JOURNAL OF MEMORY AND LANGUAGE 26, 138–164 (1987)

Recency and Suffix Effects Found with Auditory Presentation and with Mouthed Visual Presentation: They're Not the Same Thing

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Five experiments investigated recency and suffix effects in a short-term memory recall task with auditory presentation and with visual presentation when subjects silently mouthed the stimuli. It was concluded that recency and suffix effects found with auditory presentation are not mediated by the same mechanisms that mediate those effects found with visual, mouthed presentation. As expected, the typical recency and suffix effects with auditory stimuli were found with lists consisting of syllables that varied in their vowels (such as *teek, take, toke*) but not with lists that varied in their consonants (such as *pape, tape, cape*). Much weaker effects were found for mouthed stimuli; moreover, the effects were not affected by the consonant/vowel variable. The recency and suffix effects with auditorily presented stimuli were not dependent on the size of the vocabulary from which the stimuli were drawn. By contrast, the effects with mouthed visually presented stimuli were dependent on vocabulary size. © 1987 Academic Press, Inc.

A variety of paradigms have yielded support for an auditory sensory store which Neisser (1967) has called echoic memory. The majority of the research on echoic memory is based on the robust modality effect, where information at the end of a list of verbal items is better remembered when heard than seen (Crowder & Morton, 1969; see Penney, 1975, for review). However, this recency advantage for auditory presentation can be eliminated by adding a verbal suffix to the end of the list. Crowder and Morton (1969) originally interpreted this suffix effect as evidence for the separate storage of auditory and visual sensory information. Visual information was considered to last for approximately 250 ms, which was not enduring enough to produce an end of the list advantage. Auditory information was considered to last for several seconds in a Precategorical Acoustic Store (PAS), but was sensitive to auditory verbal masking, such as the subsequent presentation of an auditory verbal suffix. In accordance with this model, subjects can integrate the relatively long-lasting traces of items in PAS with the information held in short-term memory (STM). The result is two sources of recent information available for the better end-of-list recall from auditory lists.

However, several findings have been reported recently that are difficult to interpret within the PAS model. Ayres, Jonides, Reitman, Egan, and Howard (1979) presented an ambiguous suffix that was defined to subjects as either a musical note or a speech sound. Results indicated that the magnitude of the suffix effect was found to depend on the context in which the suffix appeared. A precategorical model cannot account for why the same physical stimulus did not consistently produce a suffix effect.

Salter (1975) hypothesized that if recency and suffix effects with auditory presentation are the result of a precategorical store, then these effects should NOT be influenced by semantic categorization. He demonstrated that the suffix effect was dependent on whether the terminal list item were a digit or a letter. He concluded that the recency effect is not a result of a "pre"

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0749-596X/87 $3.00

categorical auditory store. This argument, however, may be premature. An unusual item within a list will be better recalled, that is, a von Restorff effect (Howard, 1983), regardless of where it occurred in that list. Thus, better recall of the letter doesn't mean that the suffix failed to mask the echoic trace of that item. The trace may have been masked, but recall was probably based on a more permanent STM representation.

Another particularly important criticism of the PAS model comes from several findings of suffix effects with lip-read or silently mouthed stimuli (Campbell & Dodd, 1980; Greene & Crowder, 1984; Nairne & Crowder, 1982; Nairne & Walters, 1983; Shand & Klima, 1981; Spoehr & Corin, 1978). This is inconsistent with the PAS explanation of suffix effects because there is *no acoustic input involved in the stimulus presentation*. Thus, there can be no echoic trace available to aid recall.

In one of several experiments exploring how lip-read speech is encoded, Campbell and Dodd (1980) compared recall of graphic and lip-read lists followed by either an auditory suffix or no suffix. They hypothesized that if the suffix effect were specific to the auditory modality there should be no suffix effect for either the graphic or the lip-read lists. However, they found that the suffix did reduce recency performance on the lip-read lists. Campbell and Dodd argued that the PAS model was not sufficient to account for recency and suffix effects, and hypothesized that the changing state quality of stimuli would better explain these effects. They posited that lip-read and auditory information is processed temporally and sequentially due to the constantly changing state quality of the stimulus presentation. Graphic printed lists, on the other hand, were said to be processed instantaneously, because these items remain static during presentation.

Shand and Klima (1981) tested Campbell and Dodd's (1980) changing-state/static-state processing difference explanation of suffix effects using congenitally deaf signers of American sign language (ASL). They presented deaf subjects proficient in ASL three types of lists: (1) videotaped ASL signs, (2) line drawings of ASL signs, or (3) printed words. The 12-item lists were followed by three suffix conditions: (1) a videotaped ASL sign, (2) a line drawing of an ASL sign, or (3) visual snow on the screen. They found that both the static line drawing suffix and the changing-state videotaped sign suffix led to decreased recall when they followed lists of both the traced and videotaped signs. They argued these findings could not be explained by the changing state hypothesis because their static line drawings produced suffix effects. Shand and Klima (1981) concluded that these effects resulted from factors associated with the primary linguistic input that is conveyed. Accordingly, deaf subjects received the majority of their information from ASL signs. Therefore, reproductions of these signs generated recency and suffix effects. They argued that since the auditory system provides the primary linguistic input for hearing subjects, suffix effects should be generated with auditorily presented stimuli. Printed stimuli such as words and letters are considered to be secondary representations, and they do not produce recency and suffix effects. Further, Shand and Klima (1981) suggested that PAS was not a sufficient explanation of the suffix effect, since they found suffix and recency effects with visual presentation and with deaf subjects, neither of which could have been influenced by echoic memory traces.

Although the above criticisms of PAS are important, the findings that are most inconsistent with the PAS model are clearly those demonstrating *that auditory input is not necessary to produce recency and suffix effects*. Many studies have demonstrated that stimuli and/or suffixes that are silently mouthed can produce recency and suffix effects (Greene & Crowder, 1984; Nairne & Crowder, 1982; Nairne & Walters, 1983). Nairne and Crowder (1982), however, have demonstrated that the mouthed suffix effect is much weaker than this effect produced with an auditory suffix. They argued that the difference in magnitude between these effects could be considered a useful procedure for separating interference due to purely acoustic information from those effects due to anything else. These findings upheld the PAS model. However, Nairne and Walters (1983) found *recency effects with mouthed visually-presented stimuli* that were analogous to the recency effects found with auditorily presented lists. They found no difference between the suffix effect found with an auditory suffix and that found with a mouthed suffix. Thus, Nairne and Walters (1983) found no evidence that the aloud suffix was any more harmful than the mouthed suffix, making it extremely difficult for these findings to be explained by the PAS model.

In a replication of Nairne and Walters (1983), Greene and Crowder (1984) also found recency and suffix effects in the recall of passively lip-read stimuli in which an experimenter silently articulated the items. These authors concluded that recency and suffix effects found with visual input were not dependent on whether the stimuli were passively lip-read or actively mouthed, and further that these effects were nearly as large as the recency and suffix effects found with recall of auditorily presented stimuli. Since these findings could not be explained by assuming that the nature of information held in an auditory sensory memory was purely acoustic, they suggested considering an auditory sensory memory as that stage of processing where both acoustical and gestural information may be stored and that both can serve as an aid in later recall. That is, gestural information may help determine which auditory features are retrieved or activated in the same way that auditory presentation would. Greene and Crowder (1984) concluded that the same mechanism may mediate any source of precategorical information as long as it pertains to the discrimination among auditory features present in the environment.

As an alternative to the revised PAS, Penney (1985) suggested that the recency and suffix effects generated by auditory and mouthed visual presentations are not necessarily reflecting the same underlying mechanism. Penney (1985) demonstrated that the magnitude of the suffix effect on preterminal list items was dependent upon the predictability of the stimulus list length, and on the rehearsal strategies of the subjects. These factors did not influence the more structurally based suffix effect on terminal list items. She argued that the modality and suffix effects reflect the operation of two subsystems in STM, one for auditory and one for visual verbal information. For example, the terminal and preterminal effects of the auditory suffix are mediated by different processes within the auditory subsystem. The point is that only processes within an auditory subsystem, not a visual subsystem, can be reflected by the suffix effect found with an auditory suffix. She suggested that suffix effects found with mouthed visual information (e.g., Spoehr & Corin, 1978) are consistent with her theory, or any theory of auditory sensory memory, because these theories only make predictions regarding the auditory modality. Penney (1985) pointed out that since the modality effect reflects the operation of two different mechanisms there may be differences as well as similarities between auditory and mouthed suffix effects.

The case for different mechanisms mediating the recency and suffix effects found with mouthed visually presented information and with auditorily presented information is viable but difficult to test. On the other hand, if these effects are mediated by the same mechanism, then they should be affected by the same variables. One variable that has been shown to interact with the effect of the auditory suffix is the phonological nature of the list items.

Crowder (1971) found that both the modality and suffix effects were dependent on the phonetic nature of the item being remembered. When synthesized consonant/vowel (CV) syllables were used as list items and the list items varied only in their vowel content (as in *gAp, gOt, gUt* or *bEE, bOO, bIh*), both modality and suffix effects were obtained. However, when the synthesized stop consonants varied only the consonant content (as in *ba, da, ga*), neither of these effects was found. However, Cole (1973) and Neely (1983) have also found differential recall of consonant- and vowel-varied real speech stimuli lending support to the PAS theory of echoic memory for vowels and not consonants.

