On Interfering with Item versus Order Information in Serial Recall

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After learning a 15-word list, the subjects either rested (R), learned two new lists of words (B), or learned two rescrambled orders of the original words (Ar). Tests of retention (serial recall, reconstruction) over the original list showed that group B suffered loss mainly in item availability but not in order information, whereas group Ar was the reverse, with a large loss in order information but not item availability. A memory model incorporating contextual and sequential associations is proposed.

As modern interference theory of forgetting has evolved and been progressively refined (see reviews by Keppel, 1968; Postman and Underwood, 1973), there has been a concomitant refinement and restriction of the experimental paradigms used to gather evidence on the theory. Investigators have relied increasingly on studies of the retention of paired associates after a few standard conditions of interpolated learning: A-B, A-C; A-B, C-B; A-B, C-D; A-B, A-Br; and so on. For instance, in his scholarly review of critical studies of proactive and retroactive interference, Keppel (1968) hardly cites any experiments using paradigms other than the paired-associates paradigm.

The testing ground for interference theory has not always been so restricted. Earlier studies of interference used a variety of learning tasks, most notably serial learning. The judgment of recent research is that the serial-learning situation is too complex, poorly understood, and subject to strategic variations for it to serve as a simple procedure for testing hypotheses about sequential learning (see, e.g., Young, 1968). Because the search for the effective stimulus in serial learning has proved frustrating if not nonrewarding, there has been a correlated neglect of research on *retention* of serially learned lists. But the two issues — how to characterize learning, and what influences retention — are separable.

The present study aims to apply to the retention of a serially learned list some principles suggested by recent research on interference in the retention of paired associates. We will focus in particular on a study by

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Postman and Stark (1969) that suggested a sharp distinction between two factors in paired-associate recall: (a) general availability of the first-list responses, and (b) item-specific associations between stimulus and response terms. Postman and Stark evaluated the relative importance of these factors in retention by comparing recall and recognition of initial A-B pairs in three conditions of interpolated learning: using the same stimuli but with new response terms (A-C), repairing of the same stimuli with old responses (A-Br), or using new stimuli paired with new responses (D-C). Recall was greatly reduced by all conditions of interpolation, whereas pair recognition was greatly reduced only by the A-Br interpolation. These data along with more recent studies (reviewed by Postman and Underwood, 1973) suggest two principles: first, that interpolated learning of any similar (but different) responses reduces the availability of the first-list items as responses; and second, that some specific associative loss ('unlearning') occurs for an original A-B pair when a different response must be associated to the stimulus. This specific associative loss is much greater for the A-Br than for the A-C condition. The general implication is that subjects in the A-C and D-C conditions will show large losses in response availability ('recall') but little loss in specific associative pairing ('pair recognition'), whereas subjects in the A-Br condition will show little loss in response availability but large losses in recognizing the initial pairings.

It is a simple matter to adapt these procedures and principles to the retention of a serially learned list. After the subject learns a first serial list (call it A), we have him either rest, or learn a second list of new items (call it B), or learn a second serial ordering of the same items (call this Ar for 'reordered A terms'). We then ask him for full serial recall of the first list, and finally we ask him for reconstruction of the first list's original order after making the items available to him (on cards). Generalizing from the principles above, we may expect the B interpolation to produce a large loss in availability of the A responses, while the Ar interpolation should produce little if any loss in response availability but poor recall of the items' original order. Thus, by the recall test as a measure of retention, subjects in the B condition will do worse than the controls, who learned no second list, but not as poorly as those in the Ar condition. The reconstruction test, on the other hand, measures retention of the initial ordering and not item availability. Therefore, reconstruction of the original order should show little forgetting for subjects in the B condition but large amounts for subjects in the Ar condition.

These predictions follow from the idea that remembering the serial order of items is analogous to remembering the specific associations between items in the paired-associate situation. The argument would follow if the effective stimulus in serial learning were either the serial position (so that one is dealing with a list of 'position *n*/item *n*' pairs) or the prior item in the list ('sequential chaining'), or a mixture of these. By either identification, learning a new serial order of the same items (Ar) should cause more unlearning of the earlier associations than would learning a series of new items. The following experiment tested the above predictions.

METHOD

Design — Three groups of subjects learned list A, then either learned two interpolated lists or did an unrelated rating task for an equivalent time (the 'rest' controls, group R), then were tested for serial recall and finally for reconstruction of the order of the initial list. Two interpolated lists were given in an effort to increase the amount of forgetting. The interpolated serial lists for one group were new items (group B); for the other group, the interpolated lists were rescrambled orders of the initial list of words (group Ar).

Subjects — The subjects were 36 Stanford undergraduates fulfilling a service requirement for their introductory psychology course. They were tested individually, being assigned to the three treatment conditions in random alternation as they arrived. There were thus 12 subjects per condition.

