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ABSTRACT

This research project investigated some of the characteristics of primary and secondary memory. In the primary research, subjects were given a list of words followed by an interpolated task. The data of interest were the recall for terminal items in the list. Using this procedure, the researchers have demonstrated negative recency in initial recall and have provided evidence that this effect is attributable to store-specific interference in primary memory. They have also demonstrated that this effect is a necessary consequence of the procedure rather than the result of a strategy on the part of the subject. In the secondary memory research, interest was focused on procedures in which subjects learned categorized lists. It was demonstrated that subjects learned how to cluster over successive lists and that this effect probably resulted from an increase in the post-item latency used as a criterion to exit a category and search another during recall. It has also been demonstrated that ability to recall is correlated with amount of clustering. Another set of results came from experiments demonstrating that repeated-category interference can be eliminated through the use of subcategorization or adjectival modification. (WR)

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A Study of Retention of Verbal Material

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A study of retention of verbal material

Summary

Research in our laboratory under this grant has been primarily concerned with storage and retrieval from secondary memory. However, as we have become increasingly convinced that a distinction between primary and secondary memory is both necessary and desirable, we have been led to investigate some of the characteristics of primary memory. In the primary memory research, we have adopted the strategy of giving Ss a list of words followed by an interpolated task. The data of interest are the recall for terminal items in the list. Using this procedure, we have demonstrated negative recency in initial recall and provided evidence that this effect is attributable to store-specific interference in primary memory. We have also demonstrated that this effect is a necessary consequence of the procedure rather than the result of a strategy on the part of the subject.

In our secondary memory research, we have relied heavily on procedures in which Ss learn categorized lists. We have been able to demonstrate that Ss learn how to cluster over successive lists and that this effect probably results from an increase in the post-item latency used as a criterion to exit a category and search another during recall. We have also been able to demonstrate that ability to recall is correlated with amount of clustering. The most important set of results come from the experiments demonstrating that repeated-category interference can be eliminated or minimized through the use of subcategorization or adjectival modification. These results strongly suggest that encoding in memory is on the basis of some sort of "tagging" of the attributes of the items. Finally, in a study unrelated to our main line of research, we demonstrated that the relationship between probability of recall and output order in recall is curvilinear.

Organizational note.

For the convenience of the reader, the introduction, method and results, and conclusion sections will be presented separately for the primary memory and secondary memory research. Further, since the research program consists of a series of small studies, these will be presented separately with background, method, results, and conclusion sections for each. Finally, let me note that the analysis of variance was the statistical tool used throughout these experiments. In the interest of clarity, no statistical analyses are presented and, unless otherwise stated, all differences cited are reliable statistically.

Primary memory research

Background

The serial position curve in free recall is a root phenomenon underlying many recent models of memory (e.g., Waugh & Norman, 1965; Atkinson & Shiffrin, 1968; Norman & Rumelhart, 1970). Removal of the recency portion of the curve through the introduction of an interpolated task (e.g., Postman & Phillips, 1965; Glanzer & Cunitz, 1966) remains the most convincing demonstration that there are (at least) two processes in memory and manipulation of the primacy effect (e.g., Bruce & Papay, 1970) provides suggestive evidence favoring the hypothesis that one of these processes has a limited capacity. Recently, the demonstration that the final free recall of a series of lists--initially recalled immediately--produces a clear negative recency effect (e.g., Craik, 1970) also provides strong support for two-process models. The initial recall shows the usual (positive) recency efffect--a systematic increase in probability of recall for terminal to-be-remembered (TBR) items with the last TBR item showing the greatest increase. The subsequent negative recency (a systematic decrease in probability of recall for terminal TBR items) suggests strongly that the processing of TBR items in secondary memory is interrupted by the initial recall or, as suggested by the most recent evidence (Jacoby & Bartz, 1972), as the result of a deliberate strategy on the part of the subject.

While the variation in the serial position curve observed under different conditions of free recall has provided substantial support for two-process models of memory, there is one clear prediction which, somewhat surprisingly, has not yet been confirmed in the literature. Specifically, one ought to be able to produce rather substantial negative recency effects in initial recall following an interpolated task. The prediction may be outlined as follows: Two-process theories typically assume that primary memory is a limited-capacity system. Each item is automatically entered into this system upon its perception. Entry into secondary memory is not automatic but involves processing of items in primary memory. This processing takes time so that, other things being equal, the amount or degree of processing depends upon how long an item remains in primary memory. With those basic assumptions in mind, note that immediately after the presentation of the final item in the list, the last few items in the list will not, on average, have been in primary memory as long as other items in the list. The last item will have spent the least time in primary memory, the next-last the next-least time--and so on back for several items. Therefore, if the processing of items is terminated at that point in time, one would have to predict a negative recency effect in recall from secondary memory. The most obvious way to achieve this predicted effect is to introduce a task following list presentation which prevents additional processing of list items. There are two alternative views regarding the necessary characteristics of a task to accomplish this purpose. Most theorists (e.g., Waugh & Norman, 1965; Atkinson & Shiffrin, 1968) assume that processing is active and would argue that the task must prevent rehearsal. An alternative view would be that processing is passive (and parallel) and that, therefore, the task must produce very rapid--preferably immediate--replacement of the items in primary memory.

It should be clear that a negative recency effect would be predicted given a sufficiently rapid and/or difficult interpolated task. In fact, although interpolated tasks covering a fair range of rate and difficulty have been used, there exists no convincing demonstration of negative recency during initial recall following an interpolated task. Most studies using an interpolated task show no suggestion of such an effect (Postman & Phillips, 1965; Glanzer & Cunitz, 1966; Raymond, 1969; Bruce & Crowley, 1970). There are some published data which show a reduction in recall restricted to the last position (Glanzer, Gianutsos, & Dubin, 1969) but negative recency should increase systematically over terminal positions, reaching a maximum on the last position. Thus far, a systematic negative recency effect extending over several terminal positions has been demonstrated only in the final free recall paradigm (Craik, 1970; Craik, Gardiner, & Watkins, 1970; Rundus, Loftus, & Atkinson, 1970; Madigan & McCabe, 1971; McCabe & Madigan, 1971; Darley & Murdock, 1971; Jacoby & Bartz, 1972). Finally, it must be noted that there are a large number of free-recall experiments using a filled-delay procedure which present no serial position curves and whose outcome regarding the phenomenon of interest here is therefore unknown. These experiments are, of necessity, ignored in this discussion.

Experiment I: Demonstration of negative recency in initial recall.

Introduction and method--Our interest in the characteristics of primary memory began with the serendipitous production of negative recency in initial recall. In that study, twenty-five subjects each received a unique set of ten lists of high-frequency words. Free recall of each list followed a 30-second filled delay. The interpolated task was shadowing single digits presented orally at the rate of two each second. The list items were also presented orally at the rate of one every 2.5 seconds. The results are shown in Figure 1.

Results and discussion--As can be seen, there is a clear (and reliable, $p < .001$) negative recency effect. Our immediate reaction was that our interpolated task was faster, and probably more difficult, than the interpolated tasks in previous experiments--and that either the rate or the difficulty of the task produced the negative recency effect in these data. However, since all subjects were treated identically on all lists, it is also possible that the results reflect an encoding strategy that subjects use when faced with this particular interpolated task.

Experiment II: Negative recency without differential encoding.

