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# The effects of visual presentation method on single-trial free recall

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In two experiments four different conditions of visual presentation were studied with the purpose of furthering our understanding of the role of temporal and spatial factors underlying modality effects in single-trial free recall. Enriching spatial factors in the visual presentation did not produce a higher performance in the recency part of the serial-position curve, and it was therefore concluded that the modality effect could not be due to any visual handicap. A lag distribution measure was suggested and applied to the data to characterize output order (the order of recall) in single-trial free recall. The two experiments carried out used a within-subjects and a between-subjects design, respectively, and illustrate the importance of the methodological difference between these two designs.

This paper investigates the role of temporal and spatial factors in the modality effect of single-trial free recall. The modality effect (e.g., Craik, 1969; Murdock & Walker, 1969) refers to the fact that auditory presentation results in a serial position curve which differs from the visual serial position curve in only one way; namely, a greater recency effect. The last (up to eight) words in a list will be better recalled if the presentation is auditory than if it is visual. Earlier words in the list are not differentially affected by the modality manipulation.

One possible reason for the modality effect is that the auditory modality is specialized for sequential or temporal associations while the visual modality is specialized for simultaneous or spatial associations. Since short-term memory experiments generally test sequential associations, the auditory system is favored. One attempt to test this view (Murdock, 1969) did not support it, but the test may not have been critical (Murdock, 1972). Here the test employed only visual presentation to assess the importance of spatial cues more directly.

The logic is as follows: Perhaps with visual presentation there is a handicap because the cues normally present, when the information-processing system is working with visual information, are absent. The normal mode of presentation of a visual stimulus is such that the complete stimulus array is in view and the eyes can range over it at leisure. While it may be only for a brief instant (as in reading or watching a motion picture), still the usual auditory pattern (say speech or music) is constantly changing and is never stationary. A typical visual presentation of words in a STM experiment using either a memory drum, a slide projector, or a CCTV display seems, therefore, to give little opportunity for spatial cues to work. That is, the words to be learned are sequential not simultaneous; at least in free recall, the offset of Word i-1 always precedes the onset of Word i. There are at least two ways in which this handicap could be critical. First, there is only one word in view at the time. Second, each word overwrites its predecessor in the visual field. Perhaps the modality effect, then, reflects a visual handicap for either or both of these reasons. If so, enriching the spatial cues (those on which the system normally works) should improve performance.

This, then, was the general rationale of the experiments, and four conditions were employed. They can be ordered from poor to good in terms of the quality of the spatial information available. The weakest cues were available when a simple in-line display was used; each word overwrote its predecessor on the screen. The strongest cues were available with the method of whole presentation. The entire list was available for the full presentation duration. There were two intermediate conditions, a displaced single-presentation condition and an unfolding condition. If these variations fail to affect performance in free recall, it will be hard to argue that the alleged visual handicap underlies the modality effect. It should be noted that the present study is not investigating the question raised by Mandler and Anderson (1971); that is, whether temporal and spatial cues are additive or independent retrieval cues. Rather, the question is whether progressively richer or more detailed spatial information is of any value in free recalling words from short-term memory.

There is reason to believe that the visual system is capable of a spatiotemporal integration, since the subjects in visual but spatially poor conditions can, after

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all, utilize the temporal cues that are available. Given this flexibility in the visual system, it seems that a manipulation of spatial (and temporal) cues might be critical to the type of experimental design used. In a within-subjects design, the subjects might try to optimize their efforts according to the spatial and temporal cues available in all the conditions and use a mixture of strategies in spite of the condition they are being tested in. In a between-subjects design, it is hopefully the case that they are using the type of strategy that is appropriate for whatever condition they are tested in. Since Experiment 1 used a within-subjects design and Experiment 2 used a between-subjects design, the experimental situations used in the present paper may say something about the questions raised by Poulton (1973) concerning these two types of designs.

## METHOD

### Experiment 1

**Design and procedure.** A within-subjects design was used to compare four spatially different types of visual presentation. The first type was the standard presentation, that is, presentation of one word at a time in the same position on the screen (Condition S). The presentation time was 0.5 sec/word.

In the second condition, the words were also presented one word at a time for 0.5 sec/word. However, in this condition the words appeared in different positions on the screen (Condition D). The first word appeared at the top of the screen for 0.5 sec, then the second word appeared in a position just below that of the first word, the third below the second, and so on to the tenth word which appeared at the bottom of the screen. It was assumed that this condition contained usable spatial cues that were absent in Condition S.

