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# ORDER AND NUMBER REQUIREMENTS IN IMMEDIATE SERIAL RECALL[1]

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Eight groups of 16 *S*s recalled 10-number sequences in which two order requirements and one response number requirement were imposed. Both order requirements, production order and final protocol order, significantly influenced retention and interacted with primary and recency effects within the recall sequences. Restriction of the number of responses emitted influenced only the level of performance and did not interact with any other variable. Differences in ordered retention were attributed to differential availability of recency items in recall.

The problem of order is inherent in any study of retention which involves the production of more than one response. Recent discussions of immediate serial recall have suggested that order requirements may play a crucial role in immediate retention. For example, Postman (1964) has suggested that the relative invariance in the length of the memory span may be due to order retention requirements rather than to item retention. Conrad (1959) and Crossman (1960) have suggested that the retention of item information and order information can be separated. Item information refers to the knowledge of whether or not a particular item was presented; order information refers to the extent to which an item can be correctly located in the required sequence of items. Crossman has argued that item information and order information may be stored and retrieved separately and that an increase in required retention of one type of information may produce a decrease in retention of the other.

Further investigation of order information in short-term retention depends upon distinctions between several types of order requirements. First, there is the order in which the presented items are to be arranged in the final response protocol. Examples of protocol orders frequently used in memory span studies would include forward (same as presented), backward (the reverse of the presented order), free recall (no order specified), and natural serial (rearrangement into some hierarchical, well-learned "natural" sequence such as the ordinal numbers or the alphabet). A second type of order is the order in which the items are produced or emitted by *S*. In some memory tasks, production order is constrained by other characteristics of the experimental paradigm. For example, in oral recall, the production order usually must be the same as the required final protocol order. In written reproduction, however, *S* often is free to emit the responses in any order and is required only to have the final form of the response protocol in the specified order. A third type of order may be specified in scoring recall sequences. Recall may be scored as correct or incorrect according to position in the presentation sequence or position in the produced recall sequence. Most commonly, an item must be in the same recall position as its presentation position to be scored as correct.

The purpose of the present study was to examine the effects of these three types of order on the short-term retention of serially presented items. Two types of order requirements, production order and protocol

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order, were manipulated and the third type of order variable, scoring order, was considered by employing two scoring procedures. Written recall of the sequences was used in all conditions, but the production order was either strictly constrained to be consistent with the final protocol order or else the production order was not specified and *S* was free to produce the items in any order. The final protocol order of the presented items was either to be in the same order (SO) as originally presented, or in natural serial (NS) order. Both presentation-order scoring and recall-order scoring were used to examine serial position effects.

All order requirements potentially could be influenced by the number of responses produced by *S*. If left free to vary, the number of responses might be expected to interact with the order variables. That is, some protocol or production orders might be more conducive to producing more responses, and hence more correct responses, than other orders. For example, one possible advantage of NS recall over SO recall is the fact that more responses are produced in NS recall (Buschke & Hinrichs, 1968). On the other hand, similar arguments might be made that requiring the emission of a fixed number of responses might differentially affect the ordering of responses by constraining efficient or well-learned retrieval systems. Consequently, the number of responses, either restricted or unrestricted was introduced as a third independent variable.

## Method

*Design.*—The eight conditions in the experiment consisted of the $2 \times 2 \times 2$ combination of three factors: protocol order, response production order, and response number. Protocol order refers to the order in which the the responses were required to appear in the final written response protocol. The required protocol order was either natural serial (NS) or the same as the presentation order (SO). In NS recall, *S* was required to reorder the presented numbers and produce them on his answer sheet in their ascending numerical order. In SO recall, *S* was required to reproduce the original serial presentation order as closely as possible. Response production order refers to the constraint or lack of constraint on the order in which the responses were to be emitted and recorded by *S*. In the controlled production (CP) conditions, *S*s were required to record the responses in a strict left-to-right order on their answer sheets. In the uncontrolled production (UCP) conditions, *S*s were allowed to produce and record their responses in any order, limited only by the recall order required in the final response protocol. The third factor, number of responses, was either restricted or unrestricted. In the restricted number conditions, *S*s were required to produce exactly 10 responses; in the unrestricted number conditions, the number of responses to be produced was not specified.

An additional within-*S* variable was introduced to allow examination of serial position effects in each condition. The 10-item presentation sequence was divided into two halves with Serial Positions 1–5 designated as the primacy component and Serial Positions 6–10 as the recency component.

*Materials.*—Each *S* was required to recall 20 sequences during the course of the experimental session. The sequences each consisted of 10 numbers drawn from random permutations of the numbers from 1–20 inclusive; no number was used more than once within each sequence. The same set of 20 sequences was used in all eight experimental conditions.