Introduction and method--The next study, then, had two purposes. First, the experiment was designed to prevent differential encoding of list items. That was accomplished by using several conditions with the recall condition designated *following* presentation of each list. Second, the study was designed to demonstrate that, when the possibility for differential encoding is eliminated, differences between recall following our shadowing task and recall following the usual counting task will still occur. That is, both tasks should reduce recall of terminal items but only the shadowing task should produce negative recency.

Fifty subjects served in the second experiment. The lists, the conditions of list presentation, and the shadowing task were the same as in the previous experiment. In this study, however, each subject recalled five lists under each of the following three conditions: immediate recall, recall following shadowing for 30 seconds, or recall following counting for 30 seconds. The counting task was counting backwards by three's from an orally presented

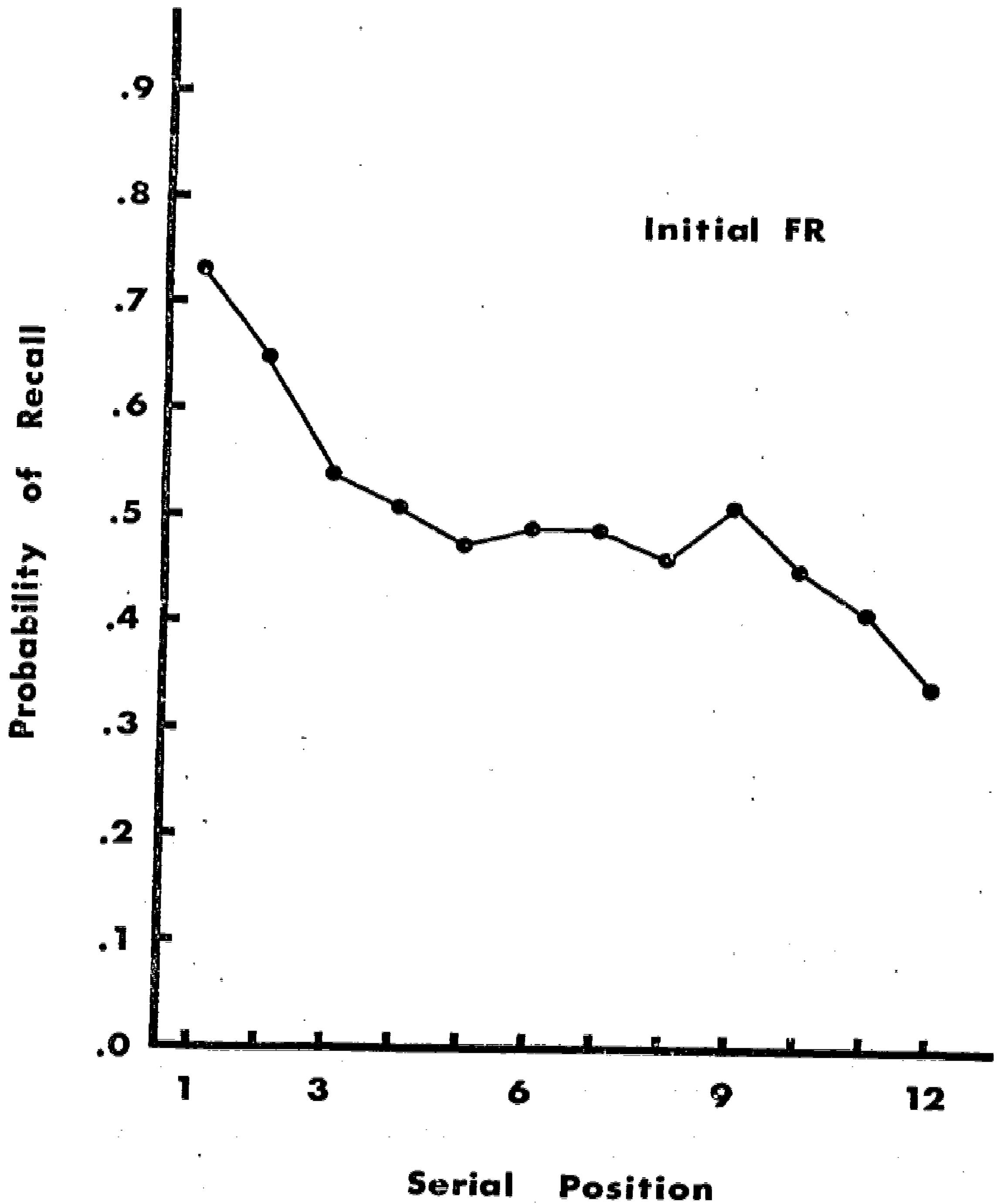

Figure 1. Probability of recall by serial position following interpolated shadowing.

3-digit number at a rate of one count per second. Following presentation of each list, subjects were instructed to either "recall," "count," or "shadow." The results of this study are shown in Figure 2.

Results and discussion--As can be seen, the expected difference between the shadowing and counting conditions was confirmed ($p < .01$). Shadowing produces a greater decrement in recall of terminal items than does the counting procedure. What was not expected was that both interpolated tasks produced negative recency ($p < .001$). As noted earlier, other experiments using the same sort of counting interpolated task have not produced negative recency in initial recall. Obviously, the critical difference between those results and these data cannot be the rate or difficulty of the interpolated task. Some other factor must be involved.

Experiment III: Store-specific interference and negative recency.

Introduction--At this point, the obvious difference between our study and previous similar experiments was in the mode of presentation as all other (critical) experiments had used visual presentation. It seemed likely that, at the procedural level, there is an interaction between the interpolated task and the mode of presentation. At the theoretical level, our hypothesis was that the interpolated task was producing interference which was, to some degree, store-specific. The first prediction, then, was that the counting procedure would produce negative recency when presentation was auditory but not when presentation was visual. It occurred to us that we ought to be able to reverse that large interference effect by using an interpolated task with a large visual component (e.g., copying series of numbers). That is, we might be able to produce negative recency with visual but not auditory presentation. We introduced a copying interpolated task to test this second hypothesis.

Method--In this study, each of sixty-four subjects received a set of thirty lists of high-frequency words. Half the lists were presented orally, and half visually, at a rate of one item every two seconds. Within each modality of presentation, each subject recalled five lists under each of the following three conditions: immediate recall, recall following counting for 30 seconds, or recall following copying for 30 seconds. The counting task was the same as in the second experiment. The copying task was attempting to copy as many digits