In the third condition, the spatial cues were assumed to be more pronounced. The presentation was similar to Condition D in every respect except that each word remained on the screen after its initial appearance (Condition R), rather than flashing on for .5 sec and then going off before the next word appeared. Thus, in Condition R the list of words was formed at a rate of 0.5 sec/word, and the whole list was in view with the presentation of the tenth word.

In the fourth condition, the whole list of words was presented at one time (Condition W). That is, the 10 words appeared together for 5 sec. In this condition, therefore, there were no experimenter-imposed temporal cues, but there was the most complete or richest set of spatial cues.

Before the experiment, the subjects were instructed about the four types of presentation and about immediate written free recall at the end of each list. The subjects were allowed 20 sec for recall. Each subject was given eight lists in each condition, for a total of 32 lists. Two lists from one condition were presented in succession, then two lists from another and so on. The subjects were informed between each two lists of the condition in which the next two lists would appear.

**Materials.** Thirty-two different 10-word lists were constructed of two-syllable nouns from the Toronto word pool. There were two different random orders of words in each list, and two different random orders of lists were used. Half of the subjects were given one order and half were given the other order. Presentation of the word lists was visual by means of an Ampex videotape recorder and a Shibaden CCTV monitor.

**Subjects.** The subjects were 16 volunteer undergraduate students from the University of Toronto. They were tested individually.

### Experiment 2

The main difference between the two experiments was in the use of a between-subjects design in the present experiment rather than the within-subjects design used in Experiment 1. The same four types of visual presentation were used; 25 randomly selected lists of those used in Experiment 1 were used for each condition in the present experiment. As in Experiment 1, two different orders of words within each list were used, and two different orders of lists were constructed. Presentation of the word lists was visual by means of a Sony videotape recorder and a Shibaden CCTV monitor. Forty-eight subjects from the same source as in Experiment 1 were randomly assigned to the four different conditions (S, D, R, and W). Each subject was instructed only about the appropriate type of presentation. Rate of presentation (0.5 sec/word) and recall interval (20 sec) were the same as before. Instructions about immediate written free recall were also given. After the experiment proper, the subjects were also asked for final free recall. This interval was 3 min.

## RESULTS

### Number Recalled

The mean number of words recalled per list for Conditions S, D, R, and W was 4.00, 3.96, 4.05, and 3.90, respectively, for Experiment 1 and 4.10, 4.26, 3.93, and 3.84, respectively, for Experiment 2. Analyses of variance revealed no differences between conditions ($Fs < 1$). Thus, the manipulation of the spatial cues in the present experiments did not show any differences with respect to total recall. However, when considering recall as a function of input position of the words in the list, pronounced differences between the conditions were found. Serial position curves for the four conditions in the two experiments are presented in Figures 1 and 2.

A general impression of the data is that each condition shows about the same type of curve in both the experiments, although the effects seem to be more pronounced in the between-subjects experiment (Experiment 2). The typical recency effect is found for Conditions S and D but not for Conditions R and W; on the other hand there is a slight compensatory effect for prerecency items for Conditions R and W relative to Conditions S and D. Analyses of variance show a significant Condition by Serial Position interaction in both cases, $F(27,405) = 5.95$, $p < .001$ and $F(27,396) = 7.89$, $p < .001$ for Experiments 1 and 2, respectively. The standard errors of the mean, based on the appropriate mean squares, were .340 and 1.16, respectively. From these data it must be concluded that the modality effect for recency items cannot be explained by a handicap for visually presented items, since the richest conditions with respect to spatial cues (Conditions R and W) did not result in any superior recency effect.