Thus, the consonant-varied and vowel-varied differential processing effect appears to be characteristic of echoic memory. If, as Greene and Crowder (1984) suggest, PAS is the mechanism underlying the similarity between auditory and mouthed recency and suffix effects, then differential processing effects should also be similar between auditory and mouthed stimuli.

The question that motivated the following series of experiments was whether a suffix effect obtained with mouthed stimuli is mediated by the same mechanism as the suffix effect obtained with auditory input. Greene and Crowder (1984) posited that the same mechanism (PAS) may mediate any source of precategorical auditory information if it is activated by either acoustic or gestural cues pertaining to the discrimination among auditory features. We wished to test the PAS model of echoic memory which allows gestural cues to activate and consequently affect any information stored therein. Experiment 1 replicated the findings (e.g., Greene & Crowder, 1984; Nairne & Crowder, 1982), of similar recency and suffix effects with both read-aloud and mouthed visually presented digits. In Experiments 2 and 3 we used the consonant/vowel difference as a tool to investigate mouthed and auditory suffix effects. We hypothesized that if PAS is responsible for mouthed suffix effects, then we should find that the nature of the stimulus items (vowel-varied or consonant-varied) affects the magnitude of the recency and suffix effects when visually presented stimuli are mouthed. Typical recency and suffix effects, as well as differential processing effects, were found with auditorily presented stimuli. However, only weak recency and suffix effects were obtained for mouthed visually presented stimuli. More importantly, these weak suffix effects were not dependent on whether the stimuli were vowel varied or consonant varied. These results are not consistent with the Greene and Crowder interpretation of mouthed suffix effects. Thus, Experiment 3 was designed to selectively produce modality and suffix effects with mouthed visually presented stimuli like those used by Crowder (1971). However, again we found that the nature of the stimuli (vowel varied or consonant varied) did not determine the magnitude of recency and suffix effects in the same way as with auditorily presented stimuli. More importantly, we did not find convincing recency or suffix effects with the mouthed visually presented stimuli, even though the same stimuli had led to typical recency and suffix effects with an auditory presentation (Crowder, 1971).

These findings do not support the Greene and Crowder version of PAS because convincing recency and suffix effects were not found with mouthed visually presented items. Therefore, we considered a comparison of procedures we used and those used by other researchers finding recency and suffix effects with mouthed visually presented stimuli. The major procedural difference that we considered worthy of further investigation was the type of stimuli. Mouthed suffix effects have generally been found when the items are digits.

In Experiments 4 and 5, we questioned whether recency and suffix effects for mouthed visually presented stimuli could only be obtained with digits, or, whether some other factor which varied across studies caused the conflicting findings. In Experiment 4 we again varied mouthing instructions, this time varying the nature of the stimulus used in the task, either digits or letters. Vocabulary size was also varied, that is, whether the stimuli were drawn from a pool of size 3 or size 8. Results showed that the important manipulation was vocabulary size, not type of stimulus, since recency and suffix effects were both found with mouthed visually presented digits or letters, but only when they were drawn from a vocabulary pool of size 8. However, Conrad and Hull (1964) had found that memory span does not depend on vocabulary size when stimuli were presented auditorily. Thus, we questioned whether the vocabulary size dependence of the recency and suffix effects we found with mouthed visually presented items in Experiment 4 would also be found with auditorily presented items. Experiment 5 was essentially a replication of Experiment 4, but with auditory presentation. Although we found the typical recency and suffix effects usually found with auditorily presented digits and letters, these effects were independent of vocabulary size.

Experiment 1

Greene and Crowder (1984) used a revised PAS model of echoic memory in the explanation of their finding that mouthed visually presented and heard auditorily presented suffixes similarly interfered with the enhanced recency recall of end-of-list items. They posited new assumptions that allowed speech gestures to be added to the acoustical information represented by the precategorical store. Thus, the acoustic features in PAS can be activated by mouthed gestural information. This could explain the enhanced recall of items at the end of the list over earlier positions for mouthed visually presented as well as heard auditorily presented stimulus lists. Experiment 1 is an attempt to replicate recency and suffix effects found with mouthed visually presented stimuli (Greene & Crowder, 1984; Nairne & Crowder, 1982; Nairne & Walters, 1983). Consequently, the main variable was mouthing instructions, that is, whether subjects were required to read aloud, silently mouth, or read silently without mouthing the digits 1–9. In addition, the digits were seen either centered or spread out on the screen.

Method

Subjects and Design

The subjects were 60 University of South Carolina students who particpated to satisfy a course requirement. Six between-subjects conditions crossed mouthing instructions with stimulus position. Subjects were instructed to either read the digits out loud, read and mouth the digits emitting no sounds, or read passively the digits refraining from any and all obvious articulation. In addition, subjects saw the items centered or spread out on the monitor. The two within-subjects variables were (1) whether the 9-item lists were followed by a suffix or nonsuffix, and (2) the serial position of the 9 items within each list.

Stimuli and Procedure

The stimuli consisted of the digits 1–9 randomly chosen without replacement and presented one at a time on the monitor of an Apple microcomputer on each trial. Each digit was presented either (1) centered in exactly the same position, or (2) centered vertically but spread out horizontally on the monitor. In both conditions the stimulus digit was erased after a 500-ms duration, so that the subject saw only one digit at any one time. In the suffix condition the word "go" randomly followed half of the trials as the subjects' cue to begin recall, and a pair of asterisks (**) or tone served in the nonsuffix condition as the cue to begin recall.

In the read-aloud condition, subjects were instructed to repeat the digits so that the experimenter could hear them. Subjects in the mouthing condition were told to silently mouth the stimulus items, that is, to move their lips in a somewhat exaggerated manner so that the experimenter could understand each item from watching their lips. However, they were cautioned not to whisper or make any sound while mouthing the items. Subjects in the nonmouthing group were instructed to listen silently or to view without moving their lips. An experimenter remained with each subject throughout the entire experiment checking and reminding him/her to follow the specific read-aloud/mouthing/nonmouthing instructions. Next, all subjects were given three practice trials in their particular condition, immediately followed by the 40 experimental trials. On each trial the subject either heard or saw the /ready/ signal, and after 1000 ms, sequentially heard or saw the nine digits followed by either the suffix (heard or seen /go/) or the non-suffix (tone /**/). All items were presented sequentially including the suffix (nonsuffix) at a rate of two per second with an item duration of 300 ms followed by a 200-ms interitem silence. A minimum of 20 s separated the onset of the last item (suffix or tone) from the /ready/ signal that began the next trial. During this period the subject typed the recalled digits on specially marked keys on the computer. All subjects were individually instructed to type the items in the same serial order as seen or heard, after which they were given an opportunity to correct their response. After recall, immediate feedback was given about the number correctly recalled and the subject was encouraged to keep trying.

Since there were two experimenters in this study, each experimenter ran five subjects in each condition, counterbalancing any experimenter bias.

Results and Discussion

The major goal of Experiment 1 was replicating the findings of current research (e.g., Greene & Crowder, 1984; Nairne & Crowder, 1982; Nairne & Walters, 1983). The manner in which the stimuli were positioned on the screen had no effect whatsoever on subjects' recall. Therefore, all of the results are reported from the analysis collapsing over this variable.

The responses were recorded as the subject typed them on the computer. Only correct responses in the correct serial position were counted. Planned comparisons were computed using an F ratio (Hayes, 1981) for the specific hypotheses regarding recency and suffix effects. All tests for recency were based on the difference in recall between items in the preterminal (eighth) and terminal (ninth) serial position. Also, all tests for suffix effects were based on the differential recall of items in the suffix versus nonsuffix conditions for the terminal serial position.

Again, the major question prompting all the experiments in this paper was whether recency and suffix effects found with mouthed visually presented stimuli are affected in the same way as recency and suffix effects found in auditorily presented stimuli. Figure 1 shows the overall three-way interaction central to this question, the Mouthing condition (whether items were mouthed or nonmouthed) by Suffix condition (whether lists were followed by a suffix or nonsuffix) by Serial Position (1–9). This interaction was significant, $F(16,432) = 4.04$, $p < .0001$, $MS_e = 51.23$.

