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Voice-Specific Information and the 20-Second Delayed-Suffix Effect

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Two experiments were conducted to investigate the nature of the delayed-suffix effect reported by Watkins and Todres (1980). In both experiments, subjects were presented lists of digits for serial recall. At the end of each list either a tone or a voice reading aloud the word *go* was presented. The voice was either in the same voice that read the digits or in a different voice. Past research has indicated that the tone control produces the least interference, followed by the different-voice suffix, which in turn produces less interference than the same-voice suffix. The results of both experiments indicated that when subjects were tested on immediate recall for the lists, the typical ordering of tone control, different-voice suffix, and same-voice suffix on recall at the last serial position was found. However, when there was a 20-s filled interval between the last list item and the suffix, there was only a difference between the tone control and the same- and different-voice suffixes with no difference between the latter two conditions. In addition, Experiment 2 failed to support a simple attentional account of the differential influence of voice in the immediate and delayed-recall conditions. The results are viewed as supporting a perceptual tuning mechanism in which perceptual specificity decreases with the passage of time.

The notion that there exists an auditory sensory store (hereinafter referred to as echoic memory) that extends the availability of the acoustic characteristics of auditory stimuli has been a useful construct in discussing a wide variety of empirical data. In fact, it has been suggested (Crowder, 1976) that because auditory information occurs dispersed over time, such a sensory store would be especially useful, almost obligatory, in the auditory modality. Consider, for example, the utility of such a store in holding unidentified speech segments for brief periods of time such that contextual information can aid in their recognition.

Although there have been a number of different methodological approaches to demonstrate the existence of echoic memory, the most widely used technique is the suffix paradigm (Dallet, 1965). In a typical suffix experiment, a list of items is presented auditorily for serial recall. In the control condition, some nonspeech signal, such as a tone, is presented at the end of the list as a cue to begin recall. In the suffix condition, a redundant speech suffix, such as the word *go*, is presented at the end of the list. Subjects are asked to recall only the list items. Although one might expect that subjects would ignore the redundant recall cues (the tone or *go*), the results indicate that recall of the last few list items is considerably lower in the suffix condition than in the control condition.

Crowder and Morton (1969) and Crowder (1978) have viewed the suffix effect as a reflection of a form of echoic memory they referred to as precategorical acoustic storage or PAS. They argue that in the control condition, the subject has extra echoic information available to aid recall of the last few list items. This extra echoic information leads to the robust recency effect typically found for auditorily presented items. The subject presumably uses this echoic information during a brief rehearsal before overt recall (see Crowder, 1976, 1978). However, when a speech suffix is appended to the end of the list, it interferes with the representation in echoic memory for the last few list items, thereby lowering performance on the terminal items.

Support for the underlying precategorical nature of the suffix effect has been provided by studies in which the characteristics of the suffix item have been manipulated. For example, there has been evidence indicating that

(1) The suffix effect is relatively unaffected by the meaning of the suffix (Morton, Crowder, & Prussin, 1971). That is, a similar-sized suffix effect is obtained when the suffix is from the same set of items as the to-be-recalled list (e.g., a zero following digits), is the word *go*, or is even a grunt (see, however, Salter & Colley, 1977).

(2) There is no suffix effect when the list items are presented visually and the suffix is presented auditorily (Morton & Holloway, 1970), suggesting that the interference is not due to interference in a modality-independent short-term memory.

(3) The suffix effect is dependent on the physical similarity between the list items and the suffix item. That is, the suffix effect is greater if the suffix is produced in the same voice in which the list items are read, compared to a condition in which there is a shift in voice between the list items and the suffix item (Morton et al., 1971).

(4) The suffix effect is eliminated when the suffix is delayed approximately 2 to 3 s after the last list items (Crowder, 1971, 1973), suggesting, as one would expect in a sensory trace, that the echoic trace is relatively short-lived. Taken together, the above findings have been viewed as converging evidence for a precategorical auditory memory that decays in a brief period of time.

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More recently, Watkins and Todres (1980; see also Engle & Roberts, 1982; Watkins & Watkins, 1980b) have reported an interesting suffix-effect study that appears to indicate that the echoic trace lasts at least 20 s. In their first experiment, Watkins and Todres delayed the suffix item for 2, 4, 8, or 16 s and found that the suffix effect decreased, as reported in earlier studies. However, Watkins and Todres noted that the decreased suffix effect occurred because of an increase in performance in the suffix condition across delays rather than a decrease in performance in the control condition as a result of a decaying echoic trace. They also noted that a similar change occurred in the early work on delayed-suffix effects by Crowder (1969, 1971). The authors reasoned that this pattern suggests that the trace was available throughout the longer delays and during those delays subjects used this auditory information and converted it into a "nonechoic, suffix-resistant" memory trace. Such a readout would increase performance in the suffix condition, precisely as the results indicated. In order to further address this possibility, Watkins and Todres filled the interval between the list items and the suffix item with a distractor activity that would decrease the likelihood that subjects would recode information from that sensory trace into a nonechoic, suffix-resistant format. In their Experiments 2 and 3, the suffix was delayed by as much as 12 and 20 s, respectively, during which subjects received a distractor activity.[1] In both experiments a significant suffix effect was obtained when subjects engaged in the distractor task during the delay. Presumably, because of the demands of the distractor task, subjects could not recode the echoic information into a suffix-resistant format. Thus, Watkins and Todres concluded that some form of echoic information lasting at least 20 s was being affected by the suffix item.