The main source of the significant interactions is the reverse relationship between Conditions S and D on the one hand and Conditions R and W on the other for recency and prerecency items, respectively. This result

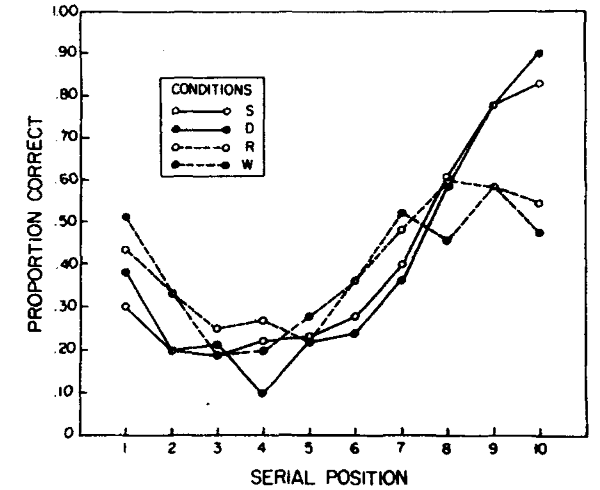


**Figure 1. Serial-position curves for the 4 conditions of visual presentation (Experiment 1).**

may give rise to the conclusion that spatial cues have a facilitating effect for prerecency items, since Conditions R and W have more spatial cues available than Conditions S and D. The conclusion is strengthened by the fact that there is a difference between Conditions S and D for Experiment 1 in the beginning of the serial position curves. Condition D is supposed to contain more spatial cues than Condition S, and there is consistently better recall for Condition D for the first five serial positions. (A separate analysis of variance for Conditions S and D revealed a significant interaction between condition and list half, $F(1,198) = 5.12$, $p < .05$). Whether or not the lack of recency effect in Conditions R and W indicates an inhibitory effect of spatial cues in short-term memory must however still be considered a question for further investigation. The reason for this is partly that such a conclusion seems contraintuitive and partly that no similar lack of recency effect could be detected in Condition D, which also showed a facilitating effect for prerecency items. A more

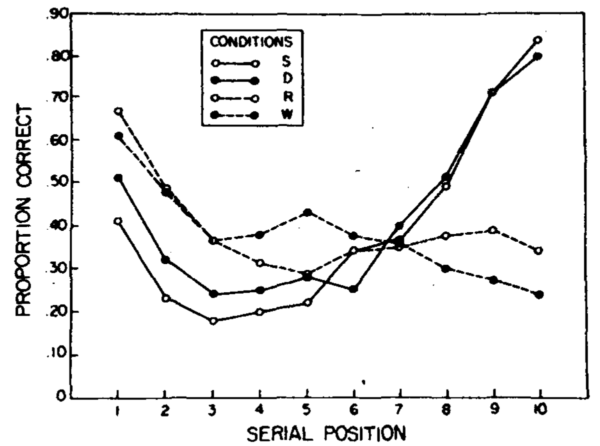


**Figure 2. Serial-position curves for the 4 conditions of visual presentation (Experiment 2).**

reasonable way of explaining the lack of recency effect in Conditions R and W is that it might be a consequence of the fairly high performance for prerecency items. Perhaps the subjects in these two conditions start recalling the words from the beginning of the list and, as a consequence of output interference, there is a poorer recall of recency items. This possibility might be tested by analyzing output order effects in the recall protocols.

## Order of recall

A problem of long standing in the area of single-trial free recall is how to describe the order of recall. As is common knowledge among investigators, there are clear regularities in the data – but they are not so clear as to be easily describable. A fairly common method of characterizing recall protocols is to record input serial position as a function of output order. That is, the dependent variable is the input or serial position, and the basis of classification is the ordinal output or recall position. Typical examples of recall from a 10-item list are given in Table 1. From this format, it is easy to transform the data to accuracy (recall or nonrecall) as a function of input serial position. One then pools over lists or subjects to obtain serial position curves, and one can also sum over serial positions for total recall scores.

What can be said about the sample protocols of Table 1? There is clearly a tendency to start recall near the end of the list. However, there is neither perfect backward recall (10, 9, 8) nor perfect forward recall (7, 8, 9, 10) though of course these do happen occasionally. There are contiguity effects in that there is a tendency for words presented together to be recalled together. Furthermore, such contiguity effects as there are tend to be more in a forward than a backward order. Words recalled from the middle of the list are more haphazard than words recalled from the end, and words recalled from the beginning are intermediate. All these are tendencies only, though some documentation is available (Murdock, 1974). There is enough consistency here to suggest some lawfulness but enough variability to defy a simple descriptive attempt. When one adds all this to the variability in the total number of words recalled on each trial, it is no wonder that investigators have been intrigued by these effects but have been unable to do much more than note their existence.

