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Differing Suffix Effects for the Same Physical Suffix

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Two experiments tested the hypothesis that how subjects categorize a stimulus will alter the amount of interference that it produces when it follows a list of words to be serially recalled. The results demonstrated that different categorizations of a single ambiguous stimulus determined the magnitude of the suffix effect. This casts doubt on whether the suffix effect can be marshaled as evidence for a *pre*categorical acoustic storage.

Many recent models of human information processing have incorporated a processing stage that corresponds to an initial, modality-specific storage site for incoming stimulus information (e.g., Atkinson & Shiffrin, 1968; Morton, 1970; Norman, 1970). Although the characteristics and functions of such sensory buffers have not been well established, they are presumed to store information in a relatively literal code for brief periods of time until that information is processed further or forgotten.

In the auditory modality, this sensory buffer has been called echoic memory by Neisser (1967) and precategorical acoustic storage (PAS) by Crowder and Morton (1969). Evidence for such a structure comes from several sources. Darwin, Turvey, and Crowder (1972) demonstrated a larger partial report superiority effect for spatial than for categorical cues, akin to the finding of Sperling (1960) in the visual domain. In another vein, Massaro (1972) and Massaro and Kahn (1973) used a masking paradigm to show that a relatively unprocessed image of a stimulus is stored for a brief interval after its presentation. Studies by Burrows (1972) and Cole, Coltheart, and Allard (1974) lend support to this position by demonstrating that subjects use a relatively unprocessed auditory representation when they are engaged in tasks that require matching of stimuli that are presented successively but with a short interstimulus interval. Yet another technique used by Kubovy and Howard (1976) demonstrates that echoic memory preserves pitch information as well with great fidelity.

One of the most intensively investigated lines of evidence concerning PAS is drawn from studies of the stimulus suffix effect: When a spoken list of words is followed by an extra (often redundant) item, called the suffix, immediate recall of the last items in the list suffers in comparison with recall without a suffix. A series of experiments attempted to establish that this suffix effect depends on the acoustic similarity of the suffix to the list items and not on any associative or semantic relatedness (Morton, Crowder, & Prussin, 1971; Morton & Holloway, 1970). So, for example, any speech sound of the same pitch and loudness as list items served as an effective suffix; in contrast, a visual item, a buzz, a musical sound, or a speech sound of different pitch, spatial location, or voice than the list items produced a diminished suffix effect or no effect at all.

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However, if list items were nonspeech sounds, then a suffix effect would be produced only by a similar nonspeech suffix (Rowe & Rowe, 1976). Crowder (1973) demonstrated that a suffix was only effective if it occurred within about 1 sec of the last item in the list and that it need not fall into the same rhythmic pattern as the list items. All of these results suggest interference among precategorized acoustic traces, leading to the construct of a precategorical acoustic store: a memory buffer with brief duration whose contents are sound representations held in a form uncategorized as to meaningful content. Successive inputs to this buffer interfere with the buffer's contents unless their gross physical features differ from those of the items in the store (Morton et al., 1971).

This interpretation of the suffix effect has recently been challenged. Salter and Colley (1977) found that the magnitude of the suffix effect can depend on the associative connection between the suffix and the list items (e.g., recall of the final list item was better with a synonymic than with a nonsynonymic suffix). Although this is a relatively small effect, it can be interpreted as evidence for suffix interference arising from categorical similarity. In addition, Watkins and Watkins (1973) found that the size of the effect is indifferent to whether the list words are either one or four syllables in length. If acoustic factors were the major determinants of the interference between suffix and list, then there should certainly be some effect of word length (i.e., only the last two syllables of the last four-syllable word would suffer, whereas two whole one-syllable words would suffer.) Finally, Spoehr and Corin (1978) have recently demonstrated a suffix effect when the suffix was articulated but not spoken, further suggesting that acoustic factors need not be crucial to obtain the effect.