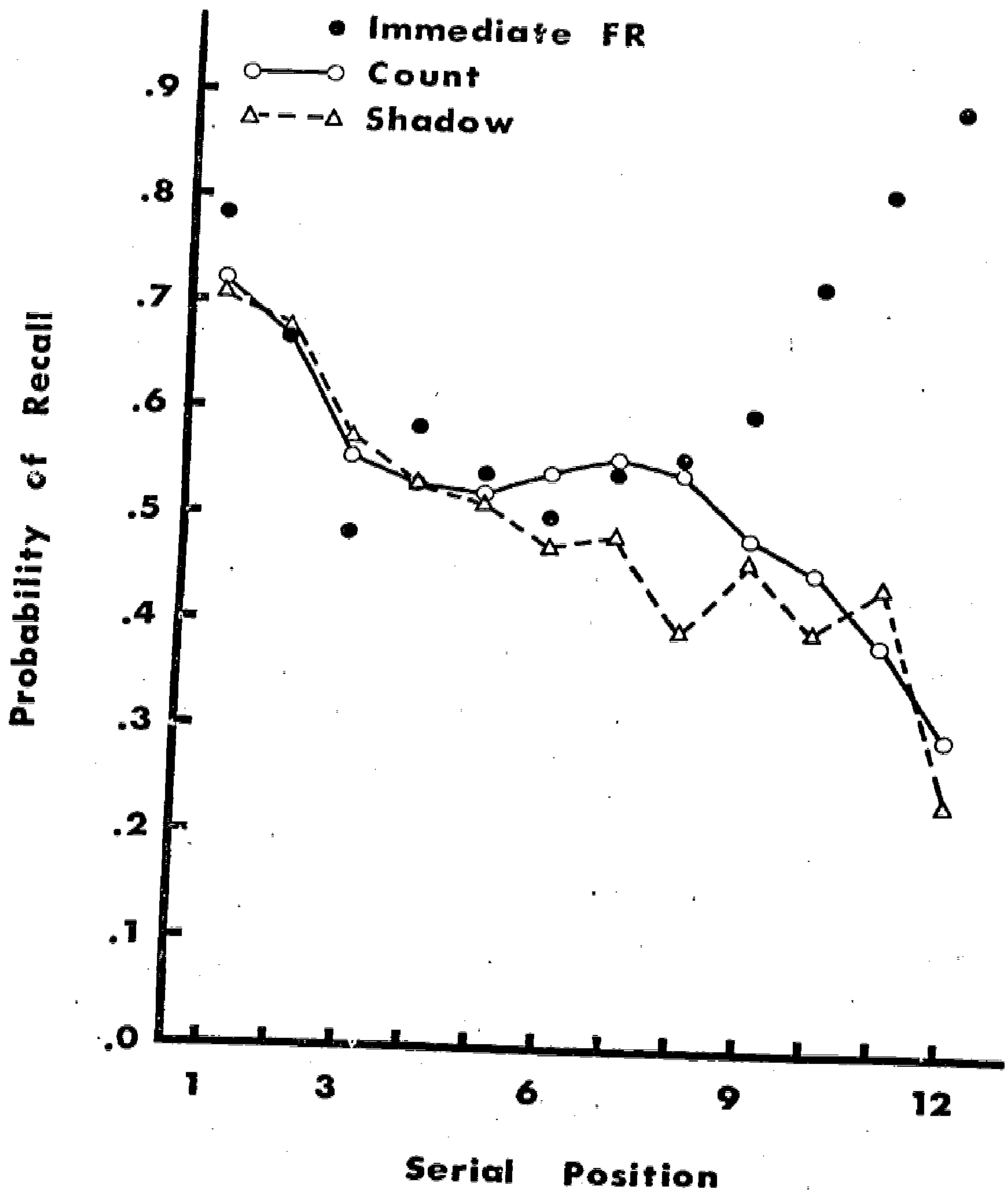

Figure 2. Probability of recall by serial position in immediate recall, recall following interpolated shadowing, and recall following interpolated counting.

as possible from a slide containing approximately 30 random digits presented visually and changed every two seconds. As before, subjects were instructed following presentation of the list to either "recall," "count," or "copy." The results of this experiment are shown in the next two figures.

Results and discussion--Figure 3 shows the data for the counting interpolated task. As expected, there is a reliable negative recency effect when presentation is auditory. There is, however, no reliable negative--or positive--recency effect when visual presentation is used. The recall of terminal positions with auditory presentation is reliably inferior to the comparable recall with visual presentation. That point is stressed because the usual finding in immediate recall is that, for terminal positions, auditory presentation is superior to visual presentation. Indeed, subjects had immediate recall in this experiment and we found the usual superiority of auditory over visual presentation in the recency portion of the curve. These data are presented in Figure 4.

These data serve to emphasize that the counting procedure interferes more with the retention of material presented orally than with the retention of material presented visually.

On the other hand, the data from the experiment did not confirm the hypothesis that the interference effect would be reversed by using an interpolated task with a large visual component. Our analyses show that both copying conditions show positive recency and are essentially indistinguishable. Thus, the copying data are inconclusive--they are not inconsistent with, nor do they support, our notion that the interference generated by the interpolated task has a large store-specific component.

Conclusions

This short series of experiments is sufficient to make the following statements: First, we have demonstrated negative recency in initial recall in three separate experiments. That should be ample replication of the effect. Second, the negative recency effect we obtain is a necessary consequence of the procedure rather than the result of a strategy on the part of the subject. On the other hand, there is considerable evidence that negative recency in final free recall (e.g., Craik, 1970) is the result of the strategy of the subject. Third, it is quite