One attempt to characterize these output-order effects more precisely was to compute mean position in recall for each serial position. This measure was first reported by Deese and Kaufman (1957), and they

**Table 1**
**Hypothetical Data to Illustrate Typical Output-Order Effects in Single-Trial Free Recall (X Denotes an Intrusion)**

| | Ordinal Position in Recall | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Protocol | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| A | 10 | 9 | 1 | X | 7 | 8 | X | |
| B | 8 | 9 | 10 | X | 1 | 2 | 6 | |
| C | 8 | 10 | 1 | 6 | 7 | | | |

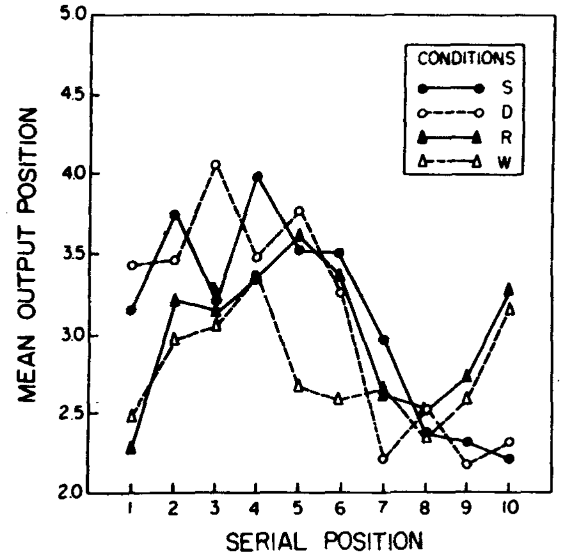


**Figure 3. Mean position of items in recall as a function of serial position for the 4 conditions of visual presentation (Experiment 1).**

showed that this function was the approximate inverse function to the serial position curve. Mean recall position showed a marked recency effect, some primacy effect, and a stable asymptote. This type of analysis was applied to the data of the present experiments and the results are presented in Figures 3 and 4.

Again it is demonstrated that the within- and between-subjects experiments showed essentially the same trend in the data, with more pronounced effects for the between-subjects design (Experiment 2). From an inspection of these mean output position data, one might be inclined to conclude that subjects in Conditions R and W usually start recalling the first word first, then items near the end of the list before ending the recall sequence with some items from the middle of the list. Inspection of the recall protocols show that this is very seldom the case. Instead, there seems to be two different types of output patterns in these conditions: Some subjects start recalling the words from the beginning of the list and end the recall with some items from the middle or end of the list; other subjects, however, very commonly start their recall from somewhere near the end of the list and then recall some words from the middle of the list. When the subjects start recalling from the end of the list, they usually start with 7, 8, or 9 and recall the rest of the final items in a forward order (e.g., 8, 9, 10). These two different output patterns, however, cannot be unequivocally interpreted from these output position curves.

The mean output position curves from Conditions S and D show a typical backward order of output: Subjects usually start recalling the last item first and then the next last item and so on; before ending the recall sequence with some items from the middle of the list they usually also recall some items from the beginning of the list. By and large this output pattern is found when inspecting subjects' recall protocols.

To our knowledge, this analysis of output order has not been much used by subsequent investigators. One problem may be that the number of observations entering into each computed mean varies quite widely. Since the last word in the list is almost always recalled but the middle words are seldom recalled, the number of observations on which the computation are based will vary accordingly. Another feature of the data may also have been considered as a limitation of this analysis; since the curve seems to mirror the serial position effect, it does not give additional information, and therefore the method is redundant. It is inappropriate for another reason as well; namely, it disguishes the real output orders in some cases (cf. the discussion of output order in Conditions R and W above). The mean output position curves give a crude overall suggestion that subjects start with some part of the list before recalling words from another part of the list, but the method is not sophisticated enough to deal with output order effects in detail.

In the literature, there are only two other methods reported that deal with the problem of output order. For different reasons, however, these methods are not appropriate for analyzing the present data. Buschke and Kintsch (1970) first Vincentized the response sequence into first and second halves and then plotted percent in the first (or second) half of output as a function of serial position. The disadvantage of this type of description is its inability to differentiate between cases of recall which obviously reflect different instances of output order. Consider, for example, the following two hypothetical free-recall protocols of a 10-item list: 5, 6,