Thus, the recall of visually presented stimulus items in Experiment 1 revealed strong recency and suffix effects with mouthed visually presented digits which

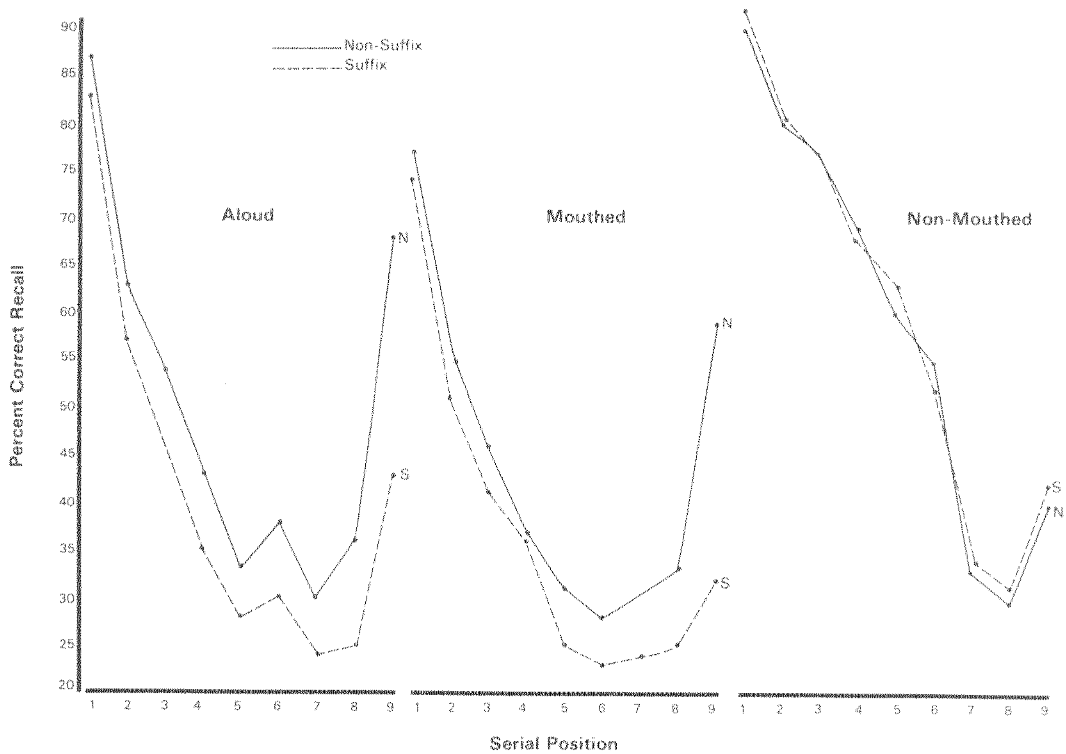

FIG. 1. Mean percentage correct as a function of Mouthing Condition (mouthed/nonmouthed/aloud) by Suffix Condition (suffix/nonsuffix) by Serial Position (1–9) with visual presentation of digits in Experiment 1.

were no different from the recency and suffix effects for digits said aloud. However, these convincing recency and suffix effects generated with mouthed visually presented digits were found with both centered and spread digits. These findings clearly support the revised PAS model, as described in Greene and Crowder (1984). This model allows both auditory and gestural cues to affect the acoustic information held in a precategorical condition. However, if both auditory and gestural input similarly contribute to the analysis of auditory features present in the environment as posited by the PAS model, then variables affecting auditory information should similarly affect gestural information. Thus, the question motivating the following series of experiments was whether recency and suffix effects obtained with mouthed visual input are affected by the same variables as the effects found with auditory presentation. If the revised PAS model of echoic memory can explain both sets of effects, then mouthed visually presented stimuli should also show a consonant/vowel effect. That is, we should find that the nature of the stimulus items, that is, whether vowels or consonants are varied, affects the magnitude of both sets of recency and suffix effects. Recency and suffix effects should be found when the stimulus items are vowel varied, and NOT when they are consonant varied, and this finding should occur for mouthed visually presented and heard auditorily presented items.

EXPERIMENT 2

Method

Subjects

Students from the subject pool of the University of South Carolina participated in this study. One fourth of the 96 students were randomly assigned to each of four between-subjects conditions: (1) auditorily presented items with mouthing instructions, (2) auditorily presented items with nonmouthing instructions, (3) visually presented items with mouthing instructions, and (4) visually presented items with nonmouthing instructions. Each subject was tested individually and participated in the experiment in order to fulfill a class requirement.

Design

Groups of 12 subjects resulted from two factorially crossed between-subjects variables: (1) whether the stimulus items were presented auditorily or visually, and (2) whether the subjects mouthed the items. There were five within-subjects variables: (1) phoneme condition, that is, whether the items were consonant varied or vowel varied, (2) initial stop consonant condition, that is, whether the items began with a voiced (e.g., *b/d/g*) or an unvoiced (e.g., *p/t/c*) initial stop consonant, (3) whether the items were from stimulus set 1 or set 2, (4) whether the seven-item lists were followed by a suffix or nonsuffix, and (5) the serial position of the seven items within each list. Further, the order of stimulus presentation was counterbalanced so that half of the subjects saw or heard consonant-varied items followed by vowel-varied items while the remaining half saw or heard the sets of items in the reverse order. Also, half of the subjects saw or heard items beginning with voiced initial stop consonants (e.g., *b/d/g*) followed by items beginning with unvoiced initial stop consonants (e.g., *p/t/c*) while the remaining half saw or heard a reverse order of initial stop consonant condition. The two stimulus sets were presented in random order, as well as whether a list was followed by a suffix or nonsuffix, with the constraint that the two levels of each of these two variables would be evenly divided among all 16 within-subjects conditions. Thus, in half (8) of the within-subjects conditions the lists were followed by the suffix, with four lists generated from set 1 vocabulary and four lists from set 2 vocabulary. The remaining 8 of the within-subjects conditions consisted of lists that were followed by no suffix, again with four lists generated from set 1 vocabulary and the last four lists from set 2 vocabulary. Within each set of four lists the stimuli were (1) consonant varied, using voiced initial stop consonants */d,b,g/* holding the vowel and final consonant cluster constant, that is, */dark, bark, gark/*, (2) consonant varied, using unvoiced initial stop consonants */p,t,c/* holding the vowel and final consonant cluster constant, that is, */park, tark, cark/*, (3) vowel varied */e,a,o/*, using voiced initial stop consonants */b,d/* holding the initial stop and final consonant cluster constant within set, that is, */beme, bame, bome/*, (4) vowel-varied */e,a,o/*, using unvoiced initial stop consonants */p,t/* holding the initial stop and final consonant cluster constant within set, that is, */peme, pame, pome/*.

Stimuli

Seven stimulus items were randomly selected from one of eight different three-item vocabularies (see Table 1). This generated eight lists from each of the within-subject conditions so that each subject saw or heard 128 lists. Table 1 shows the two sets of stimulus items. Within each set the stimulus items were consonant varied (e.g., *dark/gark/bark*) or vowel varied (e.g., *beem/bame/bome*), and all stimulus items began with voiced (e.g., *d/b/g*) or unvoiced (e.g., *p/t/c*) initial stop consonants. Stimulus items for the audio presentation were generated with a Mountain Hardware Supertalker on an Apple II Plus microcomputer. The stimulus items were spoken by a male and digitized for storage on disk so the items could be individually played back through a Marantz loudspeaker under computer control. For the visual presentation

TABLE 1
STIMULUS ITEMS

Initial stop consonant condition		Phoneme condition: Vowel-varied items	Phoneme condition: Consonant-varied items
Set 1	Voiced	beem	dark
		bame	gark
		bome	bark
	Unvoiced	peem	park
		pame	tark
		pome	cark
Set 2	Voiced	deek	dape
		dake	gape
		doke	bape
	Unvoiced	teek	pape
		take	tape
		toke	cape

the same stimulus items were shown serially on the monitor of the computer. The items were shown one at a time, centered along the horizontal axis and listed top to bottom on the screen. Thus, although subjects viewed stimulus items in a sequential order, the currently viewed item did not mask the preceding item.

The auditorily presented lists were followed by the word "recall" in the suffix condition and with a "tone" in the nonsuffix condition. The visually presented lists were also followed by the word "recall" in the suffix condition while (*****) followed lists in the nonsuffix condition. In the visual condition both the suffix "recall" and the non-suffix (*****) were presented at the bottom of the list of items on the screen. The duration of all stimulus items was 300 ms each, with the exception of a "ready" signal which lasted 1000 ms and preceded each trial.

Procedure

The mouthing and nonmouthing instructions given to subjects in Experiment 1 were replicated in this study. An experimenter remained with each subject throughout the entire experiment checking and reminding him/her to follow the specific mouthing/nonmouthing instructions. Subjects typed their recall on specially marked keys on the computer, and as in the first experiment were instructed to recall items in the same serial order as seen or heard, after which they were given an opportunity to correct any response. Immediate feedback also followed each trial which encouraged the subject to keep trying.

Since there were three experimenters in this study, each experimenter ran two subjects in each condition, counterbalancing any experimenter bias.

Results

Methods of Analyses

Results from the auditory condition and the visual condition were analyzed separately. In both analyses of variance the only between-subject variable was whether the subjects mouthed the items, while the five within-subject variables were (1) whether the items varied consonants or vowels, (2) whether the items began with voiced or unvoiced stop consonants, (3) whether the items were from stimulus set 1 or 2, (4) whether the seven-item lists were followed by a suffix or nonsuffix, and (5) the serial position of the items within each list (see Table 1). The findings were presented and discussed based on F ratios computed from the analyses of variance treating the language stimuli as a fixed effect (F). However, the quasi-F ratios (F') were also reported for those wishing to make inferences from these results to other language materials as well as to other subject populations (Clark, 1973; Clark, Cohen, Smith, & Keppel, 1976; Forster & Dickinson, 1976; Wike & Church, 1976).