The issue of whether the suffix effect tells us anything about PAS appears to be unsettled. On one hand, Crowder and Morton argue that acoustic similarity between list and suffix is both necessary and sufficient to determine whether a suffix effect will result. On the other hand, recent investigations demonstrate (albeit indirectly) that such acoustic factors may not be the sole determiners of the suffix effect, but that more cognitive variables, such as semantic interpretation and recognition of word boundaries, may be involved as well.

To directly address the necessity and sufficiency of acoustic and categorical variables, one must have independent manipulation of these variables. In particular, to directly test whether the categorical relationship between suffix and list alone could change the magnitude of the suffix effect, one must manipulate categorization while keeping acoustic characteristics the same. Experiment 1 does just this.

Experiment 1

Method

General design. To control for the acoustic relationship between suffix and list and to vary only the categorical relationship, we used the same physical stimulus as the suffix under two conditions intended to manipulate subjects' categorization of that stimulus. Specifically, we appended to lists of words a special suffix, a plunger-muted trumpet note sounding like a nasally spoken syllable, *wa*. In one condition these lists were embedded among others in which the suffixes were speech syllables; in another condition they were embedded among lists in which the suffixes were musical sounds. We intended that subjects in the former condition would interpret the *wa* as a speech sound and that subjects in the latter condition would interpret it as a musical sound. If so, and if the categorical relationship between suffix and list contributes to the suffix effect, then an effect should arise under the former condition ("speech" suffix and speech list) but not under the latter condition ("music" suffix and speech list), even though the physical stimulus is the same under both conditions. A third condition, with no suffixes, served as a control against which to compare the magnitude of the suffix effects arising from the two conditions of interest.

Subjects. The 71 subjects were undergraduate students enrolled in a laboratory course in experimental psychology, who participated as part of a course requirement. They were tested in five groups, two for each experimental condition and one for the control.

Stimulus materials. Thirty-five lists of 7 words each were constructed by drawing randomly without replacement from a 12-word population. The words were single-syllable, three-letter nouns with unique initial letters: bed, car, fit, gas, hat, job,

key, leg, map, net, rug, and top. For each of the three conditions (speech suffix, music suffix, and no suffix), 5 of these lists were designated as general practice lists. The remaining 30 lists were randomly assigned to three blocks of 10 lists each. The first 2 lists of each block were also designated as practice lists and were not included in the data on which analyses are based. This procedure left 24 lists as the test lists.

In the speech suffix condition, four different suffixes were appended to the lists. For 6 of the test lists, the appended suffix was the syllable *da*; for 6 it was *pin*; for 6 it was *wing*; and for the remaining 6 it was the ambiguous suffix *wa*. The 11 practice lists for this condition used these same suffixes.

In the music condition there were also four suffixes, each appended to 6 of the test lists. These suffixes were a trumpet playing a muted tone (*mute*), a plucked violin string (*pluck*), a bowed violin string (*bow*), and the ambiguous suffix *wa*. The 11 practice lists for this condition also used these suffixes.

The no-suffix control condition consisted of the same 35 lists used in the other two conditions with no suffixes appended.

Each list began with a 200-msec warning tone followed by 1.2 sec of silence. The list items and the suffix (if any) followed at a rate of two per second. Each list was followed by 15 sec of silence before presentation of the next list. To ensure that the auditory characteristics of the lists were identical across the three conditions, the item tokens were recorded by a male voice at approximately the same pitch and loudness and were stored in an IBM 1800 computer. All of the lists were then constructed from these stored tokens. The speech suffixes (spoken by a male voice different from that used to record the lists), the music suffixes, and the *wa* were similarly recorded, stored, and used in tape construction.

The lists in the speech and music conditions were matched on the basis of which suffix was paired with which list. This was done by matching the three music suffixes *mute*, *pluck*, and *bow* to the three speech suffixes *da*, *pin*, and *wing*, respectively. The choice of these matched pairs followed a preliminary similarity scaling of the suffixes. First, subjects were asked to listen to the three music suffixes and to suggest speech sounds that closely approximated each suffix. Then a new group of subjects was asked to judge the similarity of each candidate speech suffix to each music suffix by using the method of paired comparisons. These similarity ratings were then pooled across subjects to select the speech suffix most similar to each music suffix. The resulting pairings were then used to match each list and suffix in the condition to a list and suffix in the speech condition. Of course, the lists with *wa* as suffix in the music condition were also matched to the lists with *wa* as suffix in the speech condition by virtue of being identical.