Although the existence of a relatively brief echoic store seems useful for auditory perception, the utility of a 20-s echoic trace is unclear, and, in this light, the Watkins and Todres results are surprising. Why should a precategorical representation of a stimulus last 20 s? Possibly, the suffix effect obtained by Watkins and Todres is produced by a different mechanism than that which underlies the more short-lived suffix effect (see Cowan, 1984). In order to address the underlying nature of the suffix effect, researchers have attempted in the past to manipulate variables such as change in voice to provide converging evidence regarding its sensory nature. However, because Watkins and Todres (1980) compared only a suffix condition with a control condition at the long delays, no converging evidence regarding the nature of the mechanism underlying their 20-s suffix effect was obtained.

In Experiment 1, we attempted to replicate Watkins and Todres' delayed-suffix effect and also provide evidence regarding its underlying nature by varying the physical similarity of the suffix to the list items. The suffix was presented in either the same or different voice as the list items were presented. If the delayed-suffix effect obtained by Watkins and Todres (1980) is produced by the same mechanism that underlies the immediate-suffix effect, then one should expect the same-voice suffix to produce a larger suffix effect than the different-voice suffix, but with the latter still producing lower recency performance relative to the tone control. On the other hand, if the 20-s delayed-suffix effect reflects a different mechanism, one might expect little difference between same-voice suffix and different-voice suffix with both being lower than a tone control. We shall defer potential theoretical interpretations of such patterns of data until the results are presented.

Experiment 1

Method

Subjects. In this study, 52 undergraduates participated for partial fulfillment of a course requirement at the University of Kentucky. One subject's data were discarded because of failure to follow the distractor task instructions.

Materials. Seventy-two eight-digit lists were recorded via a Sony reel-to-reel tape recorder. Each list was produced by randomly selecting, without replacement, eight digits from the digits 1 to 9. The 72 lists were recorded twice; once in a male voice and once in a female voice. Care was taken to record all lists at a constant volume and at a constant rate of 2 digits per second. At the end of each list either the suffix word *go* was recorded or a tone (control condition) was recorded. The suffix word *go* occurred either in the same voice in which list items were read (same-voice condition, a male voice for the male list and a female voice for the female list) or in a different voice than that in which list items were read (different-voice condition, a male voice for the female list and a female voice for the male list). Thus, following list presentation, either a same-voice suffix, a different-voice suffix, or a tone was presented. These appended suffixes or tone were recorded either (a) in sequence with the list items (immediate-suffix condition) or (b) 20 s after the last list item (delayed-suffix condition). There was a 20-s silent interval after the suffix for subjects to recall the preceding list.

Procedure. Each subject received 72 lists, all of which were recorded in either a male or female voice. There were two blocks of 36 lists: The first 6 lists within each block were practice lists. Within each block all lists were either in the immediate-suffix condition or in the delayed-suffix condition. The ordering of blocks was counterbalanced such that half of the subjects received the immediate-suffix block first, whereas the remaining half of the subjects received the delayed-suffix block first. Within a block of trials, each suffix condition (same voice, different voice, tone) was presented an equal number of times. Suffix condition was randomized within a block with the constraint that a given condition did not occur more than twice in sequence. The same random ordering was used across subjects. With this design, each subject received 10 test lists per suffix condition for both the immediate-suffix condition and the delayed-suffix condition. There was a 5-min break between test blocks.

In the delayed-suffix condition, subjects engaged in an alphabet-sequencing distractor task. For this task, subjects were given separate booklets in which a randomly selected letter of the alphabet appeared in the upper left-hand corner of each page. Subjects were instructed to begin with the presented letter and to write every third letter in the alphabet in the answer booklet (e.g., G, J, M, P, . . .) as quickly as possible until they heard the signal to begin recall. Subjects were also instructed that on trials in which they reached the end of the alphabet, they were to continue forward through the beginning of the alphabet (e.g., Y, B, E, . . .). Thus, immediately following list presentation, subjects performed the alphabet sequencing task until they heard the word *go* or the tone, at which time the subjects recalled the list. Subjects were told that the alphabet task was as important as the recall task and they should work as quickly and as accurately as possible. The experimenter

[1] Watkins and Todres (1980) also included a suffix control condition in their Experiment 2 in which there was no distractor activity during the delay. In this condition the suffix effect was greatly reduced. They suggested that subjects read the information into a more permanent suffix-resistant trace during the delay interval.