Auditory Presentation

Regency, suffix, and phenome effects. Figure 2 shows the three-way interaction between Phoneme condition (whether the

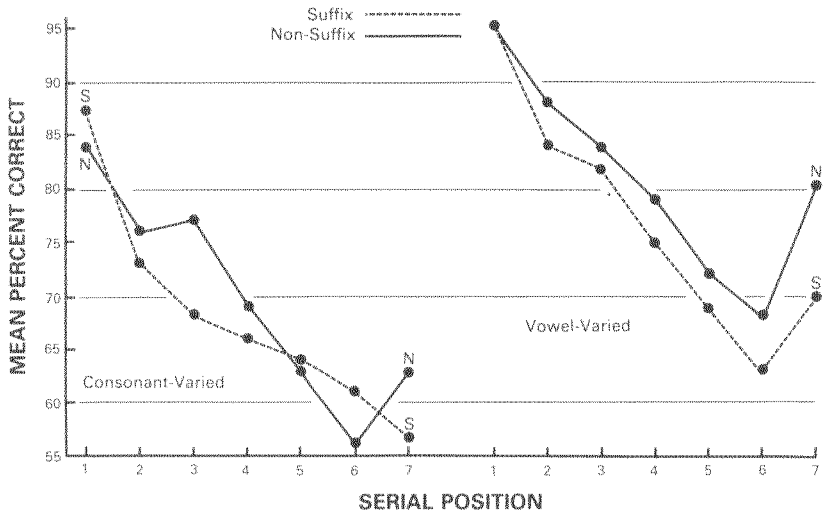

FIG. 2. Mean percentage correct as a function of Phoneme Condition (consonant-varied/vowel-varied) by Serial Position (1–7) with auditory presentation in Experiment 2.

stimuli were consonant varied or vowel varied) by Suffix condition (whether the lists were followed by a suffix or nonsuffix) by Serial Position (1–7). The recency and suffix effects usually found with auditory presentation can be seen in Figure 2. The recency effect is reflected in the better recall of items in the seventh serial position of the Nonsuffix condition, especially when the items were vowel varied. Clearly there were little or no recency or suffix effects when the stimuli were consonant varied but just as clearly there were sizable recency and suffix effects when the stimuli were vowel varied. These conclusions were supported by (1) the main effect of Serial Position, $F(6,132) = 92.55$, $p < .0001$, $MS_e = 388.48$; $F'(6,219) = 44.12$, $p < .01$, and (2) the two-way interaction between Serial Position and Suffix condition, $F(6,132) = 6.01$, $p < .001$, $MS_e = 160.78$; $F'(6,179) = 1.92$, $p < .10$.

More importantly, in reference to the questions posed by this study, Figure 2 shows that the verbal suffix only caused a significant decrement at the terminal position when the list was composed of vowel-varied items. The suffix had no effect at the last serial position for the recall of consonant-varied lists. This finding was supported by the three-way interaction between Phoneme condition, Suffix condition, and Serial Position, $F(6,132) = 2.89$, $p < .01$, $MS_e = 204.32$; $F'(6,181) = 0.94$, $p > .05$.

These findings are in line with Crowder's (1971) and Cole's (1973) results which also demonstrated differential processing of vowel-varied and consonant-varied stimulus items with auditorily presented material. Figure 2 also shows that vowel-varied items were better recalled than consonant-varied items over all serial positions, with the difference between vowel-varied and consonant-varied stimuli greatest at the last serial position, reflecting recency with the vowel-varied but not the consonant-varied stimuli. These conclusions were confirmed by the two-way interaction between Serial Position and Phoneme, $F(6,132) = 2.87$, $p < .01$, $MS_e = 245.51$; $F'(6,194) = 1.06$, $p > .05$.

Initial stop consonant effects. Several interesting interactions resulted from varying whether the items began with a voiced (*b*/*d*/*g*) or unvoiced (*p*/*t*/*c*) stop consonant.

For example, the interaction among Phoneme condition, Voicing condition, and Serial Position showed Voicing had no effect when the stimuli were vowel varied. However, when stimuli were consonant varied Voicing did not have an effect, but only over the first five positions. Here stimuli beginning with voiced stop consonants (*/bark/dark/gark/*) were recalled better than stimuli beginning with unvoiced stop consonants (*/park/cark/tark/*). This was confirmed by the significant two-way interaction of Voicing by Serial Position, $F(6,132) = 2.76$, $p < .01$, $MS_e = 207.92$; $F'(6,150) = 0.61$, $p > .05$, and the three-way interaction of Phoneme condition by Voicing condition by Serial Position, $F(6,132) = 2.99$, $p < .009$, $MS_e = 213.70$; $F'(6,190) = 1.07$, $p > .05$.

In summary, recall was dependent on whether items began with voiced (e.g., *b/d/g*) or unvoiced (e.g., *p/t/c*) initial stops. This was true, however, only in the first five serial positions of the consonant-varied stimulus items, wherin items beginning with voiced initial stop consonants were better recalled. However, this effect is of marginal importance since the focus of the study was on the terminal serial positions.

Overall, the findings from the auditory conditions of this experiment generally agreed with studies finding an interaction between the suffix condition and the phonological nature of the list item (Cole, 1973; Crowder, 1971; Pisoni, 1973). That is, when the items were presented auditorily, vowel-varied items gave rise to a recency effect that was removed by a verbal suffix while both effects were absent with consonant-varied stimuli.

Visual Presentation

Mouthing effects. The major question prompting this study was whether varying the nature of the stimuli (vowel varied or consonant varied) affected the magnitude of recency and suffix effects in the same way for both mouthed and heard items. Figure 3 shows the four-way interaction central to this study, the Phoneme condition (whether items were vowel varied or consonant varied) by Mouthing condition (whether items were mouthed or nonmouthed) by Suffix condition (whether lists were followed by a suffix or nonsuffix) by Serial Position (1–7). This interaction was not significant, $F(6,132) = 1.41$, $p > .21$, $MS_e = 160.45$. However, both panels of Figure 3 do show a pattern of better recall for vowel-varied than for consonant-varied items (vowel varied, $\bar{x} = 77\%$; consonant varied, $\bar{x} = 71\%$). Thus, the main effect of Phoneme condition was significant, $F(1,22) = 39$, $p < .0001$, $MS_e = 522.14$; $F'(1,32) = 13.88$, $p < .01$). Moreover, comparing both panels of Figure 3 suggests a greater difference in recall between vowel-varied and consonant-varied items at the seventh serial position for the mouthed than the nonmouthed items. One purpose of this study was finding whether a recency effect occurred with mouthed stimuli, and if the presence of this effect interacted with whether stimuli are consonant varied or vowel varied. Therefore, in the Nonsuffix condition, the difference in mouthed recall at the sixth and seventh serial positions was compared using planned comparisons. The Mouthed Vowel-Varied condition showed a small *increase* in recall at the seventh position over recall at the sixth position, $F(1,46) = 3.74$, $p < .06$, $MS_e = 160.45$, while the Mouthed, Consonant-Varied items showed a *decrease in* recall from position 6 to 7, $F(1,46) = 0.22$, $p > .05$, $MS_e = 160.45$. Thus, a small recency effect was found when items were mouthed, but, specifically, only when the items were vowel varied.

In the Nonmouthed condition there was no significant change in recall from the sixth to the seventh position. That is, neither vowel-varied nor consonant-varied stimuli showed a significant recency effect if they were read silently and not mouthed.

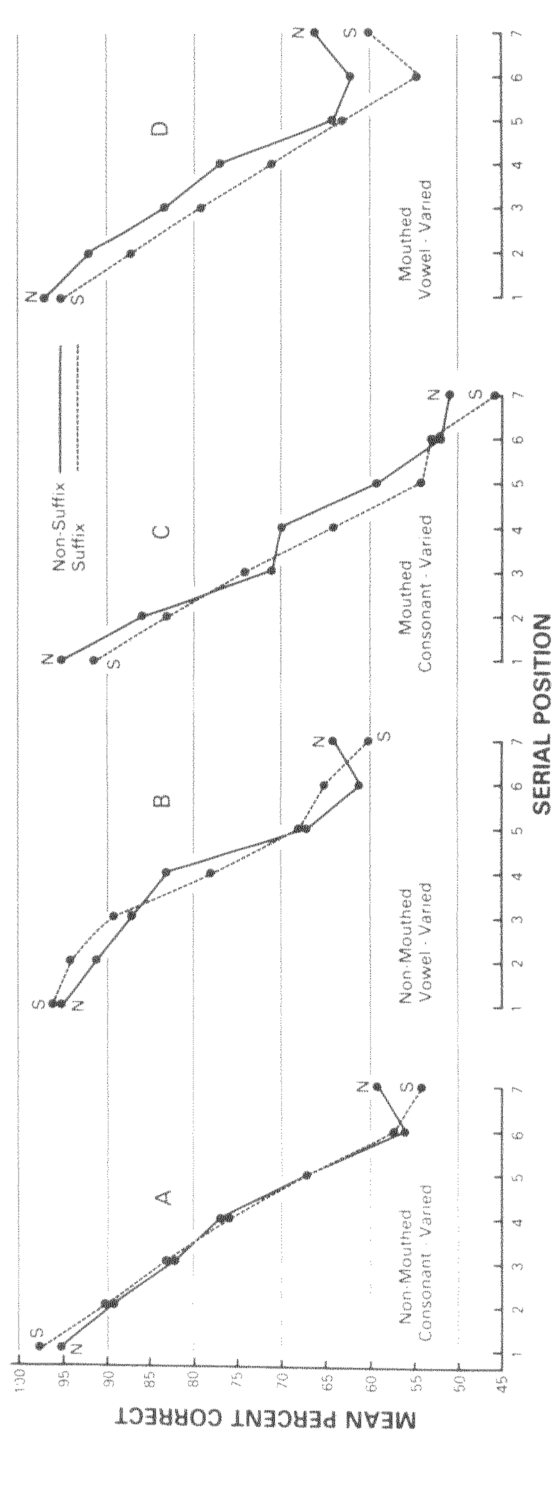

FIG. 3. Mean percentage correct as a function of Mouthing Condition (mouthed/nonmouthed) by Phoneme Condition (consonant-varied/vowel-varied) by Suffix Condition (suffix/nonsuffix) by Serial Position (1–7) with visual presentation of syllables in Experiment 2.

