating curve.

In line with the rationale for this analysis, it was hoped that a significant TxSP interaction would emerge from subanalyses performed at each level of R. Such results, however, were not found.

The analysis of set size 4 and 5 data provided little support for a hypo-

TABLE XI

ANALYSIS-OF-VARIANCE OF SET SIZE 3; .25-.25 LEVEL

Source	df	SS	MS	F
Between-Ss	23	1.672		
R	1	.001	.001	<1
Error	22	1.671	.076	
Within-Ss	48	.284		
SP	2	.026	.013	3.250
RxSP	2	.039	.020	5.00**
Error	44	.219	.004	

NOTE: ** indicates $p < .01$.

TABLE XII

ANALYSIS-OF-VARIANCE OF SET SIZE 3; 1.0-4.0 LEVEL

Source	df	SS	MS	F
Between-Ss	23	1.054		
R	1	.093	.093	2.163
Error	22	.961	.043	
Within-Ss	48	.225		
SP	2	.022	.011	2.750
RxSP	2	.012	.006	1.500
Error	44	.191	.004	

thesis of rehearsal effects on search processes. Only a significant main effect of serial position was found in each analysis (Tables XIII and XIV). This lack of significant results conforms to earlier findings with these sets.

TABLE XIII

ANALYSIS-OF-VARIANCE OF SET SIZE 4; .25-.25 AND 1.0-4.0 LEVELS

Source	df	SS	MS	F
Between-Ss	47	3.974		
T	1	.185	.185	2.202
R	1	.093	.093	1.107
TxR	1	.002	.002	<1
Error	44	3.694	.084	
Within Ss	144	1.190		
SP	3	.149	.050	7.143**
TxSP	3	.026	.013	1.857
RxSP	3	.017	.006	<1
TxRxSP	3	.034	.011	1.571
Error	132	.964	.007	

NOTE: ** indicates $p < .01$.

TABLE XIV

ANALYSIS-OF-VARIANCE OF SET SIZE 5; .25-.25 AND 1.0-4.0 LEVELS

Source	df	SS	MS	F
Between-Ss	47	8.790		
T	1	.068	.068	<1
R	1	.451	.451	2.412
TxR	1	.034	.034	<1
Error	44	8.237	.187	
Within-Ss	192	1.263		
SP	4	.128	.032	5.333**
TxSP	4	.033	.008	1.333
RxSP	4	.058	.014	2.333
TxRxSP	4	.040	.010	1.667
Error	176	1.004	.006	

NOTE: ** indicates $p < .01$.

Analysis of Recall Data and Confidence Ratings

Recall errors consisted of failures to recall a digit or the production of a digit not in the list. Item position was not considered in scoring.

There were approximately 2.9% total recall errors throughout the experiment. Sternberg (1969) has reported that total recall errors stay close to this minimal level until lists of 6 and 7 items are utilized. The lack of a large number of recall errors provides strong evidence that the task was well within the memory capacity of the subjects.

Of the 48 Ss making confidence ratings, only 5 indicated intermediate levels of confidence in their decisions. That is, 43 of the Ss used only the "1" and "5" categories on the rating sheets. This result indicates that Ss had a very high level of confidence in the correctness or incorrectness of their decisions. This finding may be taken as additional evidence that the task was well within the memory capabilities of the subjects.

CHAPTER IV

DISCUSSION

Recall and Confidence Rating Data

The low number of recall errors, together with consistently high confidence ratings, indicate that forgetting played a minimal role in this experiment. This very high degree of retention is similar to that reported by other investigators (e.g., Sternberg, 1966) and seems essential to a study concerned with the nature of memory search.

Between-Set Data

These data were consistent with a serial and exhaustive model of memory search (i.e., Sternberg, 1966). With the data collapsed over all variables but set size, RT was clearly a linear function of set size with an average search rate of about 19 items/second. While such a finding is not sufficient to establish the serial-exhaustive model, it is certainly compatible with one.

One potentially troublesome finding for this model was the fact that RT to negative probes was significantly slower than that to positive probes. This difference could be attributed, however, to some processes other than search. Regression lines plotted for the RT curves for each probe type revealed identical search rates in both situations. The difference in the Y-intercept for both lines (about 21 msec.) appears to be a little understood but common finding (Sternberg, 1969).