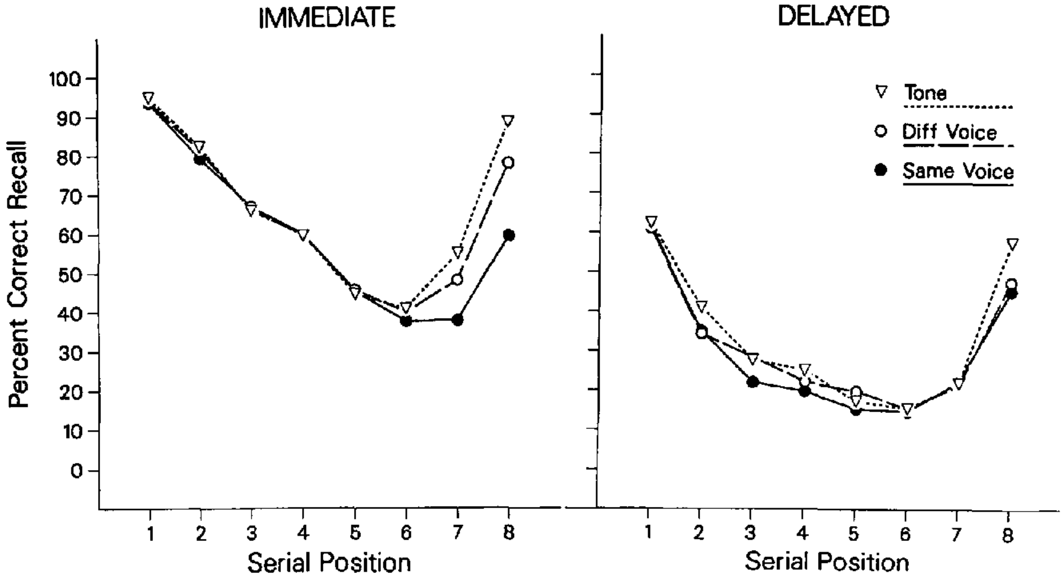

Figure 1. Mean percent correct recall as a function of delay, serial position, and suffix condition.

remained in the testing room throughout the testing session to ensure the instructions were appropriately followed.

Subjects were tested in groups ranging from 2 to 5 during a given session. The lists were presented over a loud speaker in the room. Each subject received a four-page answer booklet that consisted of 72 numbered rows of eight underlined spaces for the recall of the eight list items. Subjects were instructed to recall the list items in their presentation order and not to begin their written recall until they heard either the word *go* or the tone. They were also told to recall the items in a left-to-right fashion and to guess if they were unsure about a given position. The instructions emphasized that the word *go* or tone should be used as signals to begin their recall and that these recall cues were not to be recalled along with the list items.

Design. Experiment 1 was a 2 (male-vs. female-recorded list) × 2 (immediate-suffix block first vs. delayed-suffix block first) × 2 (immediate-vs. delayed-suffix condition) × 3 (same-voice suffix vs. different-voice suffix vs. tone) × 8 (serial position) mixed-factor design.

Results

The subjects' recall was scored via a strict scoring procedure in which a 1 was given for a correct digit recalled in the correct serial position and a 0 was given in any other case.

Figure 1 displays the mean percent correct recall as a function of delay, serial position, and suffix condition. The data in Figure 1 are easily summarized. First, comparing across the two panels, one can see that recall was considerably lower in the delayed-recall condition than in the immediate-recall condition. Second, as shown in the left panel, the suffix manipulation had its typical effect in immediate recall, because the tone control produced higher recall than the different-voice suffix, which in turn produced higher recall than the same-voice suffix. Moreover, this effect was localized at the last two serial positions. Third, as shown in the right panel, the delayed-recall condition also appeared to yield higher recall for the tone control than the different-voice suffix; however, there was little difference between the same-voice suffix and the different-voice suffix conditions for the delayed-recall condition.

