

Recall instructions and the suffix effect

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Performance on the last few items of a 12-word list was impaired when a spoken "Recall" was used as the cue for recall, relative to performance with a nonverbal cue. This suffix effect occurred with four types of recall instructions after auditory presentation, including instructions for conventional serial and free recall. Even when subjects were instructed to recall the last few items first, there was slight impairment with the suffix. The present experiment raises a problem for the notion of a system of precategorical acoustic storage in that a smaller suffix effect was expected with instructions that delayed recall of the last few items, yet the magnitude of the effect was roughly equivalent with the different instructions. Three potential solutions to this problem are outlined.

Crowder and Morton (1969) have provided evidence of a peripheral auditory storage system that holds information in prelinguistic form. This storage system is referred to as precategorical acoustic storage (see Morton, 1970, and Crowder, 1972, for summaries). It is considered to be more or less directly observed in three ways. The first of these is the *modality effect* — the superiority of auditory to visual presentation in recall of the last few elements of a list (e.g., Conrad and Hull, 1968). This effect has been found repeatedly in immediate recall with different stimulus vocabularies and a variety of instructions about recall (e.g., Craik, 1969; Murdock and Walker, 1969), and it is attributed to availability of additional echoic information that aids recall in the case of auditory presentation. A second manifestation of a precategorical acoustic storage is the *suffix effect* — the deleterious effect on recall of the last few elements in an auditory series of adding a redundant acoustical element (a stimulus suffix) at the end of the series. The suffix is assumed to degrade or displace the information in precategorical acoustic storage and thus eliminate the advantage that normally accrues to the last few items in auditory presentation (Crowder and Morton, 1969). The third way in which a precategorical acoustic storage is observed is what might be called the *partial-report effect* — the advantage of partial to whole re-

port in a multichannel listening paradigm and, more importantly, the rapid decay of partial relative to whole report when the signal to report is delayed (Darwin, Turvey, and Crowder, 1972; Treisman and Rostron, 1972).

It is an unfortunate fact that although these three effects all potentially converge on the same memory system, the vast majority of work that is in any sense analytic has been restricted to the suffix effect. This restriction is unhealthy, since it forces one to accept on faith alone that the principles isolated there will apply to other kinds of memory. These experiments have been conducted with limited stimulus vocabularies such as digits, letters, and sets of three CV nonsense syllables (thus involving repeated presentation of the stimuli) and strict serial recall of the to-be-remembered elements. The primary exception to this generalization is a report by Engle (1974) that appeared after completion of the present study.

Unusual importance is attached to the question of the generality of the suffix effect in diverse situations because even in the rather limited situations of past experiments, the suffix effect was not always found. In particular, it was not found in the recall of CV syllables that varied only in stop consonants (Crowder, 1971) and was attenuated in the recall of syllables that varied only in fricatives or vowels of short duration (Crowder, 1973a, 1973b). Evidently, precategorical acoustic storage does not hold certain phonemes or holds them only for much shorter periods of time. Interestingly, the modality effect was also eliminated in the recall of syllables that varied only in stop consonants (Crowder, 1971).

The primary purpose of the present research, then, was to establish the suffix effect in recall of common English words under four different types of instructions about recall. Besides the typical instructions for free and serial recall, modifications of both these tasks were employed. One group of subjects was instructed to recall the items in any order they wanted but to be especially certain to recall the last few items in the list first. Another group of subjects was told that they could write items down in any order they desired but that they were to write each item beside the number corresponding to the input position of the item in the list (free position recall). A comparison of the magnitude of the suffix effect with these different instructions is of considerable theoretical interest. Since precategorical acoustic storage is usually considered to last only two seconds or so and since the suffix effect is attributed to the displacement of the contents of that storage, one might reasonably expect the suffix effect to be greatest for the subjects instructed to recall the last few items first, smallest for the subjects instructed to use serial recall

Procedure

The subjects served in groups of 3 to 15. Before serving in the present experiment, all had served in an unrelated experiment on semantic memory that involved producing words from common conceptual categories.

The same general instructions were read to all subjects before they were told the manner in which they were to recall the lists. Everyone was told that he would hear 16 12-word lists presented at the rate of one word per second and that each list would be followed by a cue to begin his recall. The nature of the cues was explained and an example of a nonverbal cue was given. The subjects were told not to begin recall until they heard the cue and that it would be in cadence with the list.