Lists — The initial list, A, was composed of 15 high-frequency concrete nouns selected from the Paivio, Yuille, and Madigan (1968) norms so that their concreteness ratings exceeded 5.00. They were selected to avoid obvious strong preexperimental interassociations. Three different versions of this set of words were prepared. In each version, a given word was assigned a new position and different neighbors than in the other versions. A third of the subjects in each group learned each version as their initial list. For subjects in group Ar, the other two (rescrambled) versions were learned as the two interpolated lists. Subjects in group B learned two interpolated serial lists of new words, selected by the same criteria as before and without obvious connections to the items in the first list.

Procedure — Learning proceeded according to a study/test procedure. The items on the list were presented at a rate of one every 2 sec in the window of a memory drum. The list was preceded by the phrase "Start of List" and was terminated by a row of asterisks. After the asterisks had appeared, the memory drum was stopped and the subject tried to recall the complete list by writing the words in the appropriately numbered spaces in the column on his recall sheet. The instructions specified that he could recall in any *temporal* order so long as he wrote the words in the spaces corresponding to their temporal positions in the presentation. (A predominant strategy, therefore, was for the subject first to write down the final few items before turning to recall of earlier items.) The subject had 90 sec to complete his recall sheet, before he handed it to the experimenter to grade. After a 10-sec pause, the memory drum was turned on to present the list again.

The initial learning was carried out to a criterion of at least 13 correctly positioned items recalled out of 15. This required an average of about five trials. Thereafter, subjects in groups B and Ar received four study/test trials on each of two interpolated lists. These lists were presented by the same memory drum but appeared at a different location in the drum window. Mean recall of each interpolated list was almost perfect by the end of the fourth trial for each group.

The subjects in group R examined cartoons (from "Peanuts") and rated each of them for their funniness (on a five-point scale). They did this for 20 min, a time equivalent to that required for interpolated learning in the other groups.

To measure retention, the subject was first asked to recall (in writing) the first list he had learned. He was asked to write items in their original serial order; but if he could remember items and not their order, he was to put them down in any guessed order. He was allowed 3 min for this recall. Thereafter, the reconstruction test was given: the subject was handed a shuffled packet of 15 cards, each containing an item of the first list. He was asked to examine all the items and try to reconstruct their original order, laying the cards in a column on the table before him. The subject indicated when he had reconstructed the order as best he could remember it. After recording this order, the experimenter debriefed the subject. Questions at this point indicated that only a few of the subjects expected to be tested for their retention of the first list.

RESULTS

Performance was scored in terms of the number of items correctly recalled in their correct serial location. This stringent scoring is highly correlated with any other more lenient measure of serial recall one might adopt.

Initial learning

By the misfortunes of random sampling, the three treatment groups differed reliably [$p < .05$] in their rate of learning the first list. The trial on which the 13/15 criterion was met averaged 4.0 for group Ar, 4.3 for group B, and 6.5 for group R. This unanticipated difference need not disturb later comparisons of retention, since within this experiment, the number of trials to criterion on the first list was uncorrelated with later retention. For instance, within group R the correlation between trials to criterion and final recall was only −.04. Dividing each group at the median into fast and slow learners and then pooling across groups, the final retention score averaged 8.1 (out of 15) for the fast learners and 8.4 for the slow learners. So, apparently, we may ignore possible complications introduced by these chance differences between groups in their rates of first-list learning.

Interpolated learning

Group Ar, whose subjects learned the rescrambled orders of the first list as their second and third lists, performed more poorly on these interpolated lists than did group B, whose subjects learned sets of new items on their interpolated lists. Total errors (omissions plus misorderings) over all four trials on the second list averaged 25 for group Ar compared to 16 for group B [$t(22) = 2.00$, $p < .07$]. During learning of the third list, average errors were 22 for group Ar and 13 for group R [$t(22) = 2.21$, $p < .05$]. Clearly, reordering an old set of words is more difficult than learning the items and order of a new set. The relations between these two transfer groups should, in general, depend on the relative difficulty of the order-learning and response-learning components of the serial task involved. The reader is cautioned that the Ar and B lists compared above contained different items, so any effects due to lists are not counterbalanced.

Retention

The data of primary interest are the results on first-list retention. These are summarized in Table 1 for the three groups for three different performance measures. Column 1 displays ordered recall, which means recalling the right first-list word in the correct serial position. Relative to the controls, group R, group B showed significant forgetting [$t(22) = 1.96$, $p < .05$, one-tailed], whereas group Ar showed an even greater retention loss [$t(22) = 2.34$, $p < .05$]. The difference between groups R and B in ordered recall was very significant according to a median test [$\chi^2(1) = 6.0$, $p < .02$].