Performance differences produced by the post-decision task appeared in the context of a significant interaction in the confidence rating data. RT for recall Ss was significantly influenced only by set size. One explanation for this result is that the addition of the recall task forced Ss to treat the materials in a similar fashion regardless of other experimental variables. For example, the recall task may have forced Ss to encode all items in a similar fashion and/or in a similar abstracted form (Posner, Boies, Eichelman, and Taylor, 1969). These suggestions are tentative at best and much further research is required before definitive interpretations of this result are possible.

RT for the confidence rating Ss, on the other hand, appeared to be a function of the total amount of rehearsal time allowed. Fastest RTs were associated with those conditions where rehearsal time was minimized (.25-.25) or maximized (1.00-4.00). Although any attempt to explain this finding is admittedly post-hoc, one rather intriguing hypothesis can be derived from a two state conception of memory.

Because very little rehearsal time was allowed items in the .25-.25 condition, fast RTs would have been the result of a search of items already in primary memory (PM) when the probe appeared. The correspondingly fast times in the 1.00-4.00 condition would seem to imply that these items were processed in a similar fashion. This similarity could have arisen from one of at least two different possibilities. (1) The search of 1.00-4.00 items could have been conducted in secondary memory (SM) and, hence, would seem to indicated a similar search process in both PM and SM. Or (2) the items may have been transferred to PM before they were searched. Although little work has yet been done concerning these alternatives, recent data and theoretical notions (Sternberg, et al., 1969; Klatzky and Atkinson, 1969), as well as introspective evidence, would seem to recommend the second possibility. The explanation suggested is that enough time was allowed in the 1.00-4.00 condition for the encoding of stimuli into SM and the transferrence of a representation of them back into PM before the probe appeared. The fact that intermediate amounts of rehearsal time led to slower RTs would seem to follow rather directly from this suggestion. Enough time was allowed in these procedures for the rehearsal of the items only; when the probe appeared, a representation of the stimuli had to be transferred to PM before S could make his response.

This type of theorizing serves a function more nearly heuristic than explanatory. Other possible ways of "explaining" the data are not difficult to generate. An interesting sidelight to these results, however, is the difficulty they present for a single state model of memory (cf: Melton, 1963; Bernbach, 1970). One example of this difficulty is that single state models generally assume that the function of rehearsal is to strengthen the memory trace of an item. According to this scheme, then, RT for confidence rating Ss was fastest to the "weakest" and "strongest" traces simultaneously.

The fact that any interpretation of this data is hazardous should not, however, obscure the importance of at least two general statements that do seem warranted. First, the nature of the task required after the decision response has an effect on what S does before he responds. And, secondly, these effects are manifested through S's use of his rehearsal time. Both total rehearsal time available and the nature of the post-decision task have been shown to be important in the above data.

Within-Set Data

Because these findings seem to vary with set size, a discussion of individuals set size results seems necessary before any more general comments can be made.

The data from set size 3 provides perhaps the clearest example of the effect of a delay period before the probe. Considering the recall data only, the effect of forcing S to rehearse (i.e., introducing the delay) was to produce a strong primacy effect in the serial position curve. Without this delay, a strong recency effect was evident.

One way of interpreting a serial position curve is to suggest that the material is located partially in PM and partially in SM (e.g., Glanzer and Cunitz, 1966; Craik, 1970). Thus, if search is conducted in PM (as has been suggested, i.e., Sternberg, 1969) then unequal RTs are produced because certain material must be transferred to PM before a complete search may be conducted. Fastest RTs would be accorded those items already in PM when the probe appeared. Hence, a recency effect would seem to result when rehearsal of the last item was not allowed or was severely restricted thereby preventing its transfer to SM. Early list items would be provided some rehearsal time while the list was being presented (Aaronson, 1967) and could conceivably be encoded into SM during this period.

The fact that a primacy effect is produced when a delay is introduced before the probe would follow from this explanation if one additional assumption is allowed. This assumption states that items are transferred from SM to PM in serial order, e.g., the first item, then the second item, etc. A strong primacy effect would seem to result from this serial transfer notion (Sternberg, et al., 1969). An interesting implication of this argument is that the search process which would produce these results would be self-terminating.