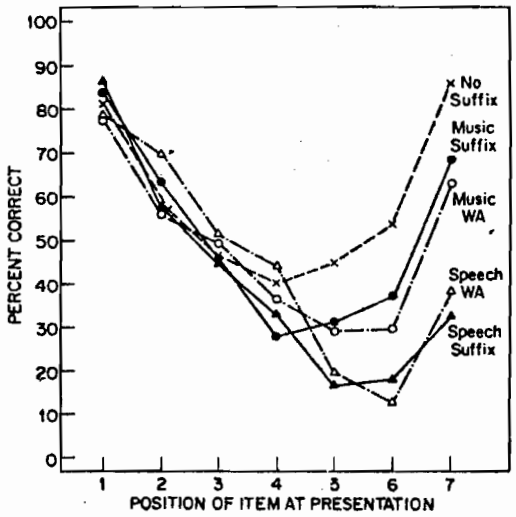

Figure 1. Percentage of correct responses for each serial position in each of the conditions of Experiment 1. (Data for the *wa* suffix are indicated separately from data for the unambiguous suffixes.)

Procedure. Subjects in the speech suffix condition were told that they would hear lists of seven words with the last word in each list followed by an irrelevant speech sound (the suffix). They were instructed to recall the words in serial order immediately after the suffix by writing the first (unique) letter of each word in the appropriate spaces of a response sheet. The 30 subjects in this condition were given 5 practice trials and three blocks of 10 trials each.

The 27 subjects in the music-suffix condition were given the same instructions, except that they were told that the suffixes would be musical sounds. Likewise, the 14 subjects in the no-suffix control condition were given the same instructions except, of course, they were told nothing about suffixes.

Results

Figure 1 presents the percentage of correct responses for each serial position in the three conditions, with the data for the *wa* suffix presented separately. Items were scored as correct only if they were reported in their correct serial positions. Casual inspection of the figure suggests several trends: (a) The unambiguous speech–suffix lists (with suffixes *da*, *pin*, and *wing*) show a much-reduced recency effect compared to the no-suffix control (i.e., a suffix effect); (b) although unambiguous music-suffix lists also show a trend toward a suffix effect, this trend

appears smaller than that for the speech suffix lists; (c) the *wa* suffix produces a greater suffix effect in a speech context than in a musical context; and (d) *wa* seems to produce effects comparable to those produced by the other suffixes of its condition.

The analyses of these effects used a priori *t* tests to compare the average recall levels at Serial Positions 6 and 7 across different suffixes. In all cases, the criterial level of significance was .01.

First, we replicated the standard suffix effect results. Recall level after the unambiguous speech suffixes was significantly lower than after unambiguous music suffixes, $t(55) = 5.79$. Recall levels after both types of suffixes were significantly lower than recall after no suffix (the control); for speech, $t(42) = 10.26$; for music, $t(39) = 3.02$.

Next, we examined the *wa* suffix to determine whether it produced a larger suffix effect in the speech than in the music condition and to determine whether it behaved similarly to the other suffixes of its respective conditions. On the first issue, the recall levels after the *wa* suffixes differed in the two conditions, $t(55) = 3.95$. Apparently, the same sound applied to the same lists produces a suffix effect that differs in magnitude depending on the condition in which those lists are presented. Furthermore, comparison of *wa* with the unambiguous suffixes of its condition reveals no reliable differences; for speech, $t(29) = .41$; for music, $t(26) = 2.02$. We therefore conclude that *wa* acts like its respective brethren in the amount of interference it produces on list recall.

