

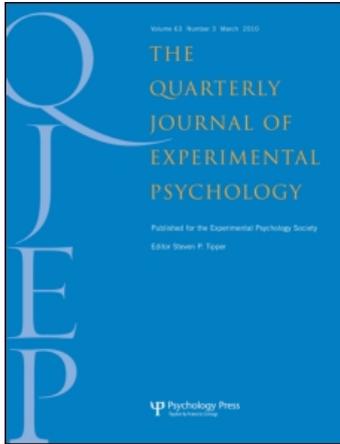
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# ABSENCE OF A CROSS-MODAL "SUFFIX EFFECT" IN SHORT-TERM MEMORY

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Three experiments are reported involving the presentation of lists of either letters or digits for immediate serial recall. The main variable was the presence or absence of a suffix-prefix, an item (tick or cross) occurring at the end of the list which had to be copied before recall of the stimulus list. With auditory stimuli and an auditory suffix-prefix there was a large and selective increase in the number of errors on the last few serial positions—the typical "suffix effect". The suffix effect was not found with auditory stimuli and a visual suffix-prefix nor with a visual stimulus and an auditory suffix-prefix. These results are interpreted as supporting a model for short-term memory proposed by Crowder and Morton (1969) in which it is suggested that with serial recall information concerning the final items following auditory presentation has a different, precatagorical, origin from that concerning other items.

## Introduction

There are two main ways of regarding the flow of information in experiments on short-term memory. In the first of these, information presented visually is recoded into an auditory form (e.g. Norman, 1966; Posner, 1967). The superiority of recall following auditory compared with visual presentation is attributed to the extra stages of processing required for the latter (see especially Posner, 1967). Sperling (1967) presents a similar model but in his case the conversion from visual to auditory coding goes via a motor code. Brown (1958) has suggested a similar function of silent rehearsal (see also Broadbent, 1958; Cohen, 1967).

The form of Sperling's model is shown in Figure 1. His is the most explicit statement of such a model and so will be taken as typical. In the model visual information is scanned and then the recognition buffer-memory "converts the visual image of a letter provided by the scanner into a program of motor instructions and stores these instructions". On rehearsal the instructions are executed and the item "is entered and remembered temporarily in auditory storage", i.e. in the acoustic information store (AIS). Further rehearsal and rehearsal of acoustically presented items is effected via the Scan system, the loop being completed as often as required.

An alternative model has been suggested by Crowder and Morton (1969). This model, shown in Figure 2, differs topologically from Sperling's in only one respect: the effect of silent rehearsal is to feed information back to the categorization system (equivalent to Sperling's scan system plus part of the recognition buffer memory) and not to the acoustic system. In addition Sperling's basic AIS

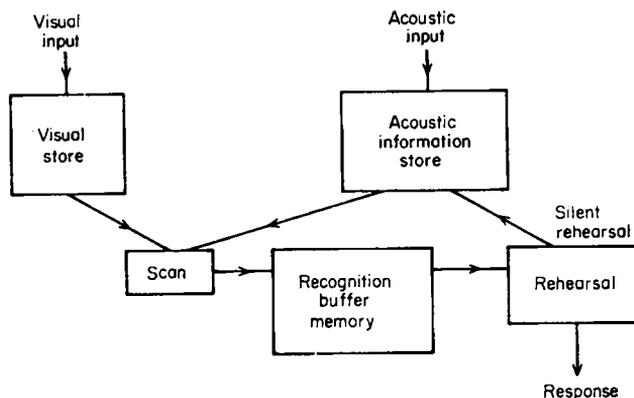


FIGURE 1. Sperling's (1967) model of the flow of information in short-term memory. The block layout differs from Sperling's, but is topologically unchanged. In Sperling's diagram there is a return line from the recognition buffer memory to the scan component. As there is no indication in his paper as to the function of this line it has been omitted.

is replaced by what Crowder and Morton rather loosely call the cognitive system. In this system, information is stored usually, but not exclusively, in a "semantic" code and within it associative effects may be found. Acoustic coding is restricted to the acoustic analysis system. Within the sphere of the present discussion information only enters this system through the ears.

Crowder and Morton (1969) have shown that a wide variety of experimental results can be simply accounted for by supposing that information can be retrieved and eliminated from the acoustic analysis system. This property of the analysis system was called precategorical acoustic storage (PAS). PAS is seen purely as a property of the analysis system and not as a memory store as such, in contrast with Sperling's AIS. It is supposed that information remains in this store for a second or two regardless as to whether the stimulus has been recognized or not, unless there is subsequent information presented auditorily.