In order to test the reliability of the above observations, a 2 (male- vs. female-read list) × 2 (immediate- vs. delayed-suffix block first) × 2 (immediate- vs. delayed- suffix condition) × 3 (type of suffix) × 8 (serial position) mixed-factor analysis of variance (ANOVA) was conducted on the mean percent correct per condition. This analysis yielded a number of significant effects. (Unless otherwise specified, all significant effects have p values less than .05.) First, as expected, there were highly significant main effects of delay condition, $F(1, 47) = 363.10$, $MS_e = .172$, serial position, $F(7, 329) = 181.42$, $MS_e = .0522$, and suffix condition, $F(2, 94) = 12.95$, $MS_e = .0435$. There was also a significant interaction between delay and serial position, $F(7, 329) = 13.74$, $MS_e = .0339$, reflecting relatively higher recall in the immediate-recall condition at serial positions 2, 3, and 4, and a significant interaction between suffix condition and serial position, $F(14, 658) = 6.84$, $MS_e = .0171$, reflecting a larger impact of the suffix at serial positions 7 and 8. More important for the present discussion, there was a significant interaction among delay, suffix, and serial position, $F(14, 658) = 4.44$, $MS_e = .0156$. The only other effect to reach significance in this analysis was a significant interaction among voice that read the lists, delay condition, and serial position, $F(7, 329) = 2.23$, $MS_e = .0339$. Note however, that this latter interaction did not include the suffix factor.

In order to pursue further the most relevant interaction, that is, among delay, suffix, and serial position, separate ANOVAS were conducted at each serial position with the aforementioned factors. The results of these ANOVAS clearly indicated that the delay by suffix interaction was localized at serial position 7, $F(2, 94) = 12.88$, $MS_e = .0156$, and serial position 8, $F(2, 94) = 11.27$, $MS_e = .02$, with all remaining serial positions not approaching significance, all $Fs(2, 94) < 1.62$. As shown in Figure 1, the interaction at serial position 7 indicated simply that there was a strong influence of suffix condition for the immediate-recall condition, $F(2, 94) = 17.78$, $MS_e = .0212$, but no influence of suffix condition for the delayed-recall condition, F(2,

94) < 1.00, MS_e = .0162. On the other hand, the interaction between delay and suffix condition for serial position 8 is primarily due to the difference between same versus different voice at the delayed- and immediate-recall conditions. That is, at serial position 8, the difference between the tone control and the different-voice suffix condition was almost exactly the same magnitude in both the immediate- (10.3%), $t(50)$ = 5.34, and the delayed-recall conditions (10.0%), $t(50)$ = 2.82; however, at serial position 8, the difference between same- versus different-voice suffix conditions was 18.6% in the immediate-recall condition, $t(50)$ = 7.01, and only 2.3% in the delayed-recall condition, $t(50)$ = .84. Thus, in sum, the present results indicate (a) significant influences, compared to a tone control condition, of a voiced suffix in both immediate- and 20-s delayed-suffix conditions and (b) significant influences of same versus different voice suffixes only in the immediate-suffix condition.

One might argue that a functional floor effect prevented any difference between the same- and different-voice suffixes in the delayed condition. However, there are two counterarguments regarding this point. First, performance in the same-voice delayed-suffix condition was 48% correct, which was 25% higher than for serial positions 3–7. This suggests that performance could have been lowered considerably more in the delayed-suffix conditions at serial position 8. Second, as shown in Figure 1, performance in the different-voice suffix condition for serial position 7 in the immediate-recall condition was also 48% correct. However, the same-voice suffix was significantly lower than the different-voice suffix for serial position 7 in the immediate-suffix condition, $t(50)$ = 3.59. There is no reason to suspect that there would be different functional floors for the immediate- and delayed-recall conditions. Thus, we conclude that the absence of a significant difference between the same- and different-voice suffix conditions for the delayed-recall conditions is not simply due to a functional floor.

Discussion

The motivation for conducting Experiment 1 was to establish whether the delayed-suffix effect reported by Watkins and Todres (1980) is affected by the same variables as the immediate-suffix effect. The results suggest that the nature of the two effects is quite different. In the immediate-suffix condition there were large effects of changes in voice between the suffix and the list items, whereas in the delayed-suffix condition there was no evidence that this manipulation had any consistent impact on performance, even though the delayed results did replicate Watkins and Todres' 20-s delayed-suffix effect.

Because there is a difference in sensitivity to voice-specific information between the immediate- and delayed-suffix effects, the question now becomes what is the nature underlying the delayed-suffix effect. One simple possibility is that the delayed-suffix effect simply reflects a degraded echoic representation, but is of the same general nature as the echoic mechanism underlying the immediate-suffix effect. Thus, with increasing delays, the echoic trace loses specificity of its original format. An alternative account is that the delayed-suffix effect is a reflection of a more attentional mechanism. That is, as subjects are engaged in the distractor task during the delay interval, it is possible that the presentation alone of a voiced cue versus a nonvoiced cue such as a tone produces a greater orienting response that disrupts recall. Obviously, such an attentional disruption hypothesis does not rely on an underlying echoic store and therefore suggests that the delayed- and immediate-suffix effects reflect different mechanisms.

If the delayed-suffix effect is due to differences in voiced versus nonvoiced attentional disruption, then one should be able to influence the delayed-suffix effect by asking subjects to attend directly to the physical characteristics of the voiced suffixes. We attempted to do this in Experiment 2 by asking subjects to make a discrimination based on the sex of the voiced suffix. If the delayed-suffix effect is due to attentional disruption, then asking subjects to attend further to the suffix should modulate the size of the delayed-suffix effect.