Some evidence for these suggestions is provided by appropriate comparisons from the left panel of Fig. 5. Here it is observed that RT is very similar for those items which were presumably in PM when the probe appeared (i.e., item 1 with D at the 4 second level and item 3 with D at the .25 second level.) The difference between these points is only 2 msec. Similarly, there is a very small difference (9 msec.) between item 3 in the 4 second curve and item 1 in the .25 second curve. Both of these items were presumably in SM when the probe appeared.

The lack of a serial position curve in the confidence rating data is difficult to interpret. One possible explanation is that the rehearsal strategy may be less consistent over Ss when recall is not demanded than when it is a necessity. When recall is not required it may be that some Ss transfer the material and others do not. No clear cut effects would, thus, appear in the data.

Analysis of the data from set sizes 4 and 5 did not conform to the pattern of results found for set size 3. A reinspection of Figures 6 and 7 indicates a tendency for strong recency and weak primacy effects in these data.

A central task of this discussion is to suggest why these results did not complement those for set size 3. Unfortunately, the available literature on this point is not very helpful. The one study which reported both between- and within-set data (Sternberg, et al., 1969) found relatively flat serial position curves for set sizes of 2, 3, and 4.

Possible explanations for these results are provided by an examination of data from other areas of research. Bower and Winzenz (1969) have noted that a basic strategy employed in the learning of an arbitrary series of symbols is to segment or group successive items into chunks. The chunks are small (2-4 items) and, according to Bower and Winzenz, facilitate the learning of lists as small as 4 and 5 items.

Because of the small number of recall errors there is no clear way to detect from these data whether or not Ss were using a chunking strategy with set sizes 4 and 5. However, the power of this technique for aiding memory (i.e., Miller, 1966) and the verbal reports of Ss in this and a similar study (Clark, 1970) strongly suggest that at least some Ss were utilizing a chunking strategy. Indeed, one explanation for the observed results is that Ss were encoding a chunked form of the first few list items into SM and maintaining the last items in PM. A recency effect would be produced by the necessity to retrieve the first items from SM before they could be searched.

Another suggestion concerning the puzzling results of this experiment is supplied by a consideration of the power of the statistical tests utilized. Considerations of power are of concern because of the high degree of variability typically associated with RT data (Woodworth and Schlosberg, 1954). Of the many ways available for increasing power (e.g., Kirk, 1969; Winer, 1962) most investigators choose to increase the number of observations in the experiment and/or use well-practiced subjects. For example, Sternberg typically used each of his subjects over many experimental sessions; Morin, DeRosa and Stultz (1967) utilized a very large number of subjects for one session each.

Evidence that this experiment suffered from "weak" statistical tests is provided by Figure 8. This figure strongly suggests that the serial position curves were considerably flatter for the 1.00-4.00 conditions than for the .25-.25 conditions. Appropriate analyses failed, however, to detect these effects. Enough similar examples could be presented to suggest that this study could be improved by the addition of more and/or less variable data.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this experiment was to study certain temporal and task variables in regard to their effects on memory search. Subjects were shown varying size lists of digits. At a predetermined interval following the last item another digit was presented and the subject indicated whether or not this digit was a member of the previous list. Latency of response was the dependent variable of main interest. The opportunity for rehearsal of the list as well as the necessity for rehearsal were manipulated in various conditions of the experiment. An additional variable was the presence or absence of a requirement to recall the list.

The point does seem well made by the data that the memory search process is sensitive to various experimental factors. While specificity does not seem warranted until more conclusive data are presented, it does seem that rehearsal processes act to influence the nature of the search. Not only the amount of time available for rehearsal but the presence or absence of a requirement to rehearse were shown to produce performance differences.

At least two other aspects of the results would seem to benefit from further study. (1) A further examination of the performance differences produced by a requirement to recall or not recall would be of empirical as well as theoretical interest. It was suggested in this paper that subjects utilize different rehearsal strategies depending upon the presence or absence of a recall requirement and that there is less variability in the nature of this strategy when recall is required. And (2), it would be very desirable to know more about the nature of the transfer process from SM to PM. For example, what are the temporal characteristics of the process? Does it proceed in a serial fashion? Is it sensitive to characteristics of the item, etc.? Very little empirical data exist on this potentially important theoretical point.