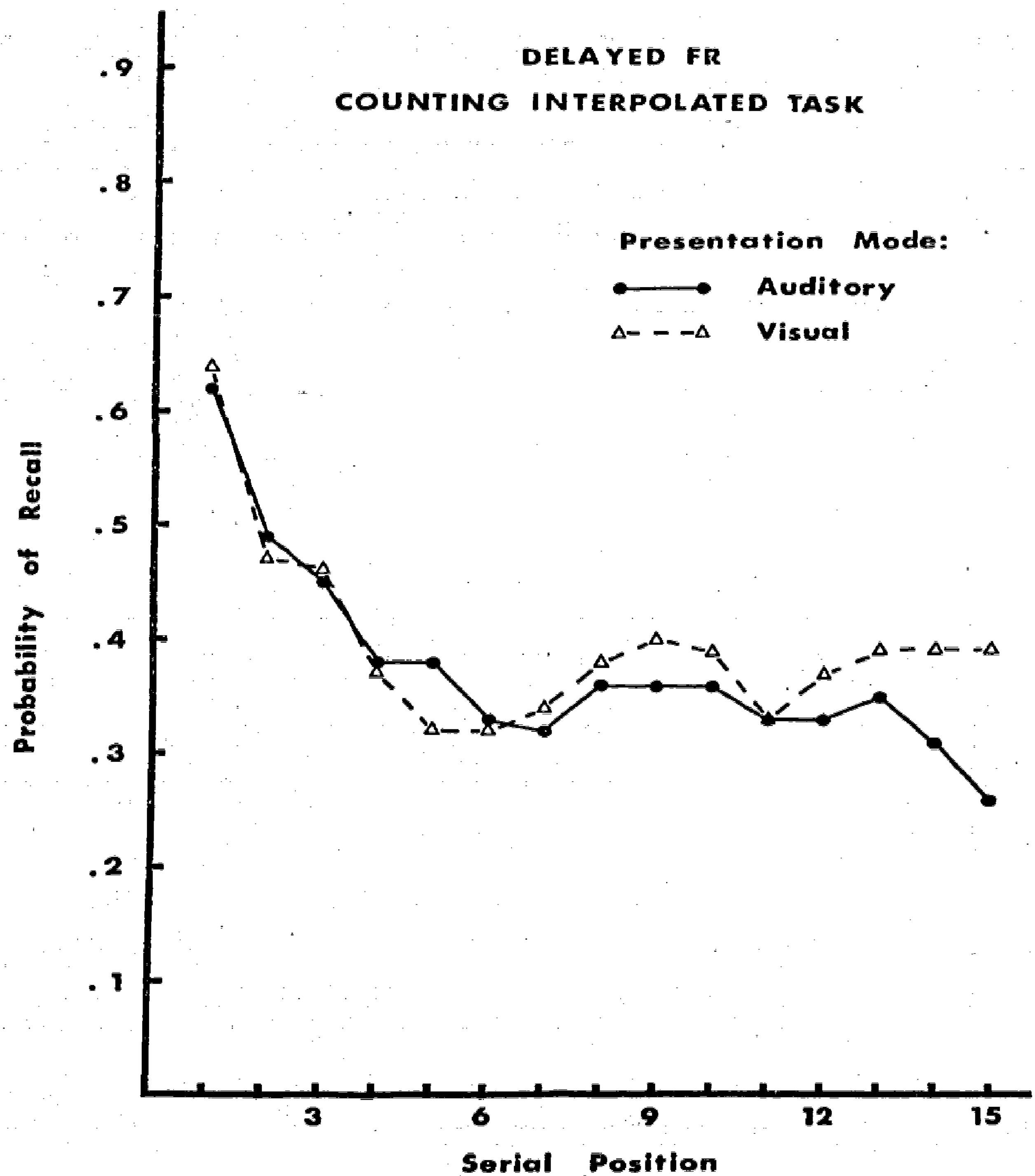

Figure 3. Probability of recall by serial position for auditory presentation for each of two interpolated tasks: counting and copying.

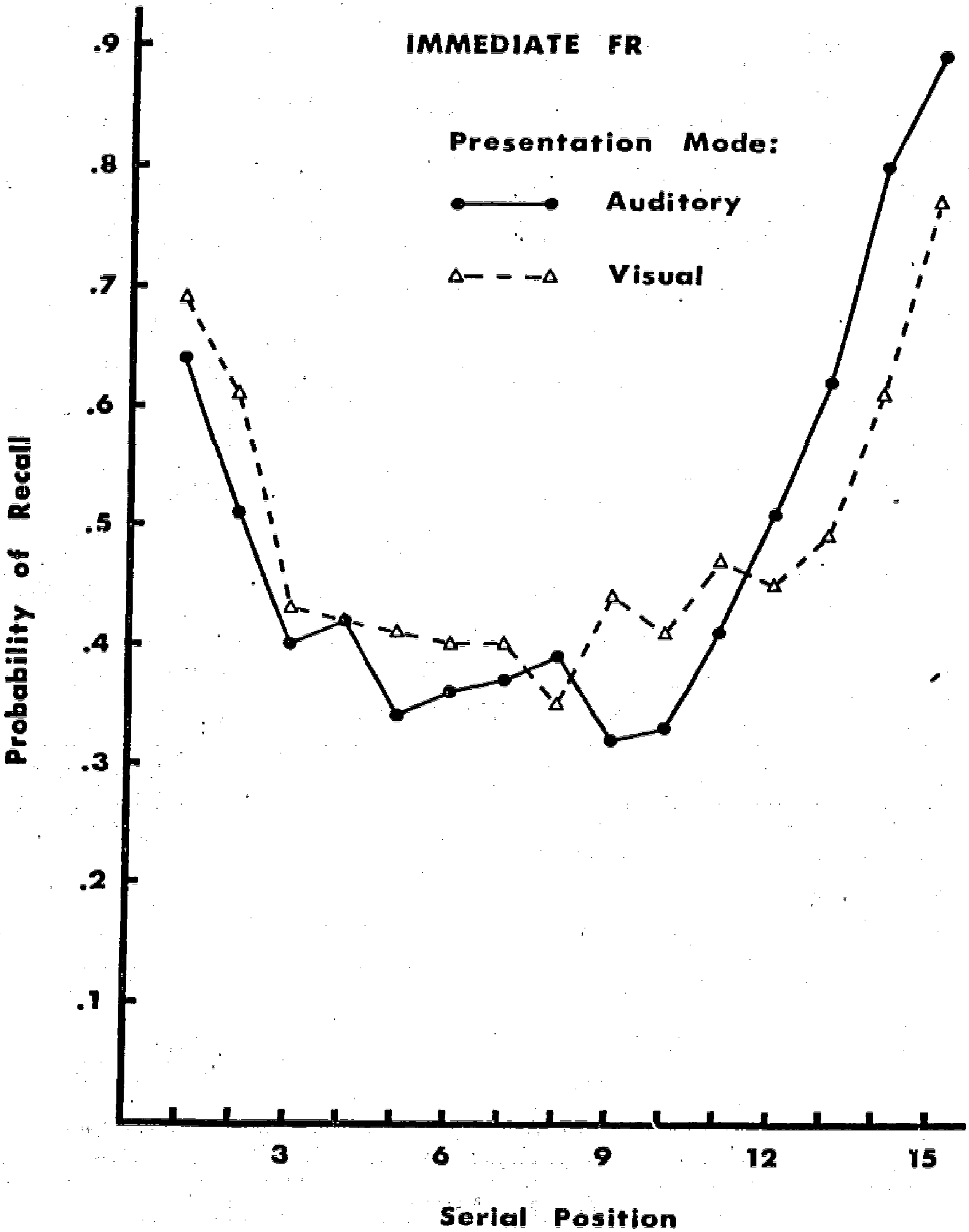

Figure 4. Immediate recall: Probability of recall by serial position for visual and auditory presentation.

clear that other very similar experiments did not produce negative recency because visual rather than auditory presentation was used. Fourth, these data add to the evidence supporting the theoretical statement that there are separate auditory and visual stores in primary memory.

Secondary memory research

Background

Modern interest in organizational processes in human long-term memory is usually dated from Bousfield's (1953) description of clustering in free recall. Tulving (1962) gave considerable impetus to this line of research when he demonstrated and named the phenomenon of subjective organization. During the decade since Tulving's paper, there has been an extremely vigorous experimental attack on the role of organization in memory. Much of the research in this attack has used free recall since that procedure tends to maximize opportunities for organization to occur. This approach has been productive and it would be brash to attempt to summarize the literature in a few statements. However, any summary of the information gleaned from these free recall studies would include these important points:

1. Subjects organize material presented to them for recall. This organization is what Tulving (1968) has termed secondary organization--i.e., it is based on characteristics other than input order. What is most interesting is that such organization occurs even when _S_ is dealing with what is presumed to be a list of unrelated words.

2. Organization of the material aids recall. Perhaps the two most dramatic demonstrations of the effectiveness of organization have been the category-recall relationship demonstrated with the Mandler procedure (e.g., Mandler & Pearlstone, 1966) and the demonstration by Bower, Clark, Lesgold, & Winzenz (1969) of the effectiveness of hierarchical retrieval schemes. Evidence from our laboratory (Thompson, Hamlin, & Roenker, 1972) suggests that organization plays an important role in aiding recall of categorized lists.

3. Organization increases with practice. Clearly, the degree of organization _could_ remain stable over trials. However, since _both_ degree of organization

and number of words recalled increase with practice, some investigators have hypothesized that increases in recall over trials must be attributable to increases in organization over trials.

4. Subjects learn how to organize. One of the most important task components in learning-to-learn may be learning how to organize. Learning-to-organize has been demonstrated both in the case of subjective organization (e.g., Mayhew, 1967) and clustering (Thompson & Roenker, 1971).