In the discrimination condition of Experiment 2, subjects were asked to recall the lists only when a designated voice (either male or female) or tone was presented, and to write the letters *A* through *H* when the other voice was presented. Thus, these subjects were asked to attend to the sex of the voice before making their response. The remaining subjects participated in a no-discrimination control group, which provided a direct replication of the design of Experiment 1. In addition to providing a comparison group, this condition provided a test of the reliability of the results of Experiment 1.

Experiment 2

Method

Subjects. In this experiment, 150 subjects recruited from Iowa State University participated for partial fulfillment of a course requirement.

Materials. The materials were the same as those used in Experiment 1.

Procedure. The procedure was the same as Experiment 1 with the exception that the subjects in the discrimination groups were instructed before the experiment began that they were to recall the lists only when the tone or a specified voice (male or female) produced the word *go* at the end of the list. When the other voice was presented, the subjects in the discrimination group were instructed to write the letters A through H in the eight blank spaces in their answer booklet for that trial. Subjects in the discrimination group were instructed that this aspect of the experiment was crucial for the purposes of the study.

Design. In the no-discrimination condition, the manipulation of same-versus different-voice suffix was a within-subjects manipulation and the design of this condition matched precisely the design of Experiment 1, thereby providing the aforementioned replication. For the discrimination condition, the design was a 2 (male- vs. female-recorded list) × 2 (immediate- vs. delayed-suffix block first) × 2 (immediate- vs. delayed-suffix condition) × 2 (recall on trials with same-voice suffix vs. recall on trials with different-voice suffix) × 2 (voiced vs. tone suffix) × 8 (serial position) mixed-factor design.

Results

Again a strict scoring procedure was used in which a 1 was given for a correct digit recalled in the correct position and a 0 was given in any other case.

Figure 2 displays the mean percent correct recall as a function of discrimination, delay, suffix, and serial position. Because there were no significant differences in performance in the tone condition between the two discrimination groups, the tone con-

