Progressive decay of the memory trace

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The effects of delay on recall of material in short-term memory were studied by presenting a sequence of items and requiring ordered recall either immediately after presentation or after 1½ min. Although the total number of errors made did not increase significantly as a result of delay, errors concerned with the ordering of the items were evident even when the material was recalled immediately, but these were replaced by errors concerned with the selection of items themselves when recall was delayed.

Short-term memory is often investigated by presenting a list of items just once and asking for recall shortly afterwards. It has been customary to require the items to be reproduced in correct order, and when a S attempts to do this he is prone to two types of error. First, items are recalled that did not appear in the original message (intrusion errors), and second, correct items may be given in the wrong order (transposition errors). This distinction was first made by Bolton (1892), who also remarked that the two types of error appeared to occur at different stages of memory. "Memory images pass through three stages in leaving the mind. First, they suffer a confusion of order; second, a loss of certain elements and the substitution of associated elements; and third, a complete loss of some elements and no recovery [Bolton, p. 380]."

The decay of the trace representing the items in a verbal message has been investigated by Conrad (1967), who varied the interval between the presentation of four consonants and their recall. When the delay between presentation and recall was 2.4 sec, intrusion errors tended to be items acoustically similar to those they replaced (e.g., B may have been replaced by V, M by N etc.). With a delay of 7.2 sec, intrusions were less strongly acoustically related to the items for which they were substituted but tended to be more random. Thus, as Bolton suggested, certain elements are lost as the trace decays, and, for verbal material, these appear to be of an acoustic nature.

Less is known about the decay of the trace representing the temporal order of items in a message. Brown (1959), like Bolton, has suggested that information

about order decays rapidly. His model, based on information theory, states that memory traces are coded with varying amounts of redundancy, traces for order being less redundant than those representing the items. Even after considerable decay, a highly redundant item trace may preserve sufficient information to guarantee a correct response, but order traces, not being well protected in this way, may have insufficient information in them to prevent transpositions after even short retention intervals. On this view there should be a change in the type of error made at different retention intervals, transpositions being dominant soon after hearing a message showing a rapid loss of order information and their place being taken later by intrusions as item information is lost.

Twenty Ss, all undergraduates from Cambridge University, heard the same tape-recorded message of eight words, spoken at the rate of one word/second. The words were: MAP, ARM, CUP, BAG, SAW, KEY, EGG, PAN, and OAK. All came from Thorndike & Lorge's (1944) A or AA frequency lists. Ss were told to remember the words in correct order. Ten Ss served in the first recall condition, in which they were told immediately after

Table 1
The Mean Number of Intrusions and Transpositions Made in Recall of the 8-Item List Immediately After Presentation or After a 1½-Min Delay

	Immediate Recall	1½-Min Delay	Mean Total
Intrusions	3.2	5.0	4.1
Transpositions	3.3	2.0	2.7
Total	6.5	7.0	

presentation to write down the eight words, guessing any items that they had forgotten. The other 10 Ss served in the second recall condition in which recall was delayed for 1½ min, during which time they received instructions for another experiment. They were then required to write down the words in correct order, guessing forgotten items.

RESULTS AND DISCUSSION

The results are presented in Table 1. It can be seen that while there is little increase in the total number of errors made as the retention interval is increased from immediate recall to 1½ min delay, a greater proportion of the immediate recall group's errors are confusions of order. An analysis of variance for a split-plot design was performed. The overall effects of delay were insignificant, but the F for error type was significant ($F = 9.14$, $df = 1/18$, $p < .01$). This appears due to the interaction between error type and delay ($F = 10.45$, $df = 1/18$, $p < 0.01$), which shows a significant tendency for the number of transpositions to decrease from immediate recall to 1½ min delay.

The result of this experiment is therefore compatible with the views of Bolton and Brown, that the short-term trace is most susceptible to loss of information about the ordering of items. Immediately after presentation, recall of items is accurate, but already memory for their positions is poor. After a delay, memory for the items themselves has worsened and intrusions are the dominant type of error. Since the conducting of this study, Murdock & vom Saal (1967) have published data that supplements this finding. Their Ss recalled three-word messages after delays of 3, 9, and 18 sec. It was found that as the retention interval increased so did the number of transposition errors. Thus it seems that the memory traces for items and their temporal order decay over time, but that those for the latter deteriorate more rapidly.

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