5. Retrieval from memory involves a search process. Tulving succinctly distinguishes between items which are available (i.e., intact in storage) in memory but are not accessible--presumably because the cues necessary to locate the items in storage are lacking (Tulving & Pearlstone, 1966). The notion of a search process in memory has been incorporated into many theories of memory (e.g., Shiffrin, 1970) and there is now considerable evidence to support that hypothesis.

6. Storage in memory, and subsequent memory search, apparently involves encoding on the basis of attributes. The evidence for this point of view has been steadily accumulating and ranges from data on the "tip-of-the-tongue" phenomenon (Brown & McNeil, 1966) to series of experiments on proactive interference in short-term (Wickens, 1970) and long-term (Thompson, 1972) memory. The evidence even includes a modern subception experiment (Wickens, Shearer, & Eggemeier, 1971). Much of the relevant data is summarized in a paper by Underwood (1969).

The aim of most of our recent research has been, as in the research outlined above, to clarify the role of organization in retrieval of information from secondary memory. We have taken the view that encoding of events involves some sort of "tagging" of attributes and, for that reason, we have made use of procedures (e.g., adjectival modification of nouns, selection of category exemplars) which would select or limit the attributes used for "tagging" in memory. We have also made frequent use of an interference paradigm since clarification of the role of interference in retrieval from memory should also provide information about processes involved in retrieval *per se*.

Most of our secondary memory experiments have used categorized lists since sorting words into categories is a very effective strategy for remembering a large number of words (e.g., Mandler, 1967). Further, repetition of categories, but not specific exemplars, in successive lists produces substantial proactive interference and, as noted above, investigation of this phenomenon should provide information about the role of organization in retrieval from secondary memory. Finally, it seems theoretically possible to manipulate the attributes used for word storage through the selection of category exemplars. For example, the word "horse" probably takes on a different set of attributes when it is in the subcategory of wild animals rather than in the subcategory of domestic animals.

The choice of a paradigm using categorized word lists to pursue our research objectives dictated that clustering would be the major measure of organization in recall. Since previous measures of clustering can be shown to vary with characteristics of recall, we developed a clustering score which is invariant with respect to factors unrelated to relative amount of clustering. In the adjusted ratio of clustering (ARC) score (Roenker, Thompson, & Brown, 1971), chance clustering is set at zero and perfect clustering at one. The ARC score represents the proportion of actual category repetitions above chance to the total possible category repetitions above chance for any given recall protocol. About a dozen studies using categorized word lists have been completed since the development of the ARC measure and the results of these studies are summarized below.

<u>General procedure</u>

Since many of the methodological details are the same in virtually all the secondary memory experiments, those details are summarized here to avoid unnecessary repetition.

When learning categorized lists, <u>S</u>s receive three successive trials on each of two to four lists. In repeated-category paradigms, some or all of the categories in the last list occur in previous lists. Excluding the last list, there are no repeated categories. Whenever possible, within-<u>S</u> designs are used with each <u>S</u> receiving all the experimental treatments.

As is customary, multiple lists are generated and used so that the results are not list-specific. Similar precautions are taken so that the results are not category-specific. The categorized lists usually contain four categories with twelve exemplars from each category. The categories and category exemplars are taken from the Battig & Montague (1969) norms with the normative frequency of occurrence of the words matched as closely as possible across categories both within and between lists. Non-categorized lists are approximately the same length and are matched on the basis of the Thorndike-Lorge (1944) frequency norms.

During the study portion of each trial, the words are presented at a 2-sec. rate with a Kodak Carousel projector. The order of presentation of the words is varied randomly from trial to trial. During presentation of categorized lists, _S_ identifies the category membership of each word by writing the category initial in an answer booklet. This procedure assures that _Ss_ attend to each word and presumably also assures that category membership is a salient characteristic of each word.

Five primacy and ten recency buffers are used in the non-categorized lists. In the categorized lists, the final word in the list is followed by a 3-digit number. The _Ss_ fill a 30-sec. interval between presentation and recall by counting backwards by 3's from that number at a 1-sec. rate. This task presumably eliminates the short-term memory component in recall (Glanzer & Cunitz, 1966).

The _Ss_ are instructed to write down the words in recall in whatever order the words occur to them. Two minutes are usually allowed for the recall portion of the trial. Each study and recall protocol is recorded on a separate sheet in an answer booklet. There is a 30-sec. interval between trials and a 3-min. interval between lists.

Experiment I: The role of clustering in free recall

Periodically, evidence has appeared in the literature suggesting that degree of clustering in free recall and amount recalled are not necessarily related (e.g., Puff, 1970). If the ability to cluster is not related to amount recalled, then the impact of the rather large body of research on clustering is considerably lessened. With this in mind, our first experiment examined the clustering-recall relationship.

Method--Sixty Ss were used in the experiment with each S receiving three trials on each of three categorized lists. The Ss were divided into three groups with each group viewing a different set of three lists. No category was repeated in any three-list set. Subjects were run in sub-groups of ten.

Results--Those Ss demonstrating a high degree of clustering were separated from those demonstrating a low degree of clustering on the basis of their performance on the first three trials of List 1. To maximize the differences in clustering ability between high and low clustering, three high and three low clusterers were chosen from each of the six sub-groups.

The difference in recall for high and low clusterers was clear, consistent, and reliable. To take List 1 as an example, high clusterers averaged 16.6, 23.2, and 25.9 items on Trials 1, 2, and 3, respectively whereas low clusterers averaged 13.2, 18.7, and 20.3 items on those three successive trials.

Discussion--The results of this experiment clearly indicate a difference in mean recall for high and low clusterers with high clusterers recalling more than low clusterers. While these results do not demonstrate that changes in degree of clustering would produce corresponding changes in recall, they are nonetheless consistent with the view that clustering seems to provide no exception to the general finding that organization aids recall.

Experiment II: Learning to cluster

The term "learning to learn" has been applied to the observation that performance improves over successive tasks which are similar in nature. Since organization aids recall and intralist organization increases with practice, it seems reasonable to hypothesize that learning-to-learn effects may reflect, at least in part, the increasing ability of S to organize the material for recall. That is, one of the task requirements is that S learn how to organize the material at hand, and once this has been accomplished, positive transfer effects may accrue to subsequent tasks of similar nature. In categorized word lists, increased organization is apparently reflected by increased clustering. Thus, several experiments were analyzed to determine whether

Ss learn how to cluster categorized word lists. Since the results were identical in all cases, only one experiment is reported here.

Method and results--Sixty Ss participated in this experiment which was identical in all respects to the experiment reported above.

The mean ARC (clustering) scores for each trial of List 1 were .49, .65, and .71 while the mean ARC scores for each trial of List 2 were .70, .83, and .82. The comparable scores for List 3 were .75, .80, and .87. The trial-by-trial increase from List 1 to List 2 was clear and reliable.

Discussion--The data unambiguously demonstrate that Ss learn to cluster over successive categorized word lists. The results show that learning to cluster occurs and is essentially complete after multiple trials on a single categorized list.

Experiment III: Inter-response times in categorized lists

One intriguing possibility is that degree of clustering reflects the efficiency of the search through memory rather than the degree of organization in memory. Thus, the learning-to-cluster effect demonstrated above may represent an increase in rate of memory search with no corresponding change in recall. If such is the case, the more rapid memory search should be reflected in more rapid output--i.e., the increase in clustering should be mirrored by a decrease in inter-response times. The experiment described here was performed to test that hypothesis.