Another finding central to the purpose of this study concerned the occurrence of suffix effects for the last position. This can be seen by comparing the effect of the suffix in both panels of Figure 3. The right panel of Figure 3 shows small suffix effects for both consonant-varied and vowel-varied stimuli when the items were mouthed. That is, there was a significant difference between Suffix and Nonsuffix conditions at the seventh serial position for (1) the Mouthed Consonant-Varied stimuli, $F(1,46) = 5.39$, $p < .025$, $MS_e = 160.45$, and (2) the Mouthed Vowel-Varied stimuli, $F(1,46) = 5.39$, $p < .025$, $MS_e = 160.45$ *Although the addition of a verbal suffix to the end of the lists did reduce recall of mouthed stimuli, the suffix did not reduce recall any more for vowel-varied items than for consonant-varied items.* In fact, the suffix effect (i.e., the mean of the Nonsuffix condition minus the mean of the Suffix condition) at the seventh position was equal (6%) for mouthed consonant-varied and mouthed vowel-varied items. Although the suffix effects for vowel-varied items that were nonmouthed (4%) and consonant-varied items that were nonmouthed (5%) were not much different in magnitude from the mouthed suffix effects (i.e., 6%), these nonmouthed suffix effects only approached significance. That is, differences between Suffix and Nonsuffix conditions were not significant for (1) the Nonmouthed Consonant-Varied stimuli, $F(1,46) = 3.74$, $p < .10$, $MS_e = 160.45$, and (2) the Nonmouthed Vowel-Varied stimuli, $F(1,46) = 2.39$, $p < .25$, $MS_e = 160.45$).

In summary, the recall of visually presented stimulus items revealed (1) that the nature of the stimuli (vowel varied or consonant varied) did not affect the magnitude of recency and suffix effects in the same way as auditorily presented stimuli, although (2) there was a rather weak recency effect for mouthed, vowel-varied items, and not for mouthed, consonant-varied items, and (3) that there were weak suffix effects for the mouthed but not the nonmouthed items, however, (4) the suffix effects at the terminal position were not dependent on whether the items were vowel varied or consonant varied.

Discussion

The results of Experiment 2 indicate that recency and suffix effects found with mouthed stimuli are not necessarily similar to recency and suffix effects found with auditory stimuli. Typical recency and suffix effects were found with auditorily presented stimuli, and further, these effects were both found to be dependent on the phonemic nature of the stimuli as had been expected. Recency and suffix effects were both present with vowel-varied but not with consonant-varied auditory stimuli. In contrast, when the stimuli were presented visually and mouthed, only weak recency effects were found to be dependent on whether the stimuli were vowel varied or consonant varied, and, although suffix effects were found with mouthed stimuli, they were not differentially dependent on the phonemic characteristics of the stimuli at the terminal position. In fact, with the mouthed visually presented stimuli, differences in recall at the terminal position for lists followed by a suffix compared with lists followed by a nonsuffix were exactly the same size (6%) for both vowel- and consonant-varied stimuli. The point is that weak recency and suffix effects were found with mouthed stimuli, but that these effects were not convincingly affected by the consonant/vowel variable, which, on the other hand, did influence the recency and suffix effects found with auditorily presented stimuli.

Theoretical Considerations

Are the same mechanisms responsible for recency and suffix effects found with auditorily presented stimuli, and, for the recency and suffix effects found with mouthed visually presented stimuli? It appears that the answer to this question is not simple. The basic tenant of both Crowder and Morton's (1969) initial and revised PAS (Greene & Crowder, 1984) explanations of recency and suffix effects found with auditorily presented stimuli posited that acoustic information about the last few items was represented in PAS for a few seconds. PAS, therefore, served as an additional source of coded information that could be accessed for later use. The coded information in PAS was considered precategorical since the recency and suffix effects found with auditorily presented stimuli were dependent on physical properties of that stimuli. The PAS theory was strongly supported by Crowder's (1971) studies which found both recency and suffix effects with vowel-varied but not consonant-varied auditorily presented stimuli.

Results from the auditory condition of Experiment 2 clearly agree with the findings of Crowder's (1971) study. Both recency and suffix effects were found for vowel-varied but not for consonant-varied auditorily presented list items. However, the results of the mouthed visual condition of Experiment 2 clearly did not support the theory. The revised PAS theory would predict that the recency and suffix effects resulting from mouthed gestural information should be obtained using vowel-varied but not consonant-varied stimuli. Therefore, Experiment 3 was designed to replicate the visual condition of Experiment 2 using mouthed and nonmouthed visually-presented stimuli, but mimicking the stimuli and procedure used by one of Crowder's (1971) experiments (i.e., his visual condition). Specifically we asked whether Crowder's vowel-varied stimuli would lead to recency and suffix effects, and also whether these effects would disappear when using Crowder's consonant-varied stimuli in our visual condition.

Experiment 3

Experiment 3, therefore, addressed the same question prompting Experiment 2, that is, whether recency and suffix effects obtained with mouthed input are mediated by the same mechanism as the recency and suffix effects obtained with auditory input. Again, we wanted to use the nature of the stimulus items (vowel varied or consonant varied) as a tool to investigate mouthing effects. However, in this experiment we used Crowder's (1971) stimuli which had selectively generated recency and suffix effects in his auditory versus visual investigation. We hypothesized that when these same stimuli were mouthed the magnitude of the recency and suffix effects would selectively be affected by the vowel-varied stimuli and not by the consonant-varied stimuli. The procedures used in the visual condition of Crowder's (1971) experiment were followed as closely as possible, except subjects were instructed to either mouth or not mouth the stimuli. Also, we were interested in a direct comparison of the differences between the written and typed response modes.

Method

Subjects

The subjects were 80 students with normal vision (including corrective lenses) from the subject pool of the University of South Carolina who participated to satisfy a course requirement.

Design

Twenty of the eighty students were randomly assigned to each of four between-subjects conditions. The subjects were instructed to (1) mouth the stimuli and type their recall, (2) mouth the stimuli and write their recall, (3) read silently the stimuli and type their recall, or (4) read silently the stimuli and write their recall. Half of the subjects saw vowel-varied items first and the other half consonant-varied. The three within-subjects variables were (1) phoneme conditon, that is, whether the items were consonant varied or vowel varied, (2) whether the seven-item lists were followed by a suffix or nonsuffix, and (3) the serial position of the seven items within each list. Counterbalancing of stimulus items and randomization of suffix condition were completed as described in Experiment 2. Each subject was tested individually with the experimenter present in the laboratory.

Stimuli

Seven stimulus items were randomly selected with replacement from one of the two three-item vocabularies used by Crowder (1971): (1) *boo/bih/bee*, and (2) *bah/dah/gah*. With the vowel-varied items (i.e., *boo/bih/bee*) the stop consonant was held constant, while with the consonant-varied items (i.e., *bah/dah/gah*) the vowel was held constant. The visually presented items were followed by the word "stop" in the Suffix condition while (****) followed lists in the Nonsuffix condition.

Procedure

The mouthing and nonmouthing instructions given to subjects in Experiment 1 were replicated in this study. On each of the 60 trials subjects saw the signal "ready" at the top left of the monitor. The seven items were shown in stairstep fashion from the upper left to the lower right corner in the screen with the suffix or nonsuffix the lowest stairstep in the stimulus array. Each item in the array appeared on the screen at a rate of one every 750 ms and remained for the duration of the trial. Each trial presentation, beginning with the first syllable and ending with the suffix or nonsuffix, lasted for a total of 6 s. The experimenter was situated approximately 3 ft away from the subject in a position which allowed observation of both the subject and the monitor. Thus, it was possible for the experimenter to ensure that the subjects complied with the mouthing/nonmouthing instructions of both the items and the suffix when it appeared.

Eight practice trials allowed each subject to become comfortable with the mouthing or nonmouthing instructions, as well as with the details of typing or writing his/her serial recall. Those subjects instructed to write their recall were given answer sheets with seven spaces opposite each trial number. The experimenter typed them on the keyboard as soon as the subject indicated he or she was finished responding. Those subjects instructed to type were shown the specially marked keys on which they were to type their recall. As in the first and second experiments, all subjects were instructed to recall items in the same serial order as seen, after which they were given an opportunity to correct any response. Immediate feedback also followed each trial which encouraged the subject to keep trying.