The capacity of PAS is taken to be about three items—the extent to which there is a difference between auditory and visual presentation (Conrad and Hull, 1968). It is equivalent to the short term visual store shown by Averbach and Sperling (1961) and Sperling (1960, 1963, 1967) but has a longer decay time. Such a statement is saved from being purely *ad hoc* by the consideration that auditory stimuli, and particularly speech stimuli, are spread in time in a way that requires that a later piece of information be processed before an earlier one can be categorised (Liberman, Cooper, Shankweiler and Studdart-Kennedy, 1967).

One way of eliminating the information in PAS is to present irrelevant acoustic information following the stimulus and before recall (Crowder, 1967; Morton, 1968; Crowder and Morton, 1969). This irrelevant item is called a *stimulus suffix*, and the characteristic effect of this suffix—a large increase in the number of errors on the last three or so items—is termed the "suffix effect". It contrasts with a *response prefix*, where the subject has to prefix his response with a redundant item before recalling the stimulus list. This form of interference has an equivalent

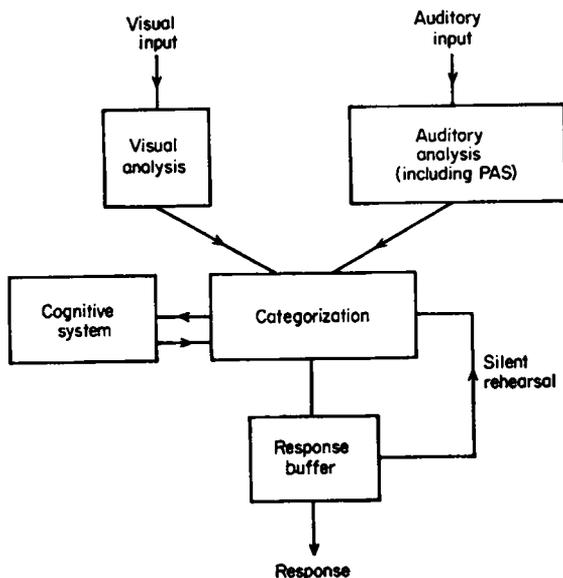


FIGURE 2. Crowder and Morton's (1969) model for short-term memory.

effect over all serial positions, and so must have a different origin from the suffix effect (Crowder, 1967).

If visual information were coded in an acoustic store as Sperling suggests, then we would expect an acoustic suffix to give rise to the suffix effect even when the stimuli were visually presented. Crowder and Morton (1969, Exp. II) showed that this was not the case. In this experiment, however, there was scarcely any effect at all of the suffix and it might be argued that the subjects were successfully directing their attention to prevent the suffix from entering the acoustic store. The first experiment reported here tests such an explanation by forcing the subjects to process the suffix fully.

### Experiment I. Visual Presentation, Auditory Suffix

#### Method

##### *Apparatus and procedure*

The stimuli were presented to groups of subjects by means of a Binaview on-line display. Each trial consisted of a sequence of six letters drawn from the set H, J, K, L, N, R, W, X, Y, and Z. The letters were presented at a rate of one every 0.75 sec., each letter being on view for 0.5 sec. with gaps of 0.25 sec. between them. Following the sixth stimulus letter the field went blank for 0.75 sec. and then was illuminated. The illumination of the field was the subjects' cue to begin to recall the letters by writing them down in the order of presentation on prepared response sheets. Subjects were encouraged to guess rather than leave blanks. There were four conditions.

(1) *Auditory suffix (S)*. In time with the onset of the blank field the experimenter spoke one of the words "tick" or "cross" selected at random. The subjects were instructed to ignore this word.

(2) *Control (C)*. The interval between presentation and the recall cue was silent. The delay of responding was the same as in condition *S*.

(3) *Auditory suffix-prefix (SP)*. This condition was identical to condition *S* in presentation. To ensure that the subjects could not ignore the suffix they were required to write down the symbol corresponding to the suffix before starting to recall the letters.

(4) *Prefix (P)*. As a control for the *SP* condition the interval during the blank field was silent. On the recall cue the subjects had to write a tick or a cross before starting to recall. For any subject the form of the prefix was the same for all trials in this condition and was written at the top of the subjects' response sheets. Half the subjects had a tick prefix and the other half had a cross prefix.