Method and results--Thirty Ss participated in the experiment. Each S was given three trials on each of three lists containing 48 words divided into four obvious categories. Three different sets of three lists were used with an equal number of Ss learning each set. Recall was oral, rather than written, and was tape-recorded. The tapes, together with a voice-key and appropriate recording apparatus, were then used to record the inter-response times (IRT's) in recall.

Analyses of the IRT's showed that within-category IRT's did not change over trials and lists but between-category IRT's did change. Specifically, the mean IRT between-categories was 2.5, 4.3, and 6.0 for Trials 1, 2, and 3, respectively, of the first list and 6.8, 8.3, and 7.0 for the comparable trials of the second list.

Discussion--Although IRT's changed over lists, they changed in a way different from that which we had predicted. Within-category IRT's did not change (as predicted) but between-category IRT's did change. Interestingly enough, the change in between-category IRT's can also be interpreted as reflecting increased efficiency of the search rather than degree of organization in memory. Our tentative interpretation is that the increase in response latency between categories represents an increase in the post-item latency used as a criterion to exit one category and go to another. In other words, the S is conducting a more exhaustive search of one category before going to another. Obviously, such a strategy would result in greater clustering.

Experiment IV: Reduction of repeated-category interference by exemplar frequency

We began this line of research by establishing that we could readily produce substantial proactive interference by repeating categories, but not exemplars, in successive lists (e.g., Thompson & Poling, 1969). Having verified that fact, we directed our research efforts toward manipulations which might overcome or minimize repeated-category interference. We have made the assumption that encoding in memory involves "tagging" of attributes and that retrieval from memory involves a search through or for these tagged attributes.

This experiment originated from the observation that the usual practice is to use common (i.e., high-frequency) words in free recall tasks. It may be that Ss use this fact to restrict their search set. If such is the case, it follows that interference should be maximum when a repeated category is represented in both lists by common (or uncommon) examples of the category. However, if common items are used to represent the category in one list and uncommon items are used for that purpose in the other list, proactive interference should be sharply reduced.

Method--Sixty-four Ss served in this experiment. Each S received two successive lists with all categories repeated and the categories arranged so that each S received the four possible interlist within-category sequences of high (H) and low (L) word frequencies (i.e., HH, HL, LH, LL). Half the Ss had one trial on the first list and half the Ss had three trials on the first list. All Ss had three trials on the second list.

Results--The mean per-category recall for the second list is presented in Table 1, separately for Ss having 1 and 3 practice trials on the first list. First-list recall for high-frequency and low-frequency words is also presented for comparison. Since second-list performance is averaged over 3 trials, only data from Ss having 3 trials on the first list is presented for comparison.

There are several comparisons of interest. First, performance on second-list high-frequency words (conditions HH and LH) was clearly superior to performance on low-frequency words (conditions LL and HL). Second, increased practice on first-list members had no effect on second-list recall if the members were high-frequency words (conditions HH and HL) but had a facilitatory effect on second-list recall if the members were low-frequency members (reliable only in condition LL). Third, proactive interference produced an apparent decrement in second-list recall (relative to comparable first-list recall in condition LL with one first-list trial. No comparable effect occurred for condition HH. The point is that, when the first list was not well-learned, the LL condition actually appeared to produce more interference than the HH condition. Four, the recall data show that conditions HL and LH tended to produce "release from proactive interference" with condition HL possibly more effective in that respect than condition LH.

Discussion--The important data for our prediction were those showing that changing the word frequency from list to list eliminated or, at least, greatly reduced proactive interference in the repeated-category paradigm. Thus, it seems likely that Ss do use word frequency to restrict their search in memory when such restriction is appropriate.

Table 1

Mean per-Category Recall for the Four Interlist within-Category Sequences of Word Frequency[a]

Condition	List 1 H	List 1 L	List 2 HH	List 2 LH	List 2 LL	List 2 HL
One practice trial			4.8	4.8	3.3	4.3
Three practice trials	4.9	3.8	4.6	5.2	3.9	4.1

[a]Four sequences (i.e., high-high, high-low, low-high, and low-low, which are designated as conditions HH, HL, LH, and LL, respectively) are represented in the second list. The data for Ss receiving 1 and 3 trials of practice on the first list are presented separately. For comparative purposes, the mean per-category recall for high- (H) and low- (L) frequency words in the first list is presented for those Ss receiving 3 trials of practice on the first list.

Experiment V: Reduction of repeated-category interference by subcategorization

If the category being repeated in successive lists is animals, then it seems reasonable to assume that proactive interference could be reduced by presenting one kind of animal (e.g., wild) in the first list and another kind (e.g., domestic) in the second. Separation into subsets of this sort should have the same beneficial effect on proactive interference as the separation into common and uncommon words in the previous experiment. A substantial reduction in interference should result from complete separation by kind with the magnitude of the reduction dropping sharply as some words from both subsets are included in both lists. The present experiment was conducted to test that hypothesis.

Method--Forty Ss participated in this experiment and each S learned two four-category lists. The same categories were used in both lists, but the 20 words in each category could be divided into two subcategories. Each of the categories presented in the first list represented a combination of items from both subcategories. The first-list combinations ranged from a set in which both subcategories were equally represented to a set in which only one subcategory appeared. Specifically, the four combinations represented in the first list contained 0 and 10, 1 and 9, 3 and 7, and 5 and 5 items from the two subcategories, respectively. (Hereafter, these will be designated as the 0, 1, 3, and 5 conditions, respectively.) The remaining items from each category were presented in the second list.

Results and discussion--Per-category recall on the second list was 4.8, 4.3, 3.9, and 4.0 for the 0, 1, 3, and 5 conditions, respectively. As can be seen, the results were in the expected direction with the condition with complete separation of the two subsets (condition 0) having shown the best second-list performance and the condition with complete overlap of the two subsets (condition 5) having shown the worst second-list performance. The conditions by list interaction was not significant, however, and the data can only be viewed as suggestive. It should be noted that there is an overall reliable difference between conditions. The results, then, can be viewed as marginal support for the original hypothesis.

Experiment VI: Effect of adjectival modification on repeated-category interference

Several authors have proposed that attributes of words constitute the crucial information used for the storage and retrieval of words in memory. Given this view, common attributes shared by members of a category may provide retrieval routes to the items within each category in a single categorized list. While categorization of a single list facilitates recall, repetition of categories in successive lists produces substantial interference. Here, the overlapping characteristics common to the words in each of the two lists makes the items difficult to distinguish from one another and leads to slower learning of the second list relative to a list with no categorical overlap. If this analysis is correct, then it can be tested by altering the saliency of the attributes common to the words of a category.

In this experiment, words were modified (and, presumably, also the saliency of the attributes associated with the words) by the use of adjectives. Words in the list were either modified with a specific modifier (meaning that the adjective was appropriate for only one word in the list) or with a class modifier (meaning that the adjective could modify any word in the category). The hypothesis was that specific modifiers would tend to increase the salience of attributes not common to the other members of the category and would, therefore, decrease proactive interference. On the other hand, class modifiers should have the opposite effect since they would increase the salience of attributes common to members of the category.