Results and Discussion

Again the major question prompting this experiment was whether varying the nature of the stimuli (vowel varied or consonant varied) affected the magnitude of recency and suffix effects in the same way for both mouthed and heard items. Figure 4 shows the four-way interaction central to this study, the Phoneme condition (whether items were vowel varied or consonant varied) by Mouthing condition (whether items were mouthed or nonmouthed) by Suffix condition (whether lists were followed by suffix or nonsuffix) by Serial Position (1–7). This interaction was not significant, $F(6,456) = 0.79$, $p > .57$, $MS_e = 105.2$. However, both panels of Figure 4 do show a pattern of better recall for vowel-varied than for consonant-varied items (vowel varied, $\bar{x} = 70\%$, consonant varied, $\bar{x} = 65\%$). Thus, the main effect of Phoneme condition was significant, $F(1,76) = 26.96$, $p < .0001$, $MS_e = 428.2$. Moreover, comparing both panels of Figure 4 suggests a greater difference in recall between vowel-varied and consonant-varied items at the seventh serial position for the

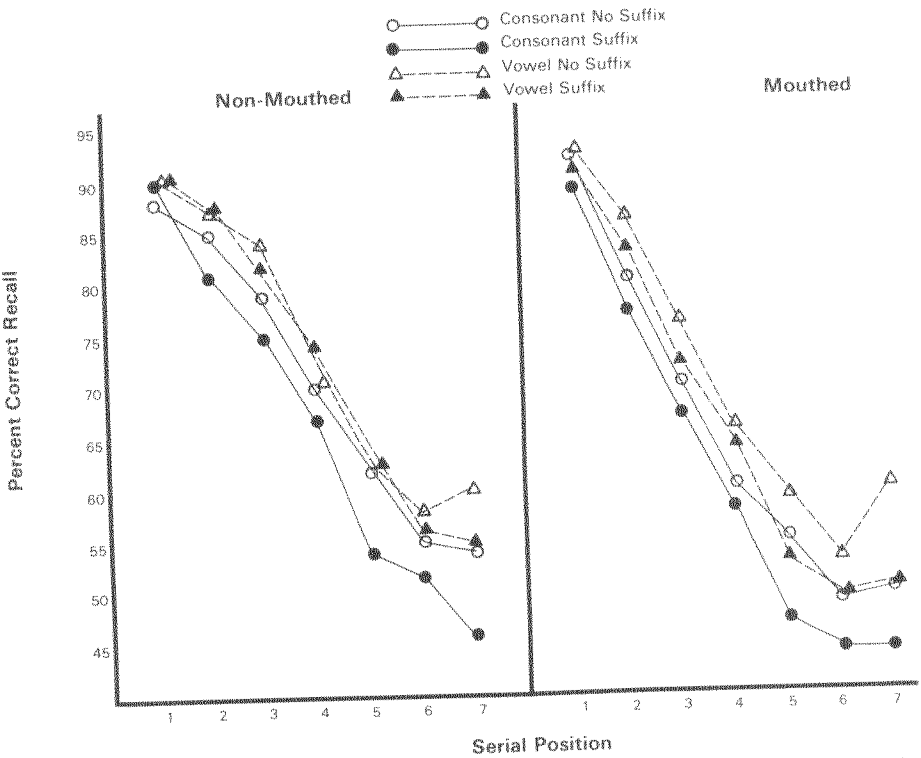

FIG. 4. Mean percentage correct as a function of Mouthing Condition (mouthed/nonmouthed) by Phoneme Condition (consonant-varied/vowel-varied) by Suffix Condition (suffix/nonsuffix) by Serial Position (1–7) with visual presentation of syllables in Experiment 3.

mouthed than for the nonmouthed items. One purpose of this study was finding whether a recency effect occurs with mouthed stimuli, and if the presence of this effect interacts with whether stimuli are consonant varied or vowel varied. Therefore, in the Nonsuffix condition, the difference in mouthed recall at the sixth and the seventh serial positions was compared using planned comparisons. The Mouthed Vowel-Varied condition showed a small *increase* in recall at the seventh position over recall at the sixth position, $F(1,38) = 8.28$, $p < .05$, $MS_e = 105.17$, while the Mouthed, consonant-varied items did not show a significant *increase* in recall from position 6 to 7, $F(1,38) = 0.19$, $p > .05$, $MS_e = 105.17$. Thus, a small recency effect was found when items were mouthed, but, specifically, only when the items were vowel varied.

In the Nonmouthed condition there was no significant change in recall from the sixth to the seventh position. That is, neither vowel-varied nor consonant-varied stimuli showed a significant recency effect if they were read silently and not mouthed.

Another finding central to the purpose of this study concerned the occurrence of suffix effects for the last position. This can be seen by comparing the effects of the suffix in both panels of Figure 4. The right panel of Figure 4 shows small suffix effects for both consonant-varied and vowel-varied stimuli when the items were mouthed. That is, there was a significant difference between Suffix and Nonsuffix conditons at the seventh serial position for (1) the Mouthed Vowel-Varied stimuli (10%), $F(1,38) = 19$, $p < .025$, $MS_e = 105.17$, and (2) the Mouthed Consonant-Varied stimuli (6.3%), $F(1,38) = 6.20$, $p <$

.025, $MS_e = 105.17$. Although the addition of a verbal suffix to the end of the lists did reduce recall of mouthed stimuli, the suffix did not reduce recall significantly more for vowel-varied items than for consonant-varied items. The suffix effects for vowel-varied items that were nonmouthed (4.6%, $F(1,38) = 4.0$, $p < .05$, $MS_e = 105.17$) and for consonant-varied items that were nonmouthed (7.4%, $F(1,38) = 10.4$, $p < .01$ $MS_e = 105.17$) were also significant.

Written recall was better than typed recall, $F(1,76) = 3.85$, $p < .053$, $MS_e = 1929$. However, there were no significant interactions between type of response, that is, whether subjects wrote or typed their responses, and any other variable.

In summary, the mouthed visually presented recall from Experiment 3 agreed with recall from Experiment 2, revealing (1) the nature of the stimuli (vowel varied or consonant varied) did not significantly affect the magnitude of recency and suffix effects in the same way as when the same stimuli were auditorily presented (Crowder, 1971), although (2) there was a rather weak recency effect for mouthed, vowel-varied items, and not for mouthed, consonant-varied items, but more importantly, (3) there were weak suffix effects for both mouthed and nonmouthed items, and (4) the suffix effects at the terminal position were not dependent on whether the items were vowel varied or consonant varied. It should be noted that the suffix decreased recall at the terminal position for *both mouthed and nonmouthed items* when presented visually in both Experiments 2 and 3. If the same mechanisms underlying the auditory suffix effect are to explain the mouthed suffix effect, then a suffix effect would not be expected when items are nonmouthed. A suffix effect would only occur when items are heard or mouthed. This prediction made by the revised PAS model held when the suffix decreased recall of *only the auditorily presented items* at the terminal position in our Experiment 2. Further, the auditory suffix effects at the terminal position occurred when the list items were vowel varied, and not when they were consonant varied, while mouthed and nonmouthed visual suffix effects were not dependent on the Phoneme condition. These results suggest that mouthed suffix effects are not caused by the same mechanisms underlying auditory suffix effects, and are in conflict with the revised PAS model.

Any discussion of underlying causes for patterns in the data of these latter two experiments when compared with the data of other research using a similar technique must, by necessity, rest on the assumption that methodological differences are irrelevant. However, a comparison of procedures used here and by other researchers finding recency and suffix effects with mouthed visually presented stimuli revealed one major procedural difference that should be considered (see Table 2). The type of stimuli used in both Experiments 2 and 3 were syllables which did not result in mouthing effects. However, Experiment 1 and studies of other researchers that did result in finding mouthed recency and suffix effects used digits as stimuli (Greene & Crowder, 1984; Nairne & Crowder, 1982; Nairne & Walters, 1983).