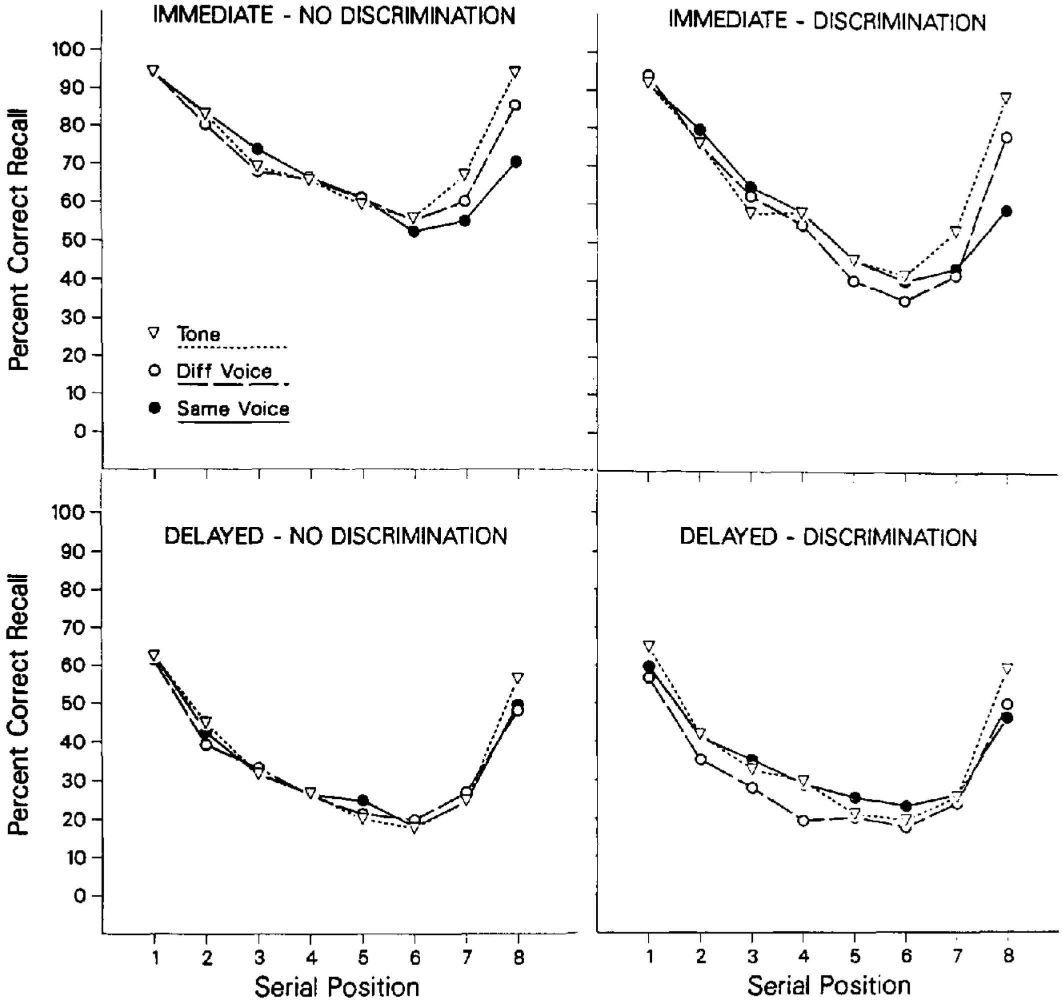

Figure 2. Mean percent correct recall as a function of discrimination, delay, serial position, and suffix condition.

dition displayed in Figure 2 is collapsed across the two discrimination groups of subjects. (These conditions were of course kept separate for the analyses.) As shown in the left two panels of Figure 2, the no-discrimination results nicely replicate those of Experiment 1. That is, in the immediate-recall condition (top left panel), performance on the last serial position indicates that the same-voice suffix produced substantially lower performance than the different-voice suffix, which in turn produced lower performance than the tone control. However, in the delayed-recall, no-discrimination condition (bottom left panel), there appears to be no difference between same- versus different-voice suffixes and both are lower than the tone control. This is precisely the same pattern that was found for Experiment 1. Turning to the discrimination conditions (the right two panels), one can see that although overall immediate recall is lower than the no-discrimination conditions, the impact of the type of suffix at the last serial position nicely replicates the corresponding no-discrimination conditions.

In order to test the reliability of the above observations, two separate ANOVAS were conducted. Two analyses were conducted because the same-voice versus different-voice factor was a within-subjects factor for the no-discrimination condition, whereas this factor was a between-subjects factor for the discrimination condition. Thus, to test the impact of discrimination, one analysis included same voice versus tone as a within-subjects factor, whereas the second analysis included different voice versus tone as a within-subjects factor. The remaining aspects of these overall ANOVAS directly followed the ANOVA described for Experiment 1. In order to ease the presentation of the results, any significant effects for both analyses will be presented with the statistics from the same voice versus tone analysis first, followed by the statistics from the different voice versus tone analysis.

These analyses yielded significant main effects of delay, $F(1, 99) = 486.73$, $MS_e = 16.66$, $F(1, 97) = 747.99$, $MS_e = 11.74$; serial position, $F(7, 693) = 236.11$, $MS_e = 4.12$, $F(7, 679) = 253.17$, $MS_e = 4.21$; suffix condition, $F(1, 99) = 20.58$, $MS_e = 4.27$, $F(1, 97) = 9.83$, $MS_e = 4.02$; along with significant interactions between delay and serial position, $F(7, 693) = 4.39$, $MS_e = 3.22$, $F(7, 679) = 3.37$, $MS_e = 3.07$; and suffix and serial position, $F(7, 693) = 26.51$, $MS_e = 1.69$, $F(7, 679) = 11.31$, $MS_e = 1.39$. More important for the present discussion, both analyses yielded significant interactions among delay, suffix, and serial position, $F(7, 693) = 12.08$, $MS_e = 1.47$, $F(7, 679) = 3.80$, $MS_e = 1.57$. The interaction among delay, suffix, and serial position for the different voice versus tone analysis was primarily due to the preterminal serial position 7 in which the difference between the tone and different voice conditions was significantly larger in the immediate-recall condition (9.1%) than in the delayed-recall condition (−.2%). This contrast was significant, $t(104) = 3.71$. A similar finding occurred in Experiment 1. However, at serial position 8, both the immediate-, $t(104) = 6.14$, and the delayed-, $t(104) = 4.53$, recall conditions produced a significant difference between the tone and the different-voice suffix conditions, and more important, the size of this effect was very similar in the immediate- (9.7%) and the delayed-recall conditions (8.8%). This contrast at serial position 8 did not approach significance, $t(104) < 1.00$. Thus, as in Experiment 1, there was no impact of delay on the difference between the tone and the different-voice suffix at serial position 8.

The interaction among delay, serial position, and suffix for the tone versus same voice analysis provides a different picture. Here the effect of delay on the suffix effect occurred primarily at serial position 8. As shown in Figure 2, the difference between same voice versus tone in the immediate-recall condition was 26.9% whereas the difference between same voice versus tone in the delayed-recall condition was only 9.9%. Here the contrast at serial position 8 is highly significant, $t(106) = 6.68$. If one considers the difference between the same-voice and different-voice conditions, one finds a 17.2% difference in the immediate-recall condition and only a 1% difference in the delayed-recall condition. In this light, these results clearly replicate those of Experiment 1.