Method--A total of 168 Ss participated in the experiment. The Ss were divided into six groups of 21 Ss each. The six groups represent the repeated-category and control (nonrepeated-category) conditions used with each of three types of adjectival modification: nouns alone (no modification), specific modification, and class modification. (Note that, owing to a bad sample in the original assignment, the number of Ss in the nouns alone conditions was doubled.) All groups received three trials on each of two categorized lists with, of course, the categories repeated on the second list for the experimental (repeated-category) conditions.

Results--The results are summarized in Figure 5 which presents the mean correct noun recall on each trial of each list for each condition. As can be seen, the usual proactive interference was found in the nouns alone conditions (right-hand panel) and in the class modification conditions (center panel) but the introduction of specific modification eliminated the interference effect (left-hand panel). Additional analyses demonstrated that the magnitude of the interference effect was comparable in the class modification and nouns alone conditions. Further, adjective recall was identical for the experimental and control conditions within the class modification and specific modification manipulations.

Discussion--The critical result is the elimination of interference through specific modification. It is clear that altering the salient attributes of a word can eliminate interference and it seems reasonable to assume that the word is being encoded differently than it would be without specific adjectival modification. Class modification, on the other hand, had no effect. Although it seems intuitively astonishing that (e.g.) "striped tiger" would produce less interference than "furry tiger"--that result is completely predictable from an attribute "tagging" theoretical viewpoint.

Experiment VII: Relationship between priority and probability of recall

This experiment was actually performed prior to receipt of this grant but written under the auspices of the grant. It is described last because it does not fit the research program undertaken during the grant period. The experiment stemmed from the considerable interest in the relationship between output order in free recall and item "strength." Previous attempts to specify this relationship had led to different conclusions depending on whether attention was focused on degree of learning or input location as the factor influencing item strength. We simply pointed out that both should be considered and performed an experiment accordingly.

Method--Two groups of Ss learned either a single-word (SW) or paired-associate (PA) list. In the PA condition, 19 Ss were tested simultaneously using a modified version of the recall method. Each trial consisted first of the successive presentation of 20 pairs of high meaningful words, followed by a recall test

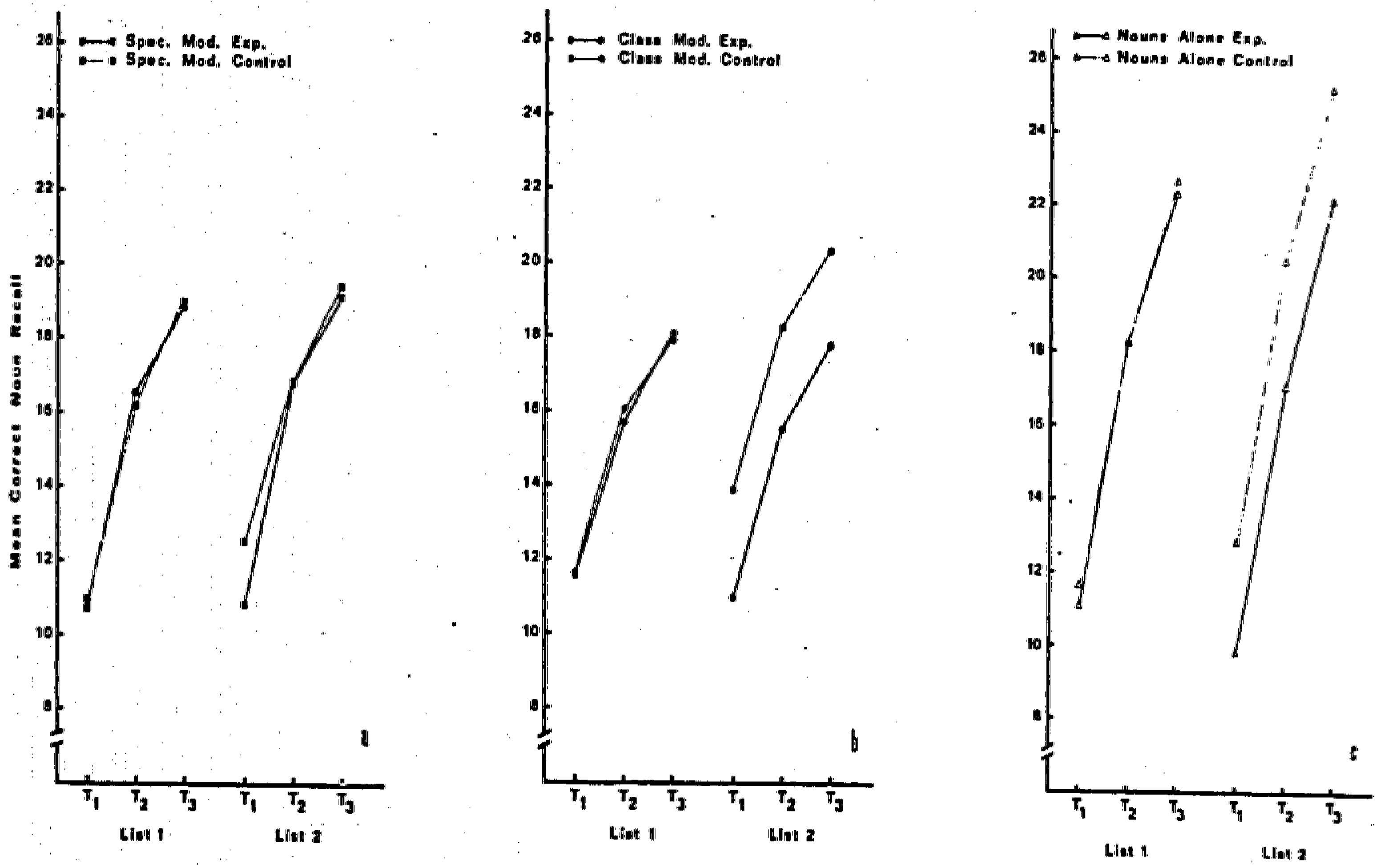

Figure 5. Mean correct recall for each of three trials on two lists for the control and experimental groups of the (a) specific modification, (b) class modification, and (c) nouns alone conditions.

during which Ss were asked to write down as many of the pairs as they could remember. Each pair was presented visually for 4 sec., with 2.5 min. allowed for recall. A 30-sec. unfilled interval was maintained between the presentation and recall portion of each trial. All Ss practiced the list for 10 trials with a different order of presentation used on each trial. In the SW condition, the procedure was identical to that used with the PA list except that items were presented at a 2-sec. rate and a different order of presentation was used with each of four subgroups of five Ss each. The 30 high-frequency words compromising the SW list were selected to be unrelated to one another.

Results--The data were recorded as a joint function of item strength (i.e., items previously recalled vs. items not previously recalled) and input location (i.e., from end, middle, or beginning positions). In both conditions, the relationship between probability of recall and priority of recall was curvilinear--that is, intermediate strength items tended to be output first with strong items given next and very weak items (and errors) given last.

Discussion--We interpreted this output order as representing a "minimal-interference" strategy on the part of the subjects. That is, Ss seem to put out first items which are relatively weak so that they do not lose those items through output interference then Ss emit strong items and, finally, Ss emit (or guess at) the weakest items.

Note: No other experiments will be reported in the body of the report. Those experiments which produced negative results are briefly summarized in the appendix. This organization reflects the accepted view that negative results rarely contribute anything to a field and, in this case, would clearly break up the flow of the narrative.