The subjects were carefully instructed as to how they were to recall the list. The FR subjects were simply told to recall the words in any order, while the FR-LF subjects were asked in addition to "recall the last few items in the list before you recall the others. You may recall the last few and the others in any order you want. Just be sure to recall the last few first." The SR subjects were instructed to recall as many of the words as possible in strict serial order from the first to the last position, drawing a dash where they did not know the appropriate item. They were told not to start at the end and not to go back and correct any items they might think wrong. The FPR subjects were told that they were to remember both the words in the list and the order in which they occurred and that at recall they were to place items next to the appropriately numbered position on their sheets. However, they were instructed that the order in which they wrote the items down was unimportant (i.e., they did not have to write items in a strict 1-12 order as did the SR subjects).

The lists were presented in the same order for all subjects, at a 1-sec rate, by a tape recorder. The list number was spoken before each list to warn subjects that a new list was coming (e.g., "List 3"). Subjects were allowed 45 sec after each list to write their responses under the appropriate list number on the recall sheets. For the SR and FPR subjects, there were 12 numbered spaces below each list number. Subjects were told before the experiment which cue would follow the first eight lists, and there was a short break after the eighth list to remind subjects that the remaining lists would be followed by a different cue.

RESULTS

In the upper portion of Figure 1 are the data from subjects given the four types of instructions, under both suffix and control conditions. Filled circles represent performance on lists followed by a control, nonverbal, cue, while open circles represent performance on lists followed by the verbal suffix "Recall." These results are based on scoring all subjects according to the criterion for free recall, giving a subject credit for every item he recalled, regardless of whether or not he assigned it to the correct serial position if he was an SR or FPR subject. Each point is based on 320 observations (40 subjects, 8 trials). A 4 (types of instructions) \times 2 (suffix versus control) \times 12 (serial positions) analysis of variance re-

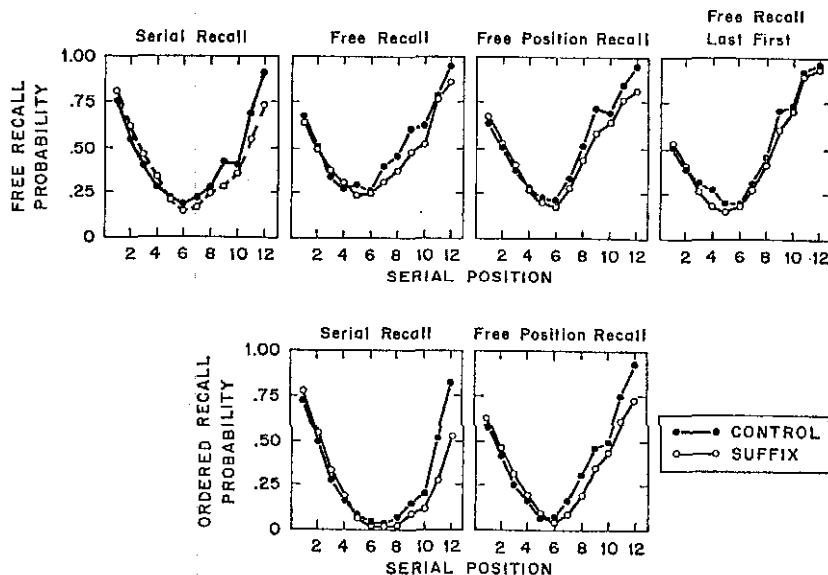


Figure 1. Upper panel shows the proportion recalled under the control and suffix conditions at each serial position for the four types of recall instructions (free-recall scoring); lower panel shows the proportion recalled under the control and suffix conditions for the instructions to use serial recall and free position recall (ordered-recall scoring)

vealed a reliable suffix effect [$F(1, 11) = 7.56$] and an effect of serial position [$F(11, 1,716) = 391.65$], but no effect of type of instructions [$F(3, 44) = 1.57$]. The suffix effect refers to the damaging effect of the redundant "Recall" on performance over the last five to seven serial positions. There was no interaction of the suffix effect with type of instructions [$F < 1$], indicating that the magnitude of the suffix effect was approximately the same under the different instructions. However, the interaction between the suffix effect and serial position was reliable [$F(11, 1,716) = 6.97$], indicating that the effect was localized at the end of the list, as it is theoretically supposed to be. The interaction of type of instructions and serial position was also reliable [$F(33, 1,716) = 15.07$]. The FR, FR-LF, and FPR subjects showed greater recency than the SR subjects, while the latter showed greater primacy. The third-order interaction was not significant.