*Procedure.*—The stimulus numbers were presented aurally via a tape recorder at a 1/sec rate with the end of each sequence signaled by the word "recall." The *S*s recalled each presented sequence by writing the numbers in boxes on answer sheets with 10 boxes provided for each sequence. Each *S* was assigned to one of eight groups according to a prearranged random schedule with a total of 16 *S*s per group. Each group received instructions appropriate to the particular combination of conditions under which it was required to perform.

*Subjects.*—The *S*s were 128 University of Iowa undergraduates fulfilling an introductory psychology course requirement. The *S*s were tested in small groups of two, three, or four members, and were screened from each other's view.

## Results

A presented item was scored as correct if it appeared in the response sequence, regardless of its position in the response protocol. If a presented number appeared more than once in a response sequence, it was scored as a correct response the first time, but not thereafter.

Table 1 shows the overall performance for each treatment condition. The first and second half scoring shown in Table 1 is by presentation order; intrusions are responses which were not part of the set of 10 numbers presented. Repeated responses are items which occurred more than once in the recall

TABLE 1

MEAN NUMBER OF CORRECT RESPONSES AND ERRORS PER RECALL SEQUENCE AS SCORED BY SERIAL POSITION IN PRESENTATION ORDER

| Number | Cond. | | Performance measure | | | |
|---|---|---|---|---|---|---|
| | Production order | Protocol order | 1st Half | 2nd Half | Repeated responses | Intrusions |
| Restricted | Controlled production (CP) | Natural serial (NS) | 3.56 | 4.12 | .05 | 2.27 |
| | | Same order (SO) | 3.70 | 3.18 | .50 | 2.62 |
| | Uncontrolled production (UCP) | Natural serial (NS) | 3.73 | 4.17 | .03 | 2.06 |
| | | Same order (SO) | 3.52 | 3.91 | .37 | 2.20 |
| Unrestricted | Controlled production (CP) | Natural serial (NS) | 3.51 | 3.77 | .04 | 1.53 |
| | | Same order (SO) | 3.57 | 2.74 | .36 | .93 |
| | Uncontrolled production (UCP) | Natural serial (NS) | 3.21 | 3.87 | .01 | 1.62 |
| | | Same order (SO) | 3.36 | 3.72 | .38 | 1.04 |

protocol and include both repeated correct responses and repeated errors. Further analyses were based on a four-way analysis of variance of the correct responses with the response number requirement, protocol order, production order, and serial position half as factors in the analysis.

When *S*s were not required to produce exactly 10 responses, the observed mean number of responses was 8.42. The reduction in the number of responses produced by the unrestricted groups also resulted in a significant reduction in the mean number of correct responses, $F$ (1, 120) = 24.96, $p < .001$, with 7.47 correct responses per sequence in restricted recall and 6.94 correct in unrestricted recall. However, the response number requirement did not interact significantly with any other factor or combination of factors, all $p$s > .05, and further analyses were pooled over the response number factor.

*Presentation order analysis.*—When recall was scored by the order of the correct items in the presented sequence, the effect of both primacy and recency factors on recall performance was demonstrated. Figure 1 depicts the four recall conditions, pooled over response number, by serial position and illustrates the differences confirmed by the statististical tests reported below.

The overall result of requiring *S*s to emit their written responses in a strict left-to-right order was to reduce the mean number of correct responses from 7.37 in the UCP condition to 7.04 in the CP condition, $F$ (1, 120) = 9.65, $p < .01$. However, production order has a differential effect across protocol orders and across serial position, as shown by several interactions. The Production Order × Protocol Order interaction was significant, $F$ (1, 120) = 9.11, $p < .01$, with no difference between UCP and CP performance in NS recall, $p > .10$, but with UCP performance superior to CP performance in SO recall, $p < .001$. The NS recall groups were superior to SO groups under CP, $p < .001$, but not under UCP, $p > .05$.

The Production Order × Serial Position interaction was significant, $F$ (1, 120) =

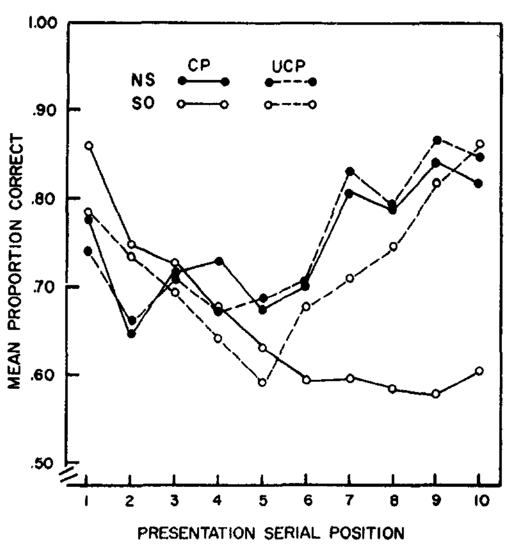


FIG. 1. Mean proportion of responses recalled as a function of serial position in the presented sequence.