EXPERIMENT 4

Experiment 4 was designed to question whether only the digitness dimension could generate recency and suffix effects for mouthed visually-presented stimuli, or whether some other dimension along which procedures varied across studies caused the conflicting findings. We again varied mouthing instructions, adding the type of stimulus variable, that is, whether the stimuli were digits or letters. Also, we noted that there was a difference between the vocabulary sizes used in Experiments 2 and 3 and those used in Experiment 1 as well as by other researchers (Greene & Crowder, 1984; Nairne & Crowder, 1982;

TABLE 2
DIFFERENCES AMONG ECHOIC MEMORY STUDIES

Name of study	Stimuli	Suffix/ nonsuffix	Mouthing varied (BS/WS)	Stimuli: Rate of presentation (per s)	Stimuli: Position	Response mode	Recall time allowed (s)	Allowed to correct response?	No. of trials	No. of sub's
N & C	Digits (1–9)	up, down/ ***	WS	2	Centered	Written	18	No	60	60
N & W E1	Digits (1–9)	—	BS	2	Centered	Written	12	No	40	30
N & W E2	Digits (1–9)	go/**	WS	2	Centered	Written	12	No	60	18
G & C E1	Letters	—	BS	2	Centered	Typed	Self-paced	No	60	14
G & C E2	Digits (1–9)	begin/ ***	WS	2	Centered	Typed	Self-paced	No	60	30
G & C E3	Digits (1–9)	begin, start/ speaker looked down	WS	2	Centered	Written	?	No	60	20
E1	Digits (1–9)	recall/ *****	BS	2	Centered/ spread	Typed	Self-paced	Yes	80	60
E2	Syllables	stop/ ****	BS	1/750 ms	Spread	Typed/ written	Self-paced	Yes	60	24
E3	Syllables	go/**	BS	2	Spread	Typed	Self-paced	Yes	128	96
E4	Digits or letters	go/**	BS	2	Centered	Typed/ written	Self-paced	Yes	80	96
E5	Digits or letters	go/tone	BS	2	—	Typed	Self-paced	Yes	80	36

* Nairne & Crowder (1982).
** Nairne & Walters (1983).
*** Greene & Crowder (1984).

Nairne & Walters, 1983). Our second and third experiments had randomly drawn the seven-item lists from a vocabulary of size 3 sampled with replacement, while the vocabulary size was 8 or 9 (sampled without replacement) in our first experiment and the earlier published work. Thus, vocabulary size appeared to be a possible parameter determining the presence or absence of mouthed recency and suffix effects. Vocabulary size has been tested by Conrad and Hull in 1964 with visually presented lists of letters. They did not find a significant difference in the recall of letters from vocabularies of either three or nine letters. However, they pointed out that the lists drawn from a size 3 vocabulary used repetitions that lists from a size 9 vocabulary did not need to use. Although Conrad and Hull (1964) found no differences in the recall of lists with and without repeated letters, Pollack (1953) did find decreasing recall with larger vocabulary size using a different procedure. In addition, vocabulary size was not tested with digits. Therefore, Experiment 4 also varied vocabulary size, that is, whether the digits or letters were drawn from a vocabulary of size 3 or size 8.

Method

Subjects and Design

University of South Carolina students from the subject pool participated in this experiment to satisfy a course requirement. Twelve of the ninety-six students were randomly assigned to each of the eight conditions resulting from the three between-subjects variables: (1) whether subjects were instructed to mouth or nonmouth, (2) whether the stimuli were digits or letters, and (3) whether the stimuli were drawn from a pool of size 3 or size 8. In addition to the two within-subjects variables used in the preceding experiments (i.e., whether the eight-item lists were followed by a suffix or a nonsuffix, and the serial position of the eight items within each list), this experiment varied response mode. Half of the subjects wrote their recall of the first 40 eight-item lists and then typed their recall of the last 40 eight-item lists, while the other half did the reverse.

Stimuli and Procedure

Eight stimulus items were randomly selected from one of four stimulus pools: (1) eight digits, (2) eight letters, (3) three digits, or (4) three letters. In the size 8 conditions each eight-item trial was randomly drawn without replacement from either the eight digits, 1, 2, 3, 4, 5, 6, 8, and 9, or the eight letters, F, H, J, K, L, N, R, and S. In the size 3 conditions each eight-item trial was randomly drawn with replacement from either the three digits, 1, 2, and 3, or the three letters, F, H, and R. Thus, each subject saw 80 lists of an eight-item series, either drawn from a size 3 or size 8 pool of letters or digits. The lists were followed either by the word "go" in the suffix condition, or by a string of (**) in the Nonsuffix condition. Other than the subject recalling half the trials by writing and half by typing, the procedure followed on each of the 80 trials was identical to that of Experiments 2 and 3.

Results and Discussion

The two manipulations we focused on in this experiment were (1) the type of stimulus, that is, whether the stimuli were digits or letters, and (2) vocabulary size, that is, whether the digits or letters were drawn from a vocabulary of size 3 or 8. Figure 5 clearly shows that the important manipulation in this experiment was vocabulary size when considering the point of our investigation, that is, end-of-list recall. Looking at the top panel in Figure 5 we can see that (1) recency effects were found with mouthed or nonmouthed visually presented *letters* when they were drawn from a vocabulary of size 8, but not when they were drawn from a size 3 vocabulary, and (2) although there was a small suffix effect for

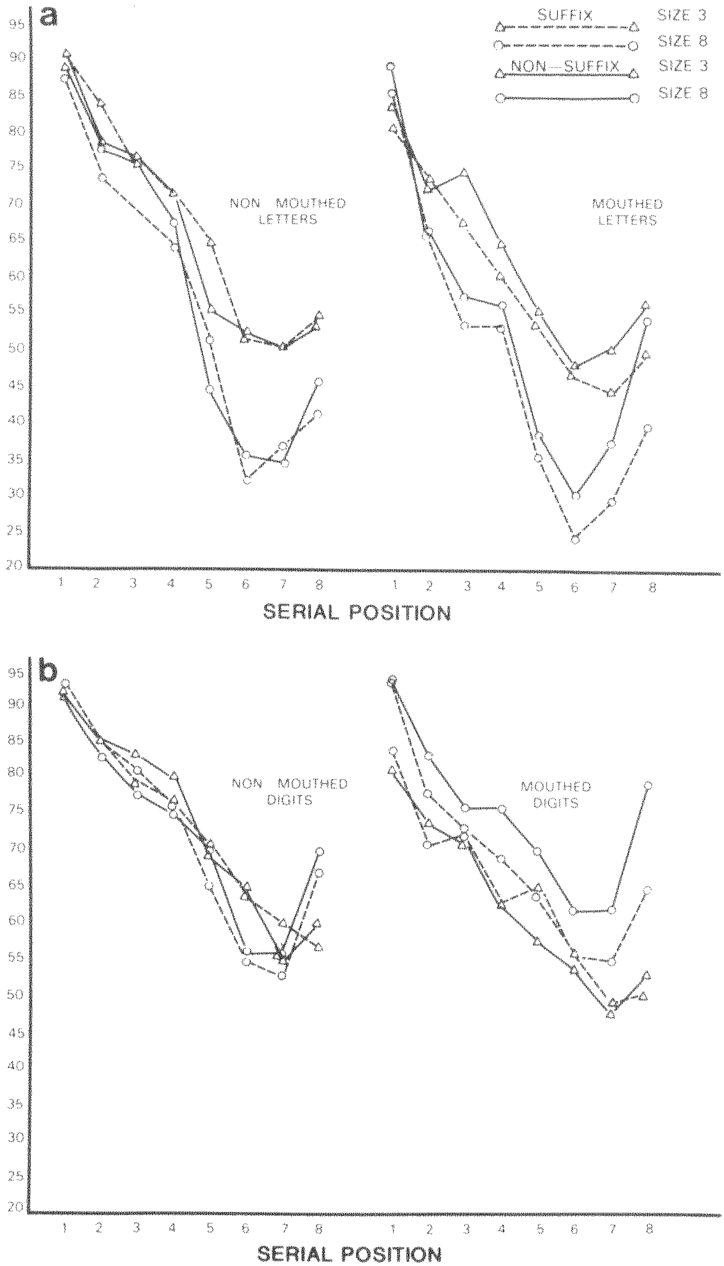

FIG. 5. Mean percentage correct as a function of Mouthing Condition (mouthed/nonmouthed) by Suffix Condition (suffix/nonsuffix) by Vocabulary Size Condition (3/8) by Serial Position (1–8) with visual presentation of letters (a) and digits (b) in Experiment 4.

mouthed letters drawn from a size 3 vocabulary, a much larger suffix effect was found when the stimuli were drawn from a size 8 vocabulary. Looking at the bottom panel we can see that (1) larger recency effects were found with mouthed visually presented *digits* drawn from a size 8 vocabulary than when drawn from a size 3 vocabulary, and (2) mouthed visually presented digits showed suffix effects only when they were drawn from a vocabulary of size 8. The important variable in finding "mouthing" effects is not whether the to-be-remembered items are letters or digits but whether they were chosen from a vocabulary of 3 or 8.

Figure 5 also shows the significant interaction between the type of stimulus and vocabulary size. Although this interaction is interesting it is nonselective as to serial position. Over all serial positions, letters were recalled better when chosen from a size 3 (64%) than from a size 8 (54%) vocabulary, but digits were recalled better from a size 8 (72%) vocabulary than from a size 3 (68%) vocabulary, $F(1,80) = 7.07$, $p < .009$, $MS_e = 2479$.

Recency Effects

In the following analysis, the recency effect is defined as an improvement in recall performance from position 7 to position 8 for the Nonsuffix conditions only, and the conclusions are based on planned comparisons at the .05 level. Mouthed letters from a vocabulary of eight showed a 17% increase from the seventh to the eighth position (38 to 55%) which was significant, $F(1,22) = 42.38$, $p < .01$, $MS_e = 81.8$. However, mouthed letters chosen from a size 3 vocabulary showed no significant recency effect (52 to 57%), $F(1,22) = 3.67$, $p > .05$, $MS_e = 81.8$. A significant recency effect (14%, from 33 to 47%) was also found with *nonmouthed letters* if chosen from a vocabulary of size 8, $F(1,22) = 28.74$, $p < .01$, $MS_e = 81.8$, but not when chosen from a vocabulary of size 3 (52 to 54%), $F(1,22) = 0.59$, $p > .05$, $MS_e = 81.8$.