The suffix effect seemed reliable, and it even appeared for subjects who were instructed to recall the last few items first, although it was severely attenuated by a ceiling effect in that case. The mean difference

in proportion recalled between suffix and control conditions over serial positions 7–12 was .04 for FR-LF subjects, while the comparable comparison for SR, FR, and FPR subjects revealed somewhat larger differences of .10, .09, and .09 respectively. Only 26 of the 40 FR-LF subjects made any errors at all on the last two serial positions under either the suffix or control condition. Of the 21 nontied subjects, 14 made more errors under the suffix than control condition ($p < .05$, one-tailed, by Wilcoxon signed-ranks test).

When the SR and FPR subjects were given credit only for items recalled in their correct serial order, as shown in the lower portion of Figure 1, the suffix effect was again quite obvious. In fact, the suffix effect appeared larger with this ordered-recall scoring than with free-recall scoring. This was especially true of the subjects given instructions to use serial recall; the mean difference favoring performance under the control condition over the last three serial positions was .12 with free-recall scoring and .21 with the ordered-recall measure. One might be tempted to conclude that the suffix has a specific effect on order information as well as item information, but it is also true that strict position scoring drives performance down from the ceiling and thus may simply sensitize the effect statistically.

A comparison of recall with the four different types of instructions showed that recall was poorest with instructions to use serial recall, but about the same with the other three types of instructions. The overall mean proportions of correct recall by the criterion for free recall under the control and suffix conditions respectively were serial recall, .45 and .41; free recall, .52 and .48; free position recall, .53 and .49; and free recall–last first, .51 and .47. Similarly, probability of recall by a strict order criterion was greater for the subjects instructed to use free position recall than for those instructed to use serial recall, except on the first few serial positions.

DISCUSSION

The robust suffix effect found for common English words with each of the four types of instructions indicates that the effect does generalize well beyond the rather restricted range of situations often employed in experiments studying the effect. Of special interest is the finding that the suffix damages recall of the last few items even for the subjects instructed to recall these items first. Despite near-perfect performance by these subjects, they still made more errors when the list was followed by a spoken "Recall." Beyond providing a broader empirical base for the suffix effect

than has previously existed, the present results raise several matters of interest for theory.

First, the generality of the suffix effect across a variety of instructions for recall and stimulus vocabularies strengthens its association with the modality effect — the selective advantage of auditory over visual presentation for the last several serial positions — in that both occur in a variety of experimental situations (Craig, 1969; Jensen, 1971; Murdock and Walker, 1969; Watkins, Watkins, and Crowder, 1974). The original interpretation of the modality effect by Crowder and Morton (1969) had, of course, used as its central foundation the assumption that this was the case.

Second, there are two ways in which the interaction of a suffix effect with serial position could cause misleading results. In many experiments, it is common to signal the end of the list by saying "Recall" after the last item. The present results show that this procedure is not without consequences for recall of the last few items. Naturally, if this method of cuing is used in all conditions of an experiment, the dangers are not too great. However, in some situations, the effect would not be constant. For example, Hinrichs (1968) presented a verbal cue to signal forward or backward recall either before or after presentation of the list, an experimental design which Morton (1969) showed to have produced a false conclusion through the operation of an inadvertent suffix effect. The modality and suffix effects also pose a problem for those who wish to make measurements of primary memory (Watkins, 1974). In several of the procedures that have become standard (Watkins, 1974), the rationale is to remove, statistically, the secondary-memory component. What we have shown here is that there may be a sensory-memory component mixed into the remainder, a circumstance which would lead to an inflated estimate of primary memory. One solution would be to employ visual presentation or a suffix to remove the echoic contribution; unfortunately, the evidence is at present mixed as to whether these are totally equivalent solutions (Engle, 1974; Morton and Holloway, 1970).