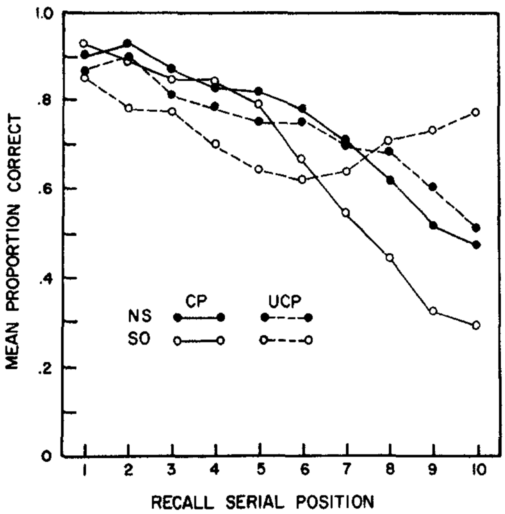


FIG. 2. Mean proportion of responses recalled as a function of serial position in the recall sequence.

12.83, $p < .001$, supporting the contention that the greatest disruption produced by order retention requirements occurs in the last half of sequences which must be recalled and produced in the same order as they were presented. In the SO groups, the Serial Position × Production Order interaction was significant, $F(1, 62) = 20.72$, $p < .001$, with first-half performance superior under CP, $p < .01$, and second-half performance superior under UCP, $p < .001$. Unlike the other conditions, the SO-CP condition produced a virtually monotonic decreasing recall function over presentation serial position (Fig. 1). The difference between SO-CP and the other conditions was further confirmed by the Serial Position × Protocol Order interaction found in CP, $F(1, 62) = 42.15$, $p < .001$, in which second-half performance decreased in SO and increased in NS recall. All other combinations of order and number requirements tended to produce the usual bowed serial position functions with small differences in the absolute level of performance. Within the NS groups, the Serial Position × Production Order interaction was not significant, $p > .10$. In NS recall, recency effects dominated with recall of the second half of the presented sequences superior to first-half recall in both CP and UCP, $p < .001$.

*Recall order analysis.*—When recall was scored by the order of the correct items in recall sequence, a general primacy effect was found except in the SO-UCP groups. As shown in Fig. 2, the bowed serial position curve was found for the SO-UCP condition as it was for the presentation serial position curve (cf. Fig. 1). Apparently, production of a monotonically decreasing recall function in the SO-UCP condition is prevented by distributing the recall of responses to maintain an approximately equal probability of correct recall at all positions in the response sequence. For the other three conditions, however, a generally monotonically decreasing function was found with the greatest decrement in performance occurring in the SO-CP condition.

## DISCUSSION

Performance in the NS conditions was generally superior to SO performance, confirming previous research (Buschke, 1967, 1968; Buschke & Hinrichs, 1968). The fact that the difference between NS and SO performance was found under both restricted-number and unrestricted-number instructions shows that the difference cannot be attributed to differences in the number of responses produced when response number is allowed to vary. However, NS and SO recall did not differ when production order was not controlled, suggesting that the order in which responses are produced plays a critical role in the difference between retention of item and order information. Controlling the order in which responses were to be produced resulted in a sharp decrement in SO performance but not in NS performance. A large part of the difference between NS and SO recall in the CP conditions can be attributed to the greater loss of the recency items in the SO recall condition. Under CP, the last-presented items cannot be produced until the end of the response protocol is reached in SO recall, producing a drop in performance. In NS recall, the recency items are scattered throughout the response protocol resulting in less debilitation in performance. This contention is supported by the Protocol Order × Production Order × Serial Position interaction, where a difference exists between NS and SO in second-half performance and not in first-half performance and only in the CP condition and not in the UCP condition (cf. Fig. 1). Hence, at least part of the superiority of NS recall over SO, in previous research, can be attributed to the superior recall of the last-presented items in NS recall.

Superior recall of the recency items in the NS and the SO-UCP conditions may also help to account for the difference between written and spoken recall (Murray, 1965, 1966). The present results are consistent with the suggestion by Murray (1966) that written recall is generally better than spoken recall because written recall permits greater flexibility in the order of producing the recall responses. Only written recall was tested in the present study, but the method of restricting response production in the CP conditions is comparable to the restriction imposed by spoken recall. Consequently, the same argument invoked above, with regard to differential retention of recency items to account for the difference between NS and SO recall, may be used to explain superior SO written recall. Specifically, when response production is restricted, as in spoken recall or in the present CP conditions, the last-presented items are not recalled as well as when greater freedom in response production order is allowed.

Finally, and not surprisingly, recall performance was higher in all conditions in which 10 responses were required than in conditions in which the number of responses was allowed to vary. The fact that superior performance resulted when 10 responses were required can be attributed to the fact that fewer than 10 responses were produced when *S* was free to choose the number of responses to be made. Hence, by guessing alone, superior performance would be expected in the restricted number condition. More interesting, however, is the finding that the number of responses produced did not interact with any of the order variables. Neither production order nor the final protocol order to be produced was differentially affected by the control or the failure to control the number of responses to be produced.

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