Discussion

The results with the unambiguous speech and music suffixes replicate the findings of previous research: A speech suffix appended to a list of speech items produces a stronger suffix effect than does a musical suffix (Morton, Crowder, & Prussin, 1971). Results with the suffix *wa* warrant the same conclusion except that the definition of speech and musical as descriptions of the suffix do not here depend on the physical stimulus, but only on the context in which the suffix appears.

We must not be too hasty in interpreting this phenomenon, however. Morton et al. (1971) have found that a suffix that could not produce a suffix effect under conditions in which subjects were prepared for it could produce such an effect if it was appended to lists presented unpredictably in a series of trials including more potent suffixes. In one experiment, for example, they found that a suffix that was presented in the ear contralateral to the one in which a list was presented had no effect. But if this kind of trial was presented with others in which the suffix was presented in the same ear as the list (a condition that produces strong interference), it too produced a suffix effect. In another experiment, these same authors found a comparable effect with a suffix presented at a pitch different from the pitch of the list: As long as those trials were unpredictably distributed through a session in which same-pitch suffixes predominated, a suffix effect was obtained.

Perhaps these effects are relevant to our Experiment 1. Consider the following possibility: Subjects perceive *wa* as a musical sound regardless of the context in which it appears and regardless of our best efforts to select a sound that was ambiguously speech or music.[1] If this were so, then if the *wa* suffix lists were embedded among speech suffix lists, they might produce a suffix effect merely because of their relatively low frequency of occurrence. (Although subjects were provided with roughly 25% trials on

[1] We should note that this possibility is not supported by ratings that we obtained from each of the subjects. Immediately after the experiment, each subject was presented with each suffix in isolation and was asked to indicate how speechlike or musiclike it was on a 7-point scale. Overall, the unambiguous speech and music suffixes were rated as speechlike and musiclike, respectively (2.2 vs. 5.1, in which the scale was specified as 1 = very speechlike and 7 = very musiclike). The suffix *wa* was consistently rated in the middle of the scale (4.3). Although these findings may bear marginally on the interpretation of recall performance, we do not place great weight on their importance. The cognitive effects of an event and one's introspective reports of such cognitive effects are by no means necessarily identical.

which *wa* was the suffix in the speech condition, its presentation may still have been relatively unexpected.) That is, if an unexpected music suffix appears among expected lists with speech suffixes, it may also produce a suffix effect, much as in the studies cited earlier.

To test this hypothesis, we ran a fourth condition identical to the speech condition in all important respects except that the *wa* suffix was replaced by an unambiguous music suffix. We reasoned that if the above interpretation has merit, then any music suffix, when appended to lists embedded among speech suffix lists, should also produce a suffix effect.

Experiment 2

Method

Subjects. Thirteen undergraduate students in an introductory psychology course participated as part of a course requirement.

Stimulus materials. The stimulus lists were identical to those of the speech suffix condition of Experiment 1, except that the *bow* music suffix used in Experiment 1 replaced the *wa* suffix.

Procedure. The instructions were identical to those of Experiment 1, except that subjects were told that although most suffixes would be speech sounds, one would be a musical sound.[2]

Results and Discussion

Figure 2 presents the recall results by serial position for the *bow* suffix lists and for the speech suffix lists in this condition. A t test of these data revealed that disruption from the *bow* suffix is markedly smaller than that from the speech suffixes, $t(12) = 3.32$.

The purpose of this control condition was to determine whether a music suffix would produce a suffix effect of the same magnitude as do the speech suffixes. It did not. The implication of this finding is that the *wa* suffix of the speech condition in Experiment 1 did not have its effect merely because it was perceived as an unexpected music suffix, embedded within lists that are presented with speech suffixes.