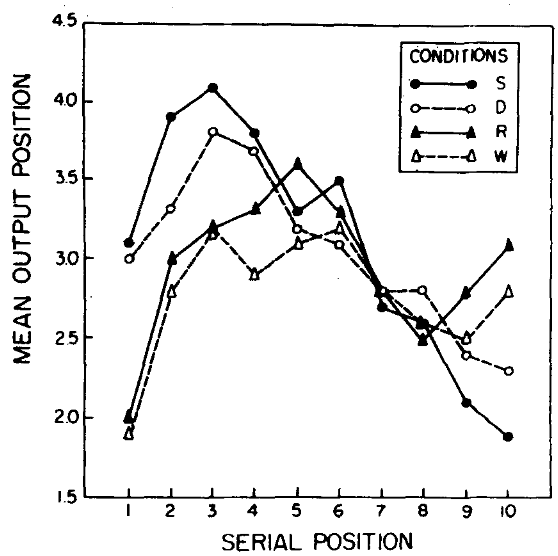


**Figure 4. Mean position of items in recall as a function of serial position for the 4 conditions of visual presentation (Experiment 2).**

7, 8, 9, 10 and 5, 6, 7, 10, 9, 8. These recall sequences would give the same result in Buschke and Kintsch's (1970) analysis. The former example shows one single, continuous response sequence of forward output order, but it is treated as two different phases. Although the latter example is also treated as two different phases, the Vincent curves do not demonstrate that the first phase is a response sequence of three items with forward output order while the second is a backward output order sequence also of three items.

Mandler and Dean's (1969) contribution to the description of output order concerns the development of serial order over successive trials and has many similarities to the organizational measures suggested by Bousfield and Bousfield (1966) and Tulving (1962). Since this measure is limited to multitrial free recall and serial forward output order, it will not be discussed in the present paper any further.

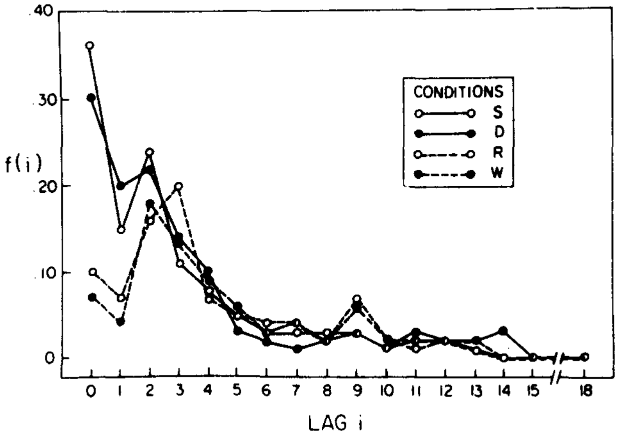


**Figure 5. Lag distributions for the 4 conditions of visual presentation (Experiment 1).**

**Lag Distribution**

Thus, none of the methods in the literature seem appropriate for describing the output-order effects in the present experiments. A final solution to the output-order problem will come when we have a satisfactory model for single-trial free recall. Then the model will tell us what sort of output-order effects one should find in the data. The appropriate measures, or summary statistics, will be deductible from the model, and the descriptive problem will be solved. One approach to this problem, then, is to temporize; to wait until the correct model comes along and disregard output-order analyses in experiments on single-trial free recall. Another approach is taken here. We would like to suggest a very simple descriptive device–the lag distribution–and show that it can be a useful analytic tool.

There is a danger in this approach, and it should not pass without notice. In effect, the description has no particular theoretical rationale, and it is introduced as merely a useful way of obtaining an ordered profile of recall. The danger is that it will be imbued with surplus meaning and disputes will arise over whether it is the "best" (or even an "appropriate") measure. As noted by Colle (1972), this is exactly what has happened with organization measures. Lacking an adequate theoretical rationale, there is now a proliferation of statistical measures, and workers in the field are in the unfortunate position of trying to demonstrate superiority for one over another. While this is the danger that could befall an atheoretical measure such as is proposed here, the alternative risk is even less attractive. It is that researchers will continue to ignore output-order effects in their data and, as a consequence, remain ignorant of whether they are the cause or the effect of the main empirical results they do find.