Conclusions

Please note that the conclusions regarding the experiments in primary memory were presented in the primary memory section of this report. The major results of our research in secondary memory may be summarized as follows:

1. Clustering and recall are positively correlated. This result is to be expected if clustering reflects a search process in memory and, indeed, Ss showing a high

degree of clustering recall reliably better than Ss showing a low degree of clustering (Thompson, Hamlin, & Roenker, 1972). This runs counter to some data presented by Puff (1970) but his measurement procedure appears to be less sensitive than that used by Thompson, et al.

2. The presumed relationship between degree of clustering and exemplar frequency (as defined by cultural norms) is probably a measurement artifact. In his review of the clustering literature, Shuell (1969) notes that several studies have shown better recall and better clustering for high-frequency words than for low-frequency words. But an examination of these studies shows that the authors used either the number of category repetitions or Bousfield's (1953) ratio of repetition (RR) as an index of clustering in recall. Both measures can be shown to increase as recall increases. The ARC measure does not have that property. In a study involving high and low frequency exemplars, we found better recall, but <u>not</u> better clustering, for high-frequency exemplars.

3. Ss learn to cluster (Thompson & Roenker, 1971). If there is some sort of search through memory during recall, it seems likely that Ss must learn how to organize the material presented to them and that this "learning-to-organize" would be an important component in the learning-to-learn effect. Our data show that the "learning-to-cluster" effect is truly impressive. With three trials on each of two lists, clustering on the first trial for the second list is equivalent to that found on the third trial for the first list. However, the sharp increase in first-trial clustering is not accompanied by a corresponding increase in recall.

4. Repeating categories, but not category exemplars, produces substantial proactive interference. This has been demonstrated in a number of experiments (e.g., Shuell, 1969; Thompson & Poling, 1969) and we have never failed to replicate this strong effect.

5. Repeated-category interference can be minimized through subcategorization or adjectival modification of category exemplars.

a. Subcategorization. It may be that repeated-category interference is analogous to the interference produced in an A-B, A-C transfer paradigm. That is, the search through the category (A) during recall produces both appropriate (C) and inappropriate (B) items. The inappropriate words interfere with recall of the appropriate words. We assumed that this interference would be reduced if the appropriate items could be distinguished in some manner other than recency of presentation. Subcategorization seemed an obvious way to distinguish two sets of words from the same superordinate category. We used a strong test of the subcategorization effect with Ss not informed of the relationship present in successive lists. In separate experiments, repeated-category exemplars were subcategorized on the basis of exemplar frequency and kind (e.g., wild vs. domestic animals) with different subcategories appearing in successive lists. Subcategorization by kind produced the expected reduction in proactive interference (PI) but the effect was not statistically reliable. On the other hand, subcategorization by exemplar frequency produced a substantial reduction in PI. The pattern of results in the latter study is of interest because it differs from the predictions generated by the hypothesis that items in recall are retrieved on the basis of pre-established inter-item associative networks. For example, categorical intrusions given to both high-frequency (H) and low-frequency (L) lists tend to be high-frequency words (Cofer, Bruce, & Reicher, 1966). From these and other data, the inter-item association hypothesis would predict that an HL sequence (i.e., first list H, second list L) would produce more PI than an LL sequence. Our data show that this is clearly not the case. This result represents a small portion of the data that have led us to conceptualize the search in memory as an active process which is not primarily dependent on already-established associations for its action.

b. Adjectival modification. The function of the adjective in language is to restrict the meanings which can be assigned to a noun. Adjectival modification effects recall (e.g., Gonzales & Cofer, 1959) and we reasoned that it would influence both the learning-to-learn effect and PI. Specifically, we predicted that modification of category exemplars by adjectives which could appropriately modify only the noun with which they were paired would produce reduced learning-to-learn and also reduce PI. On the other hand, the use of general modifiers (such as colors for the category of clothing) would lead to improved learning-to-learn and increase PI. Specific modification had the predicted effect whereas the magnitude of PI and the learning-to-learn effect do not differ for the general modification and nouns-alone conditions.

6. Reduction of category size through subcategorization improves recall. One of the subcategorization experiments allowed comparison of recall for the same words appearing in the (entire) category and in a subcategory. Better recall occurred in the subcategorization condition. These data are consistent with other evidence (e.g., Craik, 1968) suggesting that a reduction in category size will result in improved recall.

7. Learning-to-cluster may represent an increase in search efficiency rather than an increase in organization in memory. Investigation of the inter-response times (IRT's) in recall demonstrated that between-category response times increased in a manner exactly paralleling the increase in clustering over trials and lists. The preferred interpretation is that _Ss_ increase the post-item latency used as a criterion to exit from a category and thereby increase category clustering.

8. The relationship between output order of items and probability of recall of items must take into account both the "strength" of the item and its position in input. When both are considered, there is a curvilinear relationship between output order and probability of recall with items of intermediate "strength" recalled first (Brown & Thompson, 1971).

These results demonstrate that research using the free recall paradigm has been quite effective in the examination of the role of organizational processes in memory. Such research should continue to make an important contribution to our understanding of human thought processes.

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Appendix

The studies reported herein are those which produced negative results or were terminated for some reason. Since they made no significant contribution to the research program, they are summarized very briefly below.

Experiment I: Effect of adjectival modification on recall and recognition

If items are encoded in memory through "tagging" of attributes, then it should be possible to change the effectiveness of repeating an item in a single list by changing the adjective which modifies that item. In a series of four experiments (all of which were highly similar), we modified the "meaning" of repeated items in a list by using either (a) different adjectives giving the same meaning to the noun, (b) the same adjective, or (c) different adjectives giving different meanings to the noun. The differences observed in the results were minimal and, in some cases, not replicable so this line of research was abandoned.

Experiment II: Effect of prior practice on interference in categorized lists

Initial results suggested that repeated categories produced more interference when the subject had practice on a series of lists with no repeated categories than when he had no such practice. An experiment was designed to investigate this potential effect and the results did not confirm the initial observations. Since the outcome seemed of minor theoretical importance, the investigation was terminated.

Experiment III: Category size and proactive interference

One of the implications of a memory search theory is that restricting the "area" of the search should produce better recall and fewer intrusions. In addition, a restricted search set should be less subject to proactive interference. A couple of experiments intended to substantiate these hypotheses produced no conclusive evidence for the hypotheses and this line of research was also discontinued.

Experiment IV: Retrograde amnesia in free recall

Earlier research has shown that in serial lists containing a high priority event (HPE), recall and recognition of adjecent items is retarded. In recall, the decrement is symmetrical about the HPE, but in recognition the effect is asymmetrical. This asymmetrical effect in recognition may be due to a cueing of subsequent items by the HPE. An experiment to test this hypothesis was performed but the results were inconclusive. Since this was not an integral part of our research program, no additional research was performed on this problem.

Experiment V: Whole to part learning in categorized lists

Prior research has shown that the learning of a portion of a list is retarded when preceded by limited practice on the whole list. We hypothesized that this decrement in recall performance may be due to an incorporation of unlearned items into the organizational scheme of the list when the whole list is present. A study testing this hypothesis was performed and failed to confirm the hypothesis. However, there were methodological problems with the design of the experiment. Since the role of organization in the whole-to-part phenomenon has important implications for our theoretical view, further research may be performed on this problem in the future.