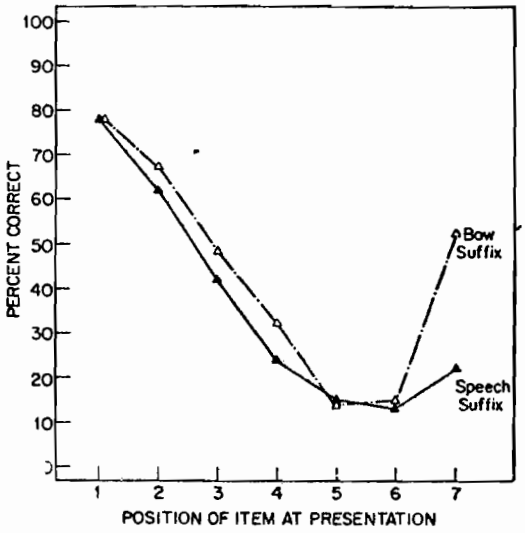

Figure 2. Percentage of correct responses for each serial position in the experimental *bow* and *speech* suffix conditions of Experiment 2.

General Discussion

Experiments 1 and 2 demonstrate that how a suffix is categorized (which can depend on contextual factors) determines the magnitude of the suffix effect. Although some previous research has suggested a similar conclusion by demonstrating the contribution of semantic and associative relatedness to the suffix effect, we have strengthened this position by demonstrating that acoustic factors are not even necessary conditions to produce the effect.

The implications of these findings are clear. Some researchers have previously proposed that the suffix effect is due to a short-lasting precategorical acoustic storage in which the last few items of a list reside (e.g., Morton et al., 1971). When the suffix is presented, according to this theory, it interferes with the memory traces of those

[2] Although it might have been ideal to use precisely the same instructions as in the speech condition of Experiment 1, this was not feasible. Subjects would have readily suspected that something was amiss if we had told them that all of the suffixes were speech sounds and then had presented *bow* as a suffix.

items in direct relationship to its acoustic similarity to the items. The present experiments have falsified this model by critically testing its assumption that this hypothesized store is precategorical. Apparently, the interference between suffix and list items occurs at a level of processing after, not prior to, such cognitive processes as recognition and categorization.

This should not, of course, be interpreted as a general critique of the construct of a precategorical acoustic store. There are other lines of evidence (Burrows, 1972; Cole et al., 1974; Darwin et al., 1972; Kubovy & Howard, 1976; Massaro, 1972; Massaro & Kahn, 1973) that may still support such a structure. We claim only that the suffix effect cannot be used as one of these lines of evidence.

How, then, do we explain the suffix effect? The present experiments do not clearly lead us to a theoretical alternative to the PAS model. However, one appealing possibility is that the effect is mediated by interference among items in a short-term memory buffer in which items have already made contact with long-term traces and hence have been categorized (at least as to their verbal nature if not to their semantic content). According to this view, interference between the suffix and the last list item is seen to differ from the general interference among items only by degree (the suffix is, after all, the most recent item). Presumably, a test of this position would hinge on showing, for example, that the interference of the suffix on the item in Serial Position 7 is of the same magnitude as the interference of the seventh item on the sixth. Such a line of reasoning is supported by the work of Dallett (1965).

This possibility is further supported by the fact that the dimensions of similarity that produce differences in the suffix effect parallel those found in short-term memory (See Shulman, 1971, for a review.) In short-term memory, little interference arises from semantic similarity (Baddeley & Dale, 1966); some interference arises from low-level categorization, such as alphabetic–numeric classification (Brown, 1958; Posner & Konick, 1966), but most arises from acoustic similarity (Wickelgren, 1965). In fact, the differences between speech and music suffixes shown here and in Crowder and Morton (1969) are very similar to the differences found between tonal and syllabic filler tasks in Reitman's (1971, 1974) short-term memory experiments.

This pattern suggests that the body of work on the suffix effect should be merged with that on the effects of similarity in short-term memory. Explanations of both types of phenomena, then, would be based on a theory in which interference increases with the similarity of the retained codes, either at encoding, during retention, or at retrieval. Whatever the final explanation, the inclusion of the suffix effect results with those of other short-term memory paradigms has the metatheoretical advantage of parsimony in that both sets of phenomena will make explanatory use of the same theoretical machinery.

References

Atkinson, R. C., & Shiffrin, R. M. Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *Advances in the psychology of learning and motivation research and theory* (Vol. 2). New York: Academic Press, 1968.