Now turning to the impact of discrimination, one can see that the effect of discrimination was localized primarily in the immediate-recall condition as evidenced by a highly significant interaction between discrimination and delay in both analyses, $F(1, 97) = 12.90$, $MS_e = 11.47$, $F(1, 99) = 12.80$, $MS_e = 16.66$. In immediate recall, the discrimination condition was 9.5% lower overall than the no-discrimination condition, whereas in delayed recall, there was only a .5% influence of the discrimination manipulation. More important, neither of the analyses yielded a significant interaction (a) between suffix and discrimination; (b) among suffix, discrimination, and serial position; (c) among suffix, discrimination, and delay; or (d) among suffix, discrimination, delay, and serial position (all $ps > .15$).

Although the overall analysis did not yield any significant interactions that included the suffix and discrimination manipulations, it is noteworthy that the different-voice suffix did appear to be influenced more by the discrimination manipulation than either the tone control or the same-voice suffix. For example, comparing the left and right panels in Figure 2, one can see a relative depression in performance in the different-voice suffix condition at the preterminal serial positions 5, 6, and 7 in the immediate-recall conditions and the preterminal serial positions 1, 2, 3, and 4 in the delayed-recall conditions. However, individual tests at these serial positions did not yield any significant effects (all $ps > .10$). More important, at serial position 8, where the overall suffix effect is the largest, there was no substantial impact of discrimination. That is, there was only a .7% impact of discrimination on the different-voice suffix effect and only a .3% impact of discrimination on the same-voice suffix effect.[2]

Discussion

The results of Experiment 2 replicate those of Experiment 1, both in conditions where subjects were required to distinguish characteristics of the suffix and in conditions where no such discrimination was required. That is, a large influence of same- versus different-voice suffixes occurred in the immediate-recall conditions, but not in the delayed-recall conditions. This same pattern occurred even though the discrimination manipulation significantly affected immediate-recall performance. Thus, the discrimination manipulation apparently did demand the subjects' attention.

Interestingly, the discrimination manipulation did not influence delayed-recall performance. In retrospect, this seems quite reasonable. That is, if the distractor activity achieved its purpose, performance in the delayed-recall condition should not reflect a more transient short-term memory component but should reflect either (a) a more permanent memory trace for the primacy items, possibly attributable to additional rehearsal during presentation for these items (see, Rundus, 1971), or (b) a more structural sensory representation for the last serial position. In fact, recall performance was near chance at the middle serial positions (4–6), where it is unlikely that either of these factors could have influenced performance. Thus, the lack of an effect of discrimination in the delayed-recall condition could be viewed as further support that delayed recall did not involve a short-term memory representation that was sensitive to attentional demands.[3]

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[2] Greenberg and Engle (1983) have also investigated the impact of making a discrimination between different types of suffixes on the suffix effect in immediate recall. They had subjects make a discrimination based on the actual suffix word (*call* or *go*) or the type of tone (either high or low frequency). They found that their discrimination manipulation primarily influenced the different-voice suffix condition and the tone control condition at the preterminal serial positions, and that there was no impact at the last serial position. They argued that this supports the notion that the preterminal-suffix effect is primarily due to an attentional component, whereas the terminal-suffix effect is primarily due to a more structural component such as echoic memory (see Balota & Engle, 1981). Their results also indicated that there was little impact of the discrimination manipulation on the same-voice suffix condition at the preterminal serial positions. This is presumably due to the fact that the same-voice suffix condition already had an attentional impact at the preterminal serial positions. With respect to the present results, one might argue that because there was no discrimination of the tone control condition, one should find that the present discrimination manipulation would have an impact primarily for the different-voice suffix condition at the preterminal serial positions, as the results suggest. However, as noted, this effect did not reach significance. Including a tone discrimination possibly would have produced a larger discrimination effect in the present study.

[3] In this light, it is noteworthy that the distractor activity was very demanding in the present experiments and overall recall performance was only 35% correct whereas chance is 11.1%. In fact, the present distractor task produced performance that is approximately 10% lower

General Discussion

The results from Experiments 1 and 2 can be easily summarized. First, in both experiments a highly significant suffix effect was found at the 20-s delay conditions, thereby replicating Watkins and Todres's (1980) results. Second, in both experiments, at the last serial position, a similar effect of a different-voice suffix versus tone occurred in both the immediate- (10%) and delayed- (9.3%) recall conditions. Third, in both experiments, there was a much larger influence of same-voice versus different-voice suffix in immediate recall (17.9%) than in delayed recall (1.7%). Fourth, the results of Experiment 2 indicated that although the requirements to respond differentially to the suffix had an interfering effect on overall immediate recall, it did not influence the impact of the delayed-suffix effect. Thus, taken together, these results indicate that the delayed-suffix effect is not sensitive to changes in voice of the suffix and also that the delayed-suffix effect does not reflect simple attentional disruption.