There were 15 trials in each condition; the first 5 trials were regarded as being practice trials and were not scored. The 10 scored trials were balanced for the serial position occurrence of individual letters.

### Subjects

There were four groups of female subjects drawn from the Applied Psychology Unit Subject Panel with ages ranging from 21 to 65. Four groups of subjects were tested with between 13 and 20 subjects in each group. The conditions were presented to the groups according to a Latin Square design. Subjects were eliminated from three of the groups strictly at random to give a total of 13 subjects in each group.

### Results

Responses were only scored correct if they occurred in the correct serial position. The data are shown in Figure 3. The effect of the suffix was greater in this experiment than in the Crowder and Morton experiment. When errors were pooled over all serial positions there were more errors in the *S* condition than in the *C* condition (Wilcoxon,  $z = 3.9$ ,  $P < 0.001$ ) and more errors in the *SP* condition than

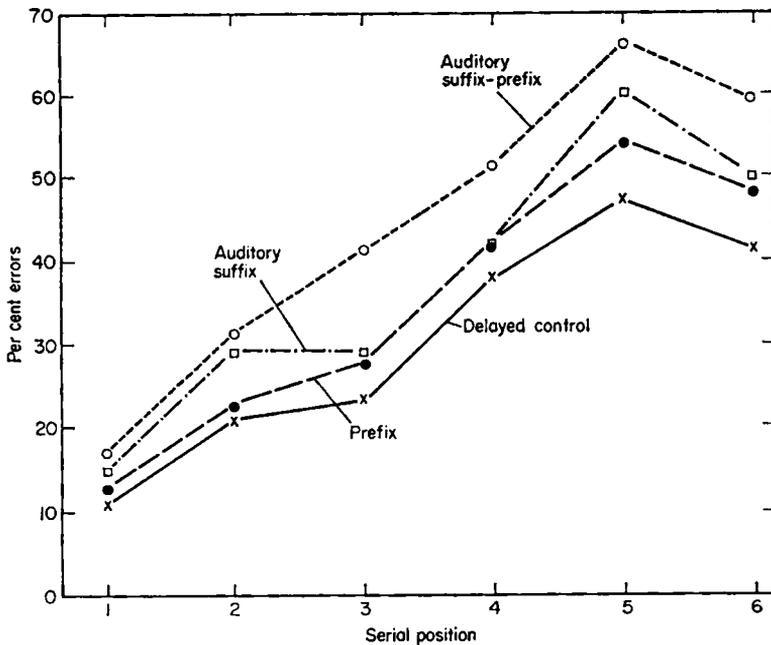


FIGURE 3. The effects of a prefix, and auditory suffix, and an auditory suffix-prefix (i.e. a non-redundant suffix which had to be copied by the subject). The characteristic *suffix effect* is absent. Presentation was visual.

in the *P* condition ( $z = 4.0$ ,  $P < 0.001$ ). This being the case it cannot be argued that the suffix was being totally ignored, even in the condition where it did not have to be responded to. The next question is whether or not its effect was a function of serial position on the second half of the list in a way characteristic of the suffix effect with auditory stimuli.

Wilcoxon tests showed that there was no apparent serial position effect of the suffix in the second half of the list either with a prefix (*SP* — *P*) or without (*S* — *C*). Comparisons were made among serial positions 3, 4, 5 and 6 and for none of these comparisons was there a difference in the size of the effect of the suffix that reached the 0.025 level of significance. Indeed only one comparison reached the 10 per cent level. Further, as can be seen in the figure, performance on the last item shows a greater improvement over that on the fifth item in the *S* condition than in the *P* condition ( $z = 1.51$ ,  $P = 0.066$ ).

We must conclude then that an auditory suffix does not have the same effect following visually presented stimuli as it does following auditory stimuli and that, accordingly, Sperling's model is either incorrect or requires severe revision.

A further feature of the Crowder and Morton model is that it predicts that there will be no effect of a visual suffix on PAS, even if the suffix has to be processed (as in the *SP* condition in the previous experiment). It is unclear what Sperling's model would predict in this situation, though it would seem that since the scan system and the recognition buffer-memory are involved both in rehearsal of auditory stimuli and in the processing of a visual stimulus there should be some interference of the suffix. More specific predictions cannot be made from the published form of the model.