Baddeley, A. D., & Dale, H. C. A. The effect of semantic similarity on interference in long- and short-term memory. *Journal of Verbal Learning and Verbal Behavior*, 1966, 5, 417–420.

Brown, J. Some tests of the decay theory of immediate memory. *Quarterly Journal of Experimental Psychology*, 1958, *10*, 12–21.

Burrows, D. Modality effects in retrieval of information from short-term memory. *Perception & Psychophysics*, 1972, *11*, 365–372.

Cole, R. A., Coltheart, M., & Allard, F. Memory of a speaker's voice: Reaction time to same- or different-voiced letters. *Quarterly Journal of Experimental Psychology*, 1974, *26*, 1–7.

Crowder, R. G. The delayed stimulus suffix effect following arhythmic stimulus presentation. *Quarterly Journal of Experimental Psychology*, 1973, *25*, 433–439.

Crowder, R. G., & Morton, J. Precategorical acoustic storage (PAS). *Perception & Psychophysics*, 1969, *5*, 365–373.

Dallett, K. M. "Primary memory": The effects of redundancy upon digit repetition. *Psychonomic Science*, 1965, *3*, 237–238.

Darwin, C. T., Turvey, M. T., & Crowder, R. G. An auditory analogue of the Sperling partial report procedure: Evidence for brief auditory storage. *Cognitive Psychology*, 1972, *3*, 255–267.

Kubovy, M., & Howard, F. P. Persistence of a pitch-segregating echoic memory. *Journal of Experimental Psychology: Human Perception and Performance*, 1976, *2*, 531–537.

Massaro, D. W. Preperceptual images, processing time, and perceptual units in auditory perception. *Psychological Review*, 1972, *79*, 124–145.

Massaro, D. W., & Kahn, B. J. Effects of central processing on auditory recognition. *Journal of Experimental Psychology*, 1973, *97*, 51–58.

Morton, J. A functional model for memory. In D. A. Norman (Ed.), *Models of human memory*. New York: Academic Press, 1970.

Morton, J., Crowder, R. G., & Prussin, H. Experiments with the stimulus suffix effect. *Journal of Experimental Psychology Monograph*, 1971, *91*, 169–190.

Morton, J., & Holloway, C. M. Absence of a cross-modal "suffix effect" in short-term memory. *Quarterly Journal of Experimental Psychology*, 1970, *22*, 167–176.

Neisser, U. *Cognitive psychology*. New York: Appleton-Century-Crofts, 1967.

Norman, D. A. *Models of human memory*. New York: Academic Press, 1970.

Posner, M. I., & Konick, A. F. On the role of interference in short-term retention. *Journal of Experimental Psychology*, 1966, *72*, 221–231.

Reitman, J. S. Mechanisms of forgetting in short-term memory. *Cognitive Psychology*, 1971, *2*, 185–195.

Reitman, J. S. Without surreptitious rehearsal, information in short-term memory decays. *Journal of Verbal Learning and Verbal Behavior*, 1974, *13*, 365–377.

Rowe, E. J., & Rowe, W. G. Stimulus suffix effects with speech and nonspeech sounds. *Memory and Cognition*, 1976, *4*, 128–131.

Salter, D., & Colley, J. G. The stimulus suffix: A paradoxical effect. *Memory and Cognition*, 1977, *5*, 257–262.

Shulman, H. G. Similarity effects in short-term memory. *Psychological Bulletin*, 1971, *75*, 399–415.

Sperling, G. The information available in brief visual presentation. *Psychological Monographs*, 1960, *74*(11, Whole No. 498).

Spoehr, K. T., & Corin, W. J. The stimulus suffix effect as a memory coding phenomenon. *Memory and Cognition*, 1978, *6*, 583–589.

Watkins, M. J., & Watkins, O. C. The postcategorical status of the modality effect in serial recall. *Journal of Experimental Psychology*, 1973, *99*, 226–230.

Wickelgren, W. Acoustic similarity and retroactive interference in short-term memory. *Journal of Verbal Learning and Verbal Behavior*, 1965, *4*, 53–61.

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