The lag distribution is simply a frequency distribution showing the proportion of times each possible lag occurred, where lag is defined as the number of items intervening between the presentation and the recall of each item. Waugh and Norman (1965) suggested that lag was the basic unit of interference; here we wish to make use of the lag measure without necessarily endorsing the theoretical significance they attributed to it. A plot of f(i) as a function of i (where i is the lag and f(i) is the relative frequency or proportion of each lag) shows what the lag distribution looks like for any set of data, and several examples will be presented later in the paper. The relative frequency of each lag is calculated by dividing the frequency of each lag by the number of times each lag could occur. Ten-item lists were used and therefore (for each list) the number of times a lag could occur increased by 1 for each lag from 1 at Lag 0 to 10 at Lag 9 and thereafter decreased by 1 for each remaining lag to a possible frequency of 1 at Lag 18 for each list.

Consider various types of output order and the shape of the lag distribution they would produce. If the subject followed a perfect backward order (i.e., 10, 9, 8, 7, . . . ) then the lag distribution would be a sawtooth curve with peaks at even-numbered lags (0, 2, 4, . . .). If the subject used a perfect forward order (e.g., 7, 8, 9, 10, . . .) then there would be a sharp spike at a lag determined by the starting point (here, since the starting point was Serial Position 7, the spike would be at Lag 3); variability in the starting point or inversions in the recall order would smooth the function around this point. With perfect serial recall the curve would be a point distribution function, as all recalled items would have the same lag.

One could hypothesize specific types of recall patterns and then test data quantitatively for their frequency. One would have to assume that the pooled data was a probability mixture of different patterns, and some variability would be necessary. Parameter estimation techniques exist to make this a quite feasible way of analyzing recall protocols. Here, however, the aim is more modest. All that is proposed is to see how the lag distribution changes with experimental variables, and draw conclusions accordingly.

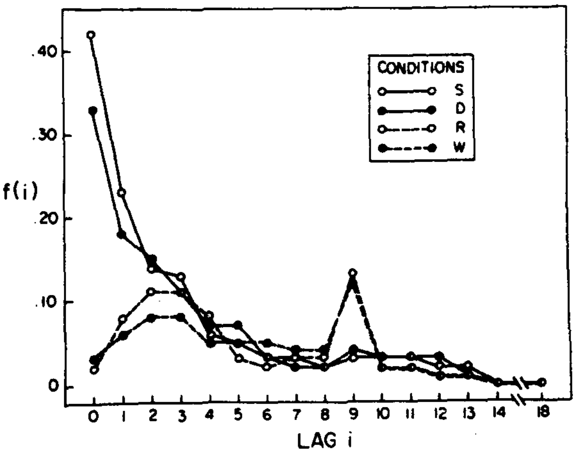


**Figure 6. Lag distributions for the 4 conditions of visual presentation (Experiment 2).**

The suggested lag distributions for the data of Experiments 1 and 2 are presented in Figures 5 and 6. Once more it can be concluded that there is the same trend in the data for both the experiments, and that the effects are more pronounced in the between-subjects experiment. In Conditions S and D in both the experiments the subjects have a higher proportion of correctly recalled items at the shortest lags, thus indicating a backward output order (e.g., 10, 9, 8, 7, . . . ). In Conditions R and W peaks are obtained at Lags 2 and 3 and the relative frequency of correct recall at Lag 0 is very low, thus indicating a forward output order of recently presented items (e.g., 8, 9, 10, . . .). However, very frequently the subjects in these conditions start recalling words from the beginning of the list, indicated by the pronounced peak at Lag 9 for these conditions. Thus, since subjects in Conditions R and W very often start recalling the words from the beginning of the list and are using a forward order, it seems reasonable to expect a poor recall of recency items for subjects in these two conditions.

It is suggested that these lag distributions provide a more complete description of the present data than the mean output position curves presented in Figures 3 and 4. For example, the peaks at Lag 9 of Conditions R and W indicate not only a recall of the first item in the list but also the subjects recall a sequence of words in a forward order (e.g., 1, 2, 3, 4, . . . ). However, the curves in Figures 3 and 4 suggest that they do not. What the curves for Conditions R and W show is a tendency to start with the first word, then recall words near the end of the list with intrusions of Items 2 or 3, and then finally items in the middle of the list are recalled. Also, from the lag distributions it can be determined whether a recall sequence is an example of forward or backward output order provided a certain starting point near the end of the list had been used. (This was the case in Conditions R and W.) No such conclusion could be drawn from the mean output position curves.

## DISCUSSION

The present two experiments have shown that visual presentation conditions with richer spatial cues do not increase recall performance in the recency part of the serial position curve. Therefore, the typical modality effect (superior recall of auditorily presented words as compared to visually presented words) cannot be attributed to a handicap resulting from the typical visual presentation, where each word is presented one at a time and with each word overwriting its predecessor.