An unanticipated result occurred with the two types of instructions emphasizing the retention of order information, that is, the instructions for serial recall and free position recall. With both of these types of instructions, the suffix not only led to impaired recall for the late serial positions but actually enhanced recall in the early portion of the list; the enhancement over the first three positions was statistically reliable [$F(1, 32) = 4.09, p < .05$]. This crossover occurred for both free- and ordered-recall criteria. Engle (1974) has reported the same tendency. In studies of the modality effect, the comparable observation is an early advantage of visual over auditory presentation; this crossover has been

observed with both free recall (Craik, 1969; Watkins et al., 1974) and serial recall (Watkins and Watkins, 1973). Inspection of the literature shows, however, that the crossover is not by any means an invariable consequence of either the suffix or the modality effect. We have no hypothesis for this and we do not even have any sense of whether it is important. But in one sense, and although the crossover is evanescent in both the modality and suffix effects, it does provide still one more instance of communality between the two.

Although the generality of the suffix effect across stimulus materials is a great reassurance, its generality across the four types of recall instructions used here highlights what must be considered an awkward aspect of the theory of precategorical acoustic storage. The problem is that when allowances are made in the present data for ceiling effects, there were *roughly* comparable suffix effects across the four types of instructions although those four types involved quite different time delays between presentation of the last items and their recall. There is really no valid evidence on the temporal duration of that storage, but the usual assumption is that it lasts about 2 sec for ordinary material. If this estimate is anywhere close to correct, and if the suffix effect depends on precategorical acoustic storage, then why is it that the suffix effect is so large when the most time has elapsed between the input of the last items and their recall?

There are three ways out. One is to reject the dependence of the suffix effect (and, by implication, of the modality effect) on a precategorical acoustic storage in favor of some alternative mechanism. For example, one could propose that the suffix impairs the quasi-perceptual role of the last item as a distinctive anchor point. This view (see Kahneman, 1973, pp. 132-135) has never been spelled out in sufficient detail to be evaluated point by point and we do not feel responsibility for doing so here, but Crowder (1974) has identified serious problems with it. There are two ways to retain the dependence of the suffix effect on a precategorical acoustic storage and rationalize the relative independence of the effect from when actual recall of the last item occurs. One possibility (Crowder, 1973b) is that there is invariably an active, rapid, and *covert* recall of the last few items immediately after they are presented — a quick dress rehearsal during which the information in precategorical acoustic storage could be used even though the instructions might call for public, overt recall only much later. The other possibility (Morton, 1970) is that there is a passive readout process that can occur early in serial recall. That is, while the subject is initiating his serial recall by producing the first few items on the list, there is an unconscious strengthening of the last few

items by combining traces in precategorical acoustic storage with more permanent, postcategorical traces. There has been little in the way of tests between the proposed active and passive readouts, although a study by Routh (1971) seems to favor the passive. Additional evidence on these points would be especially welcome in answering the question of how, exactly, precategorical acoustic storage is useful in memory.

Finally, mention should be made of the effects of the different recall instructions *per se*. The usual finding of enhanced primacy in serial (relative to free) recall and enhanced recency in free (relative to serial) recall was replicated here. Of more interest is comparison of recall under these conditions to that obtained in free position recall, a relatively rare comparison (Waugh, 1961; Dallett, 1963; Detterman, Shine, and Moore, 1974; Gianutsos, 1972). Gianutsos (1972) reported that instructions to use free position recall allowed subjects to enjoy both the enhanced primacy of serial recall and the enhanced recency of free recall, and thus had a general advantage over instructions to use free recall because of that enhanced primacy. These results were not replicated in the present experiment despite quite similar experimental conditions (Gianutsos also used 12-word lists, a 1-sec presentation rate, multiple lists). Here, primacy with instructions to use free position recall resembled much more closely the primacy effect in free recall than the effect in serial recall. Overall recall probability was only negligibly better (.01) with instructions to use free position recall than to use free recall.

On the other hand, the present results also disagree with those of Detterman et al. (1974), who reported that when the same list was repeatedly presented, subjects given instructions for 'ordinal' (free position) recall performed more poorly on the first few trials than subjects given instructions for free recall. Somewhat similar findings have been reported by Waugh (1961) and Dallett (1963), who used slightly different instructions for ordered recall than those of Detterman et al. (1974) and the present experiment. These empirical discrepancies concerning the advantages and disadvantages of instructions for free position recall relative to those for free and serial recall await resolution, but this instructional manipulation appears to offer an attractive alternative to serial recall in assessing a subject's knowledge of order information.

Notes

The present research was supported by NSF Grant GB 15157 to Robert G. Crowder. The authors thank Leslie Roediger for her aid in scoring the data

and Larry Paul for statistical analysis. Requests for reprints should be sent to Henry L. Roediger, III, Department of Psychology, Purdue University, West Lafayette, Indiana 47907. Received for publication June 9, 1975.