## Experiment II. Auditory Stimulus—Visual or Auditory Suffix

### *Method*

#### *Procedure*

Lists of digits were read out in time with a metronome at a rate of  $\frac{1}{4}$  sec. per item in blocks of 16. Digits were never repeated within a list and were balanced for serial position occurrence. There were four conditions.

(1) *Visual suffix-prefix, Non-redundant (V)*. One second after the last item a card was held up on which was inscribed either a tick or a cross. The occurrence of the two symbols was varied at random. The subjects had to copy the symbol and then recall the digits by writing them down in their order of presentation.

(2) *Auditory suffix-prefix, Non-redundant (A)*. This condition was identical to the preceding one except that the suffix was spoken, and a blank card was held up as a recall cue.

(3) *Auditory suffix-prefix, redundant (AR)*. In this condition the nature of the suffix-prefix was known in advance to the subjects; for the first 8 trials in a block it was always "tick" and for the last eight trials it was always "cross". For this condition the symbol was written at the top of each sub-block of 8 response blanks. This condition was included in order to discover whether the effect of the suffix-prefix was less if the subject did not have to make a decision as to the nature of the suffix.

(4) *Control-prefix (P)*. One second after the final stimulus item a blank card was held up as a cue to recall. Prior to recall the subjects had to write a prefix of either a tick or a cross; the prefix was determined as in condition *AR*. The delay between presentation and recall was thus the same in all conditions.

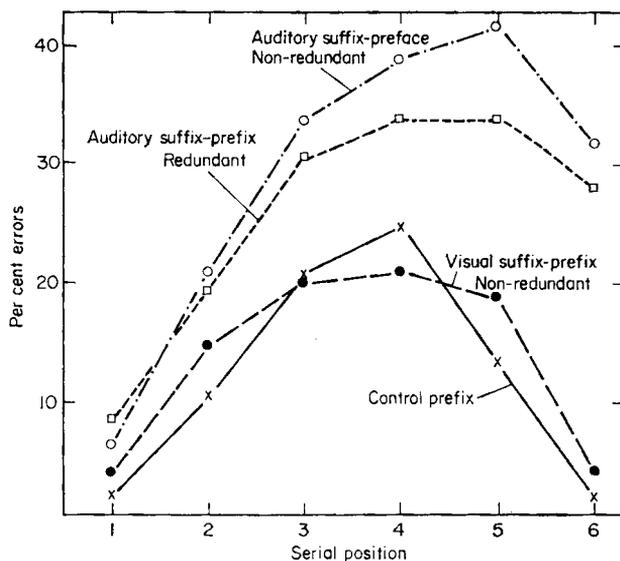


FIGURE 4. The effects of modality of a suffix-prefix on the recall of auditorily-presented six-digit lists. The visual suffix-prefix does not differ in its effect from a prefix condition. An auditory suffix-prefix has a large serial position effect whether the suffix is redundant or non-redundant.

### Design

The test was divided into two parts each part lasting about 30 min. with a rest of 5 min. between. In each part the conditions were presented in the order *P*, *AR*, *A*, *V*, *V*, *A*, *AR*, *P*, thus each condition was presented four times in all. For each condition there was a block of 16 six-digit lists followed by a block of 16 eight-digit lists. Prior to the experiment the subjects were carefully briefed and given practice items under every condition.

### Subjects

The subjects were 14 female members of the Applied Psychology Unit Subject Panel, aged 21–25. They were tested in a single group.

### Results

An item was scored correct only if it occurred in the correct serial position. The data for the six-digit lists are presented in Figure 4.

The main feature of the data is the gross difference between the effects of the visual and auditory suffixes. In fact no significant difference was found on the Wilcoxon test between the visual suffix condition and the control-prefix condition, either for the total number of errors or for any serial position. In both the auditory suffix conditions the typical suffix effect was found. The difference between both suffix conditions and the other two conditions was highly significant ( $P < 0.005$ ) at all serial positions (except position 2, *V* vs. *AR*,  $P < 0.025$ ). The difference between the auditory suffix conditions and the other two conditions were greater for serial positions 5 and 6 than at the earlier positions. The absolute effect of the suffix was not significantly greater on the last item than it was on the fifth item. The relative effect is, of course, much greater on the final item. These results are typical of the auditory suffix (Crowder, 1967; Morton, 1968). The difference