The theory implies that these observed differences in ordered recall are a composite of effects on two other components, namely, response availability and order information. Subjects in group B should perform poorly because they lose access to their old first-list responses (availability declines), but should nonetheless not have unlearned or mixed up the

Table 1. Average first-list retention (out of 15) by three different measures

	Ordered recall	Unordered recall	Ordered reconstruction
Group R	12.0	14.6	13.2
Group B	8.6	11.8	12.1
Group Ar	4.2	13.2	5.2

order of those first-list items they can recall. In contrast, subjects in group Ar should have the first-list responses readily available (since they studied the same words on all three lists), but should have unlearned the first-list order because it was rescrambled on the second and third lists.

The results relevant to these expected patterns are shown in columns 2 and 3 of Table 1. The measure of unordered recall (first-list items recalled regardless of serial order) is a rough index of response availability; it is rough because subjects might have withheld responses whose order was unknown. In any event, by this index of response availability, group B was clearly below group R [$t(22) = 3.94$, $p < .01$], whereas group Ar was about as high as group R [$p > .05$].

The measure of ordered reconstruction (column 3) also shows the expected pattern: groups R and B performed equally well and both significantly exceeded the performance of group Ar [$p < .001$ in the latter comparisons].[1] This result suggests that while interpolation of B lists disrupted item availability, it did not disrupt the subjects' knowledge of the order of the first, A, list.

Further testament to that conclusion is supplied by this conditional analysis: Given that the subject recalled a first-list item on the retention test, what is the likelihood that he remembered its correct serial position? These conditionalized percentages averaged .80, .70, and .34 for groups R, B, and Ar, respectively. The first two proportions do not differ significantly, whereas both differ reliably from the third. This pattern corroborates the conclusion that subjects in group Ar forgot order but not items, whereas subjects in group B forgot items but not the order of the items that were available.

DISCUSSION

The retention results are a rather exact analogue in serial recall of the results obtained by Postman and Stark (1969) in paired-associate recall. The theoretical explanation can be obtained by identifying the 'item information' and 'order information' components of serial learning with the 'response availability' and 'specific associations' components of modern two-factor accounts of interference and forgetting. One could formulate these speculations in several ways. For expository purposes, let us consider just one possible specification of the relationship among item and order components. The diagram in Figure 1 shows a network of associations that might represent the memory structure encoding the serial list beginning **a b c d**. Two classes of associations are indicated: connec-

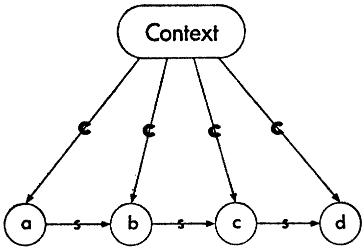

Figure 1. An associative network encoding the serial list a b c d; the arrows represent context-to-item associations, C, and sequential associations, S

tions labeled C go from the experimental context to the items of the list, and connections labeled S are sequential associations among adjacent items. In this representation, item availability corresponds roughly to the context-to-item (C) associations, whereas order information corresponds to the sequential (S) associations.

Finally, a single unlearning assumption is needed: Whenever an element in the diagram must be associated to new elements, there will be some weakening (or reduced availability) of earlier learned associations from that element. Therefore, if a new series of items (x, y, z, w) is learned as an interpolated list, these items will become associated to the context, with a consequent weakening in the availability of the prior C associations to items a b c d. However, learning of the x y z w list leaves intact the sequential associations in the a b c d list. On this basis, serial order could be reconstructed although the items could not be recalled.[2]

Consider, on the other hand, what occurs if the interpolated list is a scrambled version of the first list, say c a d b. Since the same items are repeated, there will be no weakening of the C connections, so there will be no loss in item availability. However, the items now occur in new adjacent associations, leading to a weakening of the prior sequential connections. This should be reflected, in turn, in a loss in the ability to reconstruct the original order of the first list.

The model sketched above is doubtless oversimplified, and such order information is probably represented in more complex ways than by simple chains of adjacent associations. However, to accommodate the present findings, any more complex model would still require parts that are functionally equivalent to the item-availability and order-information components that are salient in the model of Figure 1.

In conclusion, we have found that detailed predictions of modern interference theory work out well when tested in a serial-recall situation. In particular, the theory correctly predicts procedures that will cause independent forgetting of item versus order information in serial recall.

Notes

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1. Incidentally, the fact that the ordered-reconstruction score was below the unordered-recall score for Group R is an artifact of scoring a subject as having made two errors whenever he misordered a given pair in the reconstruction test.

2. One interpretation of Figure 1 would suggest that first-list recall following x y z interpolation will be perfect if the subject is always cued with the preceding item. This is surely incorrect. But one could in theory avoid this implication by supposing that series recall depends on the *conjunction* of sequential and contextual associations, so that a weakening of the C connection will reduce the apparent cuing effect of the prior item.

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