In order to discuss the implications of these results for accounts of the delayed-suffix effect, it is necessary to first present a framework to discuss the influence of changes in voice of the suffix on the immediate-suffix effect. As noted earlier, the impact of physical similarity between the suffix and list items has been viewed most often as reflecting the sensory nature of echoic memory (see, Crowder, 1976, 1978; Morton et al., 1971). Unfortunately, however, there is not complete agreement on this interpretation. For example, Watkins and Watkins (1980a) have suggested that changes in voice are totally due to an attentional mechanism which allows subjects to ignore different voice suffixes.

The framework we believe to be correct is in the spirit of arguments made by Elmes (1974).[4] The notion is that, on the basis of the acoustical properties of each auditory stimulus, a perceptual selection mechanism is temporarily tuned to the stimuli's acoustic properties. This mechanism determines what enters echoic memory and the completeness of the representation. Following Crowder (1978), we suggest that upon entry, the more overlap in features, the greater the interference. The perceptual selection mechanism normally may have a relatively broad range, thereby allowing the processing of a wide range of auditory stimuli. However, as each stimulus in a list is presented it becomes more finely tuned to the specific acoustic properties of the voice reading the list. Thus, at the end of an eight-item list, this tuning mechanism has a relatively narrow band width tuned specifically to stimuli with the same physical characteristics as the list items. This would account for the large effect of same- versus different-voice suffixes in the immediate-recall condition. As was noted above, however, this perceptual tuning may be only short-lived. This assumption of the time-dependent nature of the tuning mechanism is reasonable because unless the individual is presented a relatively continuous stream of information (e.g., as in listening to a speaker), the system has the advantage of returning to a broad bandwidth and thereby processing a wide range of auditory stimuli. Thus, in the present study, during the 20-s silent interval, this tuning mechanism could have returned to its original wide bandwidth. If the tuning mechanism were no longer adjusted to the specific properties of the list items, then there no longer would be an impact of voice at the longer delays.

With an additional assumption, this framework can also account for the important finding that there was no difference in the effect of different voice versus tone suffixes in the immediate- and delayed-recall conditions. The notion is that in the immediate-recall condition, the different-voice suffix has a decreased effect (relative to the same voice), as it is "tuned out" because of its discrepancy with the list items. In the delayed-recall condition, as was noted earlier, the tuning mechanism returns to a larger bandwidth and this allows more of the different-voice suffix to enter the echoic store. The reason for the small effect of a different-voice suffix in the delayed-recall condition is that there is some compensating decay in the echoic representation during the 20-s delay. There are two reasons to suspect that some component of the echoic trace decays during the 20-s delay. First, in both these results and the Watkins and Todres study, the delayed-recall conditions produced a suffix effect (same voice vs. tone) about one half the size of that in the immediate control conditions. Second, as Morton, Marcus, and Ottley (1981) have argued, if PAS information is actually available, then performance should be nearly perfect in the control condition for the last serial position. Because performance was only about 60% correct in the delayed-recall control condition, a somewhat decayed echoic representation was most likely available for the last item in the delayed-recall condition.

One could of course appeal to a simple-decay notion to account for all of the present results without invoking a perceptual tuning mechanism: The echoic trace may simply decay over the 20-s delay, with a consequent loss of voice-specific information. The difficulty with this approach is that no simple account exists for precisely why the same effect occurs in the different voice versus tone control in the immediate- and delayed-recall conditions. Without additional assumptions, a simple-decay model would predict a decrease in the size of this effect also. Moreover, the present perceptual tuning mechanism is in line with a considerable amount of research on attentional selection (see for example, Treisman, 1964).

One addendum regarding this line of research should be noted. Recent studies of the suffix and modality effects have indicated that neither effect is restricted to auditory presentation. For example, one can find suffix effects with mouthed suffixes (Nairne & Crowder, 1982; Spoehr & Corin, 1978) and modality effects with lists that are lip-read by subjects (Campbell & Dodd, 1980; Greene & Crowder, 1984). Such findings appear to undermine the relevance of the suffix and modality effect research to echoic memory. Recently, however, Greene and Crowder (1984) have attempted to reconcile these data with the original accounts of the suffix and modality effects. The notion is that echoic memory is the location of a precategorical synthesis of auditory features occurring prior to the point of lexical recognition. Greene and Crowder suggest that "speech

than the corresponding delayed-recall conditions in the Watkins and Todres (1980) study.

[4] We thank James Nairne for providing us with the general outline for this theoretical framework.

gestures" such as mouthing or lipreading influence what is available in this echoic store. The authors give the example that seeing a person round his or her lips will bias the perception of the sound "oo" (see MacDonald & McGurk, 1978). We would only add to such a framework that what enters the precategorical synthesis system is influenced by a perceptual tuning mechanism, and that some of the auditory features remain for extended periods of time (20 s and possibly beyond).

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