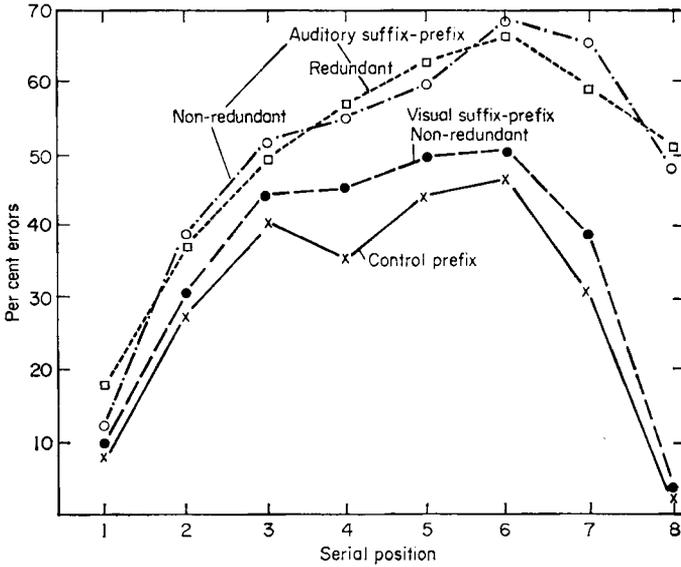


FIGURE 5. The effects of modality of a suffix-prefix on the recall of auditorily presented eight-digit lists. The visual suffix-prefix has a small effect but one qualitatively different from the effect of the auditory suffix-prefix.

between the total number of errors made in conditions *A* and *AR* was barely significant ( $T = 21$ ,  $N = 14$ ,  $P = 0.025$  one-tailed). When individual serial positions were examined the differences between these conditions only reached significance at the 0.025 level on positions 3 and 5.

The data for the eight-digit lists is given in Figure 5. For the longer lists the small difference between a redundant (*AR*) and a non-redundant (*A*) auditory suffix found with the six-digit lists has vanished. It is possible that there was a ceiling effect operating here, though the subjects averaged 30 per cent correct even at the worst position. We might alternatively conclude that the binary decision necessary in the *A* condition involves the same processes as the supposed autonomous recognition of the redundant suffix in the *AR* condition.

The effect of the auditory suffix is again clear. The differences between the suffix conditions and the control-prefix conditions are greater on position 7 and 8 than on the rest and greater on position 8 than on position 7 (Wilcoxon, one-tailed,  $P < 0.01$ ). With the eight-digit lists there was a small but significant effect of the visual suffix for total errors ( $P < 0.005$ ) but this effect is, as before, qualitatively different from that of the auditory suffix.

It remained possible that the lack of any gross effect of the visual suffix was a result of our using the symbols of a tick and a cross. The subjects might then simply be copying these symbols in some sense without having to process them verbally. Accordingly a third experiment was carried out in which the visual suffix was one of the words TICK or CROSS. The subjects would then have to recognize the word before being able to respond with the symbol in just the same way as with the auditory suffix.

### Experiment III. Auditory Stimulus—Visual (Word) or Auditory Suffix

#### Method

##### Procedure

The stimuli were lists of seven digits which were read at  $\frac{1}{2}$  sec. intervals. One second after the final digit the experimenter held up a card. There were three conditions.

(1) *Control (C)*. The card was blank and the subjects immediately attempted to recall the stimulus list.

(2) *Visual (V)*. The card contained one of the words *TICK* or *CROSS*. The subjects first wrote down the appropriate symbol and then recalled the stimuli.

(3) *Auditory (A)*. The card was blank but the experimenter simultaneously called out either "tick" or "cross". The subjects entered the symbol and then started their recall.

The three conditions were presented in random order, stimulus lists being presented in three blocks of 45 lists with two rest pauses. Prior to the experiment they were carefully instructed what they had to do and were given 15 practice lists employing all three conditions.

##### Subjects

There were 14 subjects from the Applied Psychology Unit Subject Panel. They were tested in a single group.

##### Results

The data are shown in Figure 6. It is clear that the change in the form of the visual suffix has made no qualitative difference to the results. The difference in total errors between *V* and *C* was barely significant ( $P < 0.025$ ). The effect of the auditory suffix is typical and highly significant, as in the previous experiment.