The data have also suggested that output order might be an important feature of free recall data. Investigators of the modality effect may have suspected that lists of visually presented words are recalled in a different order from lists of auditorily presented words. To explore this possibility, the lag distribution curves for the data of an experiment reported by Murdock and Walter (1969, Experiment 1) were constructed and are shown here in Figure 7. There does indeed seem to be some difference, and the pattern is similar for the fast presentation rate (two words per sec) and the slow presentation rate (one word per sec). In both cases, the lag distribution function is monotonically decreasing for visual presentation but appears to increase and then decrease for auditory presentation.

This finding is consistent with the possibility that visual presentation results in a backward order of recall while auditory presentation gives an initial forward order of recall. That is, it could be that, with auditory presentation, subjects recall the last few words in the list in forward order and then recall the remainder as best

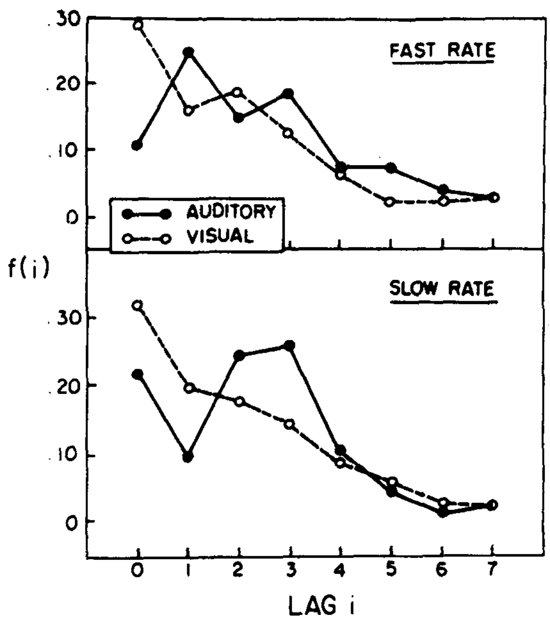


**Figure 7. Lag distributions for auditory and visual fast and slow presentation (Murdock & Walker, 1969, Experiment 1).**

they can. However, this point is not conclusively demonstrated by the data shown in Figure 7 since a given lag distribution can arise in several different ways. However, auditory-visual differences in recall order, whatever their exact nature, are consistent with the general view of modality-specific short-term stores; see, e.g., Murdock and Walker (1969) and Nilsson (1973).

In conclusion, the results of the present experiments have demonstrated three things. First, four conditions of visual presentation with progressively increasing spatial cues were investigated in two experiments and it was found that these spatial cues did not affect total recall in the conditions in a different way. When analyzing the data as a function of serial position, it was found that there was better recall in the prerecency part of the serial position as more and richer spatial cues were involved in the presentations. Uncertainty arose as to what consequences the spatial cues might have had on the recency part of the curve. For the two conditions containing the richest spatial cues there was no or a very unusual recency effect, while the recency effect was normal for the conditions with the poorer spatial cues. Thus, it seems reasonable to rule out a spatial explanation of the modality effect, since it can be concluded that the spatial cues do not, at least, facilitate recall of items in short-term memory. The present study, therefore, supports Murdock (1969) in criticizing such an explanation of the modality effect. Recall from short-term memory of visually presented words is not disfavored by the fact that most modality experiments have been carried out in situations containing temporal cues but only a minimum of spatial cues. However, the fact that spatial cues facilitated recall of prerecency items certainly suggests more investigations of the role of spatial cues in memory.

Second, the effect of output order seems to be an important feature of free recall data. A new method of describing these effects was suggested and it was found that one could be somewhat more specific about the output order than when a method suggested by Deese and Kaufman (1957) was used. It was also suggested that a backward output order may be the typical result of visual presentation, while auditory presentation results in a forward output order with a starting point near the end of the list. Third, it was demonstrated that essentially the same effects were found when using a within- and a between-subjects design. In general, the effects were somehwat more pronounced in a between-subjects design than in a within-subjects design. It is, therefore, suggested that the questions raised by Poulton (1973) ought to be taken into consideration when conducting experiments with visual and auditory presentation, or possibly in any experiments where output-order effects are of relevance.

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