One significant aspect of this study was the demonstration that much important data is lost if both between- and within-set analyses are not performed. Most studies (e.g., Sternberg, 1969; Moss and Sharac, 1970; etc.) have tended to ignore this fact. In the present study no evidence against a serial-exhaustive conception of search was gleaned from the analysis of between-set data. Most within-set effects, on the other hand, were adequately described as serial position curves with either marked recency or primacy effects. Such contradictory evidence concerning the serial-exhaustive model suggests that a more thorough analysis of this theory is needed.

BIBLIOGRAPHY

Aaronson, D. Temporal factors in perception and short-term memory. *Psychological Bulletin*, 1967, *67*(2), 130-144.

Atkinson, R. C. & R. M. Shiffrin. Human memory: A proposed system and its control processes. In K. W. Spence and J. T. Spence (Eds.), *The psychology of learning and motivation: Advances in research and theory*. Vol. II. New York: Academic Press, 1968. pp 89-195.

Bernbach, H. S. Replication processes in human memory and learning. In J. T. Spence and G. H. Bower (Eds.), *The psychology of learning and motivation: Advances in research and theory*. Vol. III. New York: Academic Press, 1970. pp 201-239.

Bower, G. H. & D. Winzenz. Group structure, coding, and memory for digit series. *Journal of Experimental Psychology*, 1969, 80, (Monogr. Suppl. 2, Part 2).

Briggs, G. E. & J. M. Swanson. Retrieval time as a function of memory ensemble size. *Quarterly Journal of Experimental Psychology*, 1969, *21*, 185-191.

Chase, W. G. & W. G. Calfee. Modality and similarity effects in short-term recognition memory. *Journal of Experimental Psychology*, 1969, *81*, 510-514.

Chomsky, N. *Syntactic structures*. The Hague: Mouton & Co., 1957.

Clark, W. R. Pupillographic study of short-term memory search. Unpublished doctoral dissertation, Oklahoma State University, 1970.

Corballis, M. C. Serial order in recognition and recall. *Journal of Experimental Psychology*, 1967, *74*, 99-105.

Craik, F. I. M. The fate of primary memory items in free recall. *Journal of Verbal Learning and Verbal Behavior*, 1970, *9*, 143-148.

DeRosa, D. V. & R. E. Morin. Recognition reaction time for digits in consecutive and nonconsecutive memorized sets. *Journal of Experimental Psychology*, 1970, *83* (3), 472-479.

Geisser, S. & S. W. Greenhouse. An extension of Box's results on the use of the *F* distribution in multivariate analysis. *Annals of Mathematical Statistics*, 1958, *29*, 885-891.

Glanzer, M. & A. R. Cunitz. Two storage mechanisms in free recall: Journal of Verbal Learning and Verbal Behavior, 1966, 5, 351-360.

James, W. The principles of psychology. Vol. I New York: Holt, 1890.

Kennedy, R. A. & R. Hamilton. Time to locate probe items in short lists of digits. American Journal of Psychology, 1969, 82, 272-275.

Kennedy, R. A. & A. L. Wilkes. Response times at different positions within a sentence. Quarterly Journal of Experimental Psychology, 1968, 20, 390-394.

Kirk, R. E. Experimental design: Procedures for the behavior sciences. Belmont, Calif.: Brooks/Cole, 1969.

Landauer, T. K. Rate of implicit speech. Perceptual and Motor Skills, 1962, 15, 646.

Martin, E. Stimulus recognition in aural paired-associate learning. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 272-276.

Martin, E. Stimulus meaningfulness and paired-associate transfer: An encoding variability hypothesis. Psychological Review, 1968, 75, 421-441.

Mechanic, A. The distribution of recalled items in simultaneous intentional and incidental learning. Journal of Experimental Psychology, 1962, 63, 593-600.

Melton, A. W. Implications of short-term memory for a general theory of memory. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 1-21.

Miller, G. A. The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review, 1956, 63, 81-97.

Miller, G. A. Information and memory. Scientific American, 1966, 195, 42-46.

Morin, R., D. DeRosa & V. Stultz. Recognition memory and reaction time. Acta Psychologica, 1967, 27, 298-305.

Morin, R., D. DeRosa & R. Ulm. Short-term recognition memory for spatially isolated items. Psychonomic Science, 1967, 9 (12), 617-618.

Moss, S. M. & J. Sharac. Accuracy and latency in short-term memory: Evidence for a dual retrieval process. Journal of Experimental Psychology, 1970, 84(1), 40-46.