### Conclusions

The main results seem conclusive. With an auditory stimulus list and serial recall we have confirmed the large and characteristic serial position effect of an

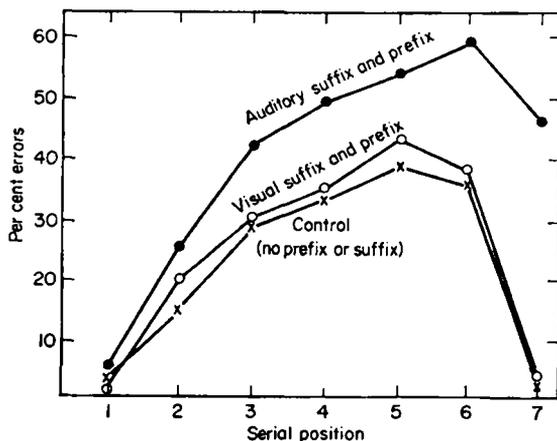


FIGURE 6. The effect of modality of a suffix-prefix on the recall of auditorily presented seven-digit lists. The visual suffix consists of either the word *TICK* or the word *CROSS* rather than  $\surd$  or *X*. The visual suffix-prefix has a small effect but one qualitatively different from the effect of the auditory suffix-prefix.

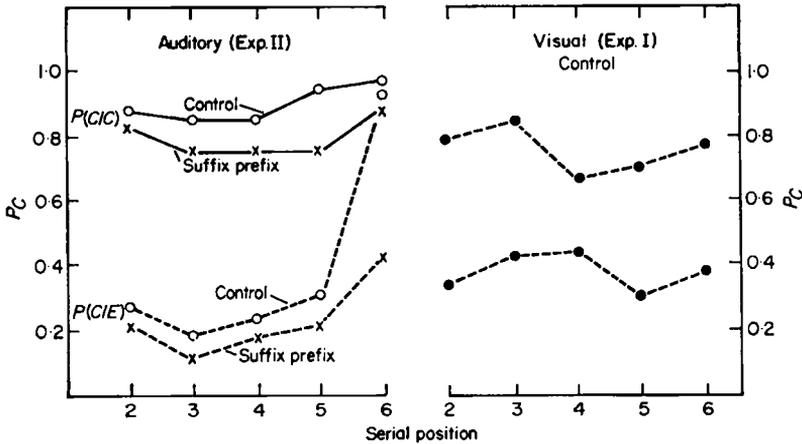


FIGURE 7. Conditional effects in serial recall. The functions plotted are the probability of being correct in a particular serial position given that the preceding item was recalled correctly,  $P(C/C)$ , and given that the preceding item was recalled incorrectly,  $P(C/E)$ . Only recall of the final item in the auditory control condition appears to be independent of the recall of the preceding item.

auditory suffix previously shown. A visual suffix, on the other hand, has a small effect and any interaction with serial position is undetectable. The same is true of the effect of an auditory suffix on a visual stimulus. These results confirm those of Crowder and Morton (1969) and support the model they propose as opposed to that of Sperling (1967).

A further feature of the proposed model is that associative phenomena in recall are restricted to that part of the system labelled "cognitive system" in Figure 2. If we suppose that information concerning the last item following auditory presentation comes from PAS, in which there is no associative mechanism, then we would expect an index of associative influence in recall to differentiate between this item and other items and between the last item in auditory and visual presentation. Such a measure has been used by Murdock (1968) who plotted the probability of an item being correct in a particular serial position for those cases where the preceding item was correct,  $P(C/C)$ , and for those where the preceding item was incorrect,  $P(C/E)$ . His data was taken from an experiment involving auditory presentation and he showed that, except for the final item,  $P(C/E)$  was substantially less than  $P(C/C)$ . We would predict that data from a suffix condition or where the stimuli were presented visually would not show this effect.

In the left-hand side of Figure 7 are shown the values of  $P(C/E)$  for the six-digit lists of Experiment II using the control and suffix-prefix conditions. In the control condition we find that  $P(C/E)$  rises sharply in the final position confirming Murdock's result. The data from the suffix condition do not show the convergence of the two functions. On the right-hand side are plotted the equivalent data from the control condition of Experiment I. They too show the wide separation between the two functions and do not show convergence at the final serial position.

This data would seem to support the idea that information concerning the final item following auditory presentation has different origins from that concerning the other items, and that this information can be eliminated by a suffix.

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