References

- Conrad, R., and Hull, A. J. 1968. Input modality and the serial position curve in short-term memory. *Psychonomic Science* 10:135-136.
- Craik, F. I. M. 1969. Modality effects in short-term storage. *Journal of Verbal Learning and Verbal Behavior* 8:658-664.
- Crowder, R. G. 1971. The sound of vowels and consonants in immediate memory. *Journal of Verbal Learning and Verbal Behavior* 10:587-596.
- Crowder, R. G. 1972. Visual and auditory memory. In *Language by ear and by eye*, ed. J. F. Kavanaugh and I. G. Mattingly, pp. 251-275. Cambridge, Mass.: M.I.T. Press.
- Crowder, R. G. 1973a. Precategorical acoustic storage for vowels of short and long duration. *Perception and Psychophysics* 13:502-506.
- Crowder, R. G. 1973b. Representation of speech sounds in precategorical acoustic storage. *Journal of Experimental Psychology* 98:14-24.
- Crowder, R. G. 1974. Inferential problems in echoic memory. In *Attention and performance V*, ed. P. M. A. Rabbitt and S. Dornic. London: Academic Press.
- Crowder, R. G., and Morton, J. 1969. Precategorical acoustic storage (PAS). *Perception and Psychophysics* 5:365-373.
- Dallett, K. 1963. Practice effects on free and ordered recall. *Journal of Experimental Psychology* 66:65-71.
- Darwin, C. J., Turvey, M. T., and Crowder, R. G. 1972. An auditory analogue of the Sperling partial report procedure: Evidence for brief auditory storage. *Cognitive Psychology* 3:255-267.
- Detterman, D. K., Shine, L. C., and Moore, J. 1974. Order information and free learning. *American Journal of Psychology* 87:203-213.
- Engle, R. W. 1974. The modality effect: Is precategorical acoustic storage responsible? *Journal of Experimental Psychology* 102:824-829.
- Gianutsos, R. 1972. The order of recall and the recall of order. Paper presented at the meeting of the Eastern Verbal Investigator's League (EVIL) at the City University of New York in October.
- Hinrichs, J. V. 1968. Prestimulus and poststimulus cueing of recall order in the memory span. *Psychonomic Science* 12:261-262.
- Jensen, A. R. 1971. Individual differences in visual and auditory memory. *Journal of Educational Psychology* 62:123-131.
- Kahneman, D. 1973. *Attention and effort*. Englewood Cliffs, N.J.: Prentice-Hall.
- Morton, J. 1969. The modality of poststimulus cueing of recall order in the memory span. *Psychonomic Science* 17:224-225.
- Morton, J. 1970. A functional model for memory. In *Models of human memory*, ed. D. A. Norman. New York: Academic Press.
- Morton, J., and Holloway, C. M. 1970. Absence of a cross-modal "suffix effect" in short-term memory. *Quarterly Journal of Experimental Psychology* 22:167-176.

- Murdock, B. B., Jr., and Walker, K. D. 1969. Modality effects in free recall. *Journal of Verbal Learning and Verbal Behavior* 8:665-676.
- Paivio, A., Yuille, J. C., and Madigan, S. A. 1968. Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of Experimental Psychology Monograph* 76(1, part 2).
- Routh, D. A. 1971. Independence of the modality effect and amount of silent rehearsal in immediate memory. *Journal of Verbal Learning and Verbal Behavior* 10:213-218.
- Treisman, R., and Rostron, A. B. 1972. Brief auditory storage: A modification of Sperling's paradigm applied to audition. *Acta Psychologica* 36:161-170.
- Watkins, M. J. 1974. The concept and measurement of primary memory. *Psychological Bulletin* 81:695-711.
- Watkins, M. J., and Watkins, O. C. 1973. The postcategorical status of the modality effect in serial recall. *Journal of Experimental Psychology* 99:226-230.
- Watkins, M. J., Watkins, O. C., and Crowder, R. G. 1974. The modality effect in free and serial recall as a function of phonological similarity. *Journal of Verbal Learning and Verbal Behavior* 13:164-181.
- Waugh, N. C. 1969. Free versus serial recall. *Journal of Experimental Psychology* 62:496-502.
- Waugh, N. C., and Norman, D. A. 1965. Primary memory. *Psychological Review* 72:89-104.