Norman, D. A. (Ed.) Models of human memory. New York: Academic Press, 1970.

Posner, M. I., S. J. Boies, W. H. Eichelman & R. L. Taylor. Retention of visual and name codes of single letters. Journal of Experimental Psychology, 1969, 79, (Monogr. Suppl. 1, Part 2).

Postman, L. & P. A. Adams. Studies in incidental learning: IV. The interaction of orienting tasks and stimulus materials. Journal of Experimental Psychology, 1956, 51, 329-333.

Rundus, D. & R. C. Atkinson. Rehearsal processes in free recall: A procedure for direct observation. Technical Report No. 149, Institute for Mathematical Studies in the Social Sciences, Stanford University, 1969.

Shiffrin, R. M. Memory search. In D. A. Norman (Ed.), Models of human memory. New York: Academic Press, 1970, pp 375-447.

Shiffrin, R. M. & R. C. Atkinson. Storage and retrieval processes in long-term memory. Psychological Review, 1969, 76, 179-193.

Sperling, G. & R. G. Speelman. Acoustic similarity and auditory short-term memory: Experiments and a model. In D. Z. Norman, (Ed.), Models of human memory. New York: Academic Press, 1970. pp 151-202.

Stanners, R. F. & G. F. Meunier. Pronounciability and rehearsal time in short-term memory with controlled acquisition. Journal of Experimental Psychology, 1969, 80(2), 359-363.

Stanners, R. F., G. F. Meunier & D. B. Headley. Reaction time as an index of rehearsal in short-term memory. Journal of Experimental Psychology, 1969, 82(3), 566-570.

Sternberg, S. Retrieval from recent memory: Some reaction-time experiments and a search theory. Paper presented to Psychonomic Society, Bryn Mawr, 1963.

Sternberg, S. High-speed scanning in human memory. Science, 1966, 153, 652-654.

Sternberg, S. Two operations in character-recognition: Some evidence from reaction-time measurements. Perception and Psychophysics, 1967, 2, 45-53.

Sternberg, S. Memory-scanning: Mental processes revealed by reaction-time experiments. American Scientist, 1969, 57(4), 421-457.

Sternberg, S., R. L. Knoll, & B. A. Nasto. Retrieval from long-term versus active memory. Paper presented to Psychonomic Society, St. Louis, 1969. (a)

Waugh, N. E. & D. A. Norman. Primary memory. Psychological Review, 1965, 72, 89-104.

Weber, R. J. & M. Bach. Visual and speech imagery. British Journal of Psychology, 1969, 60, 199-202.

Weber, R. J. & J. Blagowsky. Metered memory search with implicit and explicit scanning. Journal of Experimental Psychology, 1970, 84, 343-348.

Weber, R. J. & J. Castleman. Metered memory search. Psychonomic Science, 1969, 16(6), 311-312.

Weber, R. J., M. Cross & M. Carlton. Searching circular sequences. Journal of Experimental Psychology, 1968, 78, 588-592.

Winer, B. J. Statistical principles in experimental design. New York: McGraw-Hill, 1962.

Woodworth, R. S. & H. Schlosberg. Experimental psychology. (Rev. ed.) New York: Holt, Rinehart and Winston, 1954.

Yntema, D. B. & F. P. Trask. Recall as a search process. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 65-74.

VITA

Gary Francis Meunier

Candidate for the Degree of

Doctor of Philosophy

Thesis: MEMORY SEARCH AND REHEARSAL

Major Field: Psychology

Biographical:

Personal Data: Born in Indianapolis, Indiana, May 14, 1943, the son of Mr. and Mrs. Francis Meunier.

Education: Graduated from Warren Central High School, Indianapolis, Indiana, in May, 1961; received the Bachelor of Arts degree from Butler University, Indianapolis, Indiana, in 1965, with a major in Political Science; attended Butler University and Purdue University in 1966; received the Master of Science degree from Oklahoma State University in 1968, as a National Defense Education Act Fellow, with a major in Psychology; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in July, 1970.

Professional Experience: Served as a National Defense Education Act Fellow at Oklahoma State University, 1966-1969; served as Instructor of Psychology at Oklahoma State University during the academic year 1969-1970; am employed as Assistant Professor of Psychology at Ball State University, Muncie, Indiana.