When the items were digits and chosen from a vocabulary of size 8, mouthing led to a 17% recency effect (62 to 79%) which was significant, $F(1,22) = 42.38$, $p < .01$, $MS_e = 81.8$. When the digit list was chosen from a vocabulary of size 3 mouthing led to a recency of only 6% (48 to 54%) but this was still significant, $F(1,22) = 5.28$, $p < .05$, $MS_e = 81.8$. Also, when digits were nonmouthed, digits chosen from a size 8 vocabulary led to a 15% recency effect (56 to 71%) which was significant, $F(1,22) = 32.99$, $p < .01$, $MS_e = 81.8$, while nonmouthed digits chosen from a size 3 vocabulary did not show a significant recency effect (56 to 61%), $F(1,22) = 3.67$, $p > .05$, $MS_e = 81.8$.

Suffix Effects

Another finding central to the purpose of this study concerned the occurrence of suffix effects for the last position. This can be seen by comparing the effect of the suffix in Figure 5 at the eighth serial position.

Mouthed letters from a vocabulary of size 8 show a significant difference (14%) between the suffix and nonsuffix conditons, $F(1,22) = 28.74$, $p < .01$, $MS_e = 81.8$. The mouthed letters selected from the size 3 vocabulary show a much smaller but still significant difference (7%) between the suffix and nonsuffix conditions, $F(1,22) = 7.18$, $p < .025$, $MS_e = 81.8$. It is worth noting that the difference (14%) found for mouthed letters from the size 8 vocabulary was significantly greater than the difference (7%) found for mouthed letters from a vocabulary of size 3, $F(1,20) = 7.18$, $p < .025$, $MS_e = 81.8$. The suffix effect was not significant (4%) when the letters were nonmouthed and drawn from a vocabulary of size 8, $F(1,22) = 2.35$, $p > .05$, $MS_e = 81.8$. Also, the suffix effect was not significant (3%) and in the wrong direction for the nonmouthed letters chosen from the size 3 vocabulary, $F(1,22) = 1.32$, $p > .05$, $MS_e = 81.8$.

Mouthed digits from a vocabulary of size 8 show a significant difference (15%) between suffix and nonsuffix conditions, $F(1,22) = 28.74$, $p < .01$, $MS_e = 81.8$. However, when the mouthed digits were chosen from a size 3 vocabulary there was no significant difference (2%) between suffix and nonsuffix conditions, $F(1,22) = 0.59$, $p > .80$, $MS_e = 81.8$. When the digits were nonmouthed the suffix effect was not significant and was the same (4%) whether the items were chosen from a vocabulary of size 3 or 8, $F(1,22) = 2.35$, $p > .05$, $MS_e = 81.8$.

Written recall was better than typed recall, $F(1,80) = 10.02$, $p < .002$, $MS_e = 310.4$. However, there were no significant interactions between type of response, that is, whether subjects wrote or typed their responses, and any other variable in this experiment. These results agreed with those found in our third experiment.

In summary, results showed that the important manipulation vis-à-vis mouthing in this experiment was vocabulary size. Recency effects were found with mouthed or nonmouthed visually presented *letters* when they were drawn from a vocabulary of size 8, but not when they were drawn from a size 3 vocabulary. Although there was a small suffix effect for mouthed letters drawn from a size 3 vocabulary, a much larger suffix effect was found when the stimuli were drawn from a size 8 vocabulary. Larger recency effects were found with mouthed visually presented *digits* drawn from a size 8 vocabulary than when drawn from a size 3 vocabulary and mouthed visually presented digits showed suffix effects only when they were drawn from a vocabulary of size 8. Therefore, whether the stimulus items were mouthed or nonmouthed, letters or digits, finding recency effects depended on whether the items were drawn from a size 8 or a size 3 vocabulary. However, suffix effects were found only when the items were mouthed and drawn from a size 8 vocabulary. It is important to note that although recency effects were not influenced by mouthing, the suffix effect was dependent on the mouthing manipulation.

Experiment 5

Experiment 4 had shown the finding of recency and suffix effects with mouthed visually presented stimuli was dependent on the size of the vocabulary from which the stimuli were drawn. Therefore, the question that motivated Experiment 5 was whether recency and suffix effects found with auditorily presented stimuli were also dependent on vocabulary size. We again varied the two important manipulations in Experiment 4: (1) the type of stimulus, that is, whether the stimuli were digits or letters, and (2) vocabulary size, that is, whether the stimuli were drawn from a vocabulary of size 3 or 8. However, in this experiment all stimuli were presented auditorily.

Method

Subjects and Design

University of South Carolina students received extra credit for their participation in this experiment. Nine of the thirty-six students were randomly assigned to each of the four conditions resulting from the two factorially crossed between-subjects variables: (1) the type of stimulus, that is, whether the stimulus items were digits or letters, and (2) vocabulary size, that is, whether the items were drawn from a pool of size 8 or 3. As in the preceding experiments, suffix condition, that is, whether the eight-item lists were followed by a suffix or a nonsuffix, and the serial position of the eight items within each list were varied within subjects.

Stimuli

In the size 8 condition each eight-item was randomly drawn without replacement from either the eight digits, 1, 2, 3, 4, 5, 6, 8, and 9, or the eight letters, F, H, J, K, L, N, R, and S. In the size 3 condition each eight-item trial was randomly drawn with replacement from either the three digits, 1, 2, and 3, or the three letters, F, H, and J. Thus, each subject heard 80 lists of an eight-item series, drawn from either a size 3 or a size 8 pool of letters or digits. The lists were followed by the word "go" in the suffix condition, or by a "tone" in the Nonsuffix condition. Whether the 80 lists were followed by a suffix or nonsuffix was random, with the constraint that the number of lists in each condition was even. The stimulus items, the suffix word "go", and the nonsuffix "tone" were generated with the Mountain Hardware's Supertalker on an Apple II Plus microcomputer as in the auditory condition of Experiment 2. The average duration of each stimulus item was 300 ms, with the exception of a "ready" signal which lasted 850 ms and preceded each trial.

Procedure

Subjects were instructed to listen carefully to the stimulus items and the order of presentation, and then to type their recall in the correct serial order on specially marked keys on the computer keyboard. They were given four practice trials during which time the experimenter remained with the subject to be certain the subject followed the instructions.

On each of the 80 trials the subject first heard the "ready" signal, followed by a preparation period of 1000 ms. Next, the eight-item list for that trial was auditorily presented at a rate of approximately two per second, and followed in sequence by the suffix "go" or the nonsuffix "tone." The subject was instructed to use either the suffix or the nonsuffix as a cue to begin his/her recall. The duration of each subject's recall was self controlled, with a minimum of 20 s separating the onset of the last item (suffix or tone) from the "ready" signal that began the next trial. During this period the subject typed the items he/she recalled on specially marked keys on the computer. Each subject was instructed to type the items in the same serial order as they were heard, after which each subject was given an opportunity to change any particular response he/she wished to correct. As the subject finished recalling each trial, immediate feedback was given about the number correctly recalled and the subject was encouraged to keep trying.

There were three experimenters in this study and each ran three subjects in each condition, counterbalancing any experimenter bias.

Results and Discussion

The question motivating this final experiment was whether recency and suffix effects found with auditorily presented stimuli are dependent on vocabulary size. Figure 6 clearly shows that they are not. The statistical analysis confirmed that the important interaction, that is, the Type of Stimulus × Vocabulary Size × Suffix Condition × Serial Position, was not significant, $F = 0.38$. More importantly, planned comparisons showed that recall in the *Nonsuffix* condition at the eighth serial position was consistently greater than recall at the seventh position when the stimuli were (1) digits drawn from a size 8 vocabulary (14%), $F(1,7) = 15.6$, $p < .01$, $MS_e = 12.6$, (2) digits drawn from a size 3 vocabulary (15%), $F(1,7) = 17.86$, $p < .01$, $MS_e = 12.6$, (3) letters drawn from a size 8 vocabulary (26%), $F(1,7) = 53.65$, $p < .001$, $MS_e = 12.6$, (4) letters drawn from a size 3 vocabulary (19%), $F(1,7) = 28.65$, $p < .001$, $MS_e = 12.6$. Thus, recency effects occurred regardless of whether the stimuli were digits or letters, and whether the stimuli were drawn from a vocabulary of size 3 or 8.

In addition, Figure 6 clearly shows that suffix effects occurred regardless of type of stimuli or vocabulary size. That is, there was a significant difference in recall between Suffix and Nonsuffix conditions at the eighth serial position when the stimuli were (1) digits drawn from a size 8 vocabulary (11%), $F(1,7) = 9.6$, $p < .01$, $MS_e = 12.6$, (2) digits drawn from a size 3 vocabulary (20%), $F(1,7) = 31.7$, $p < .01$, $MS_e = 12.6$, (3) letters drawn from a size 8 vocabulary (16%), $F(1,7) = 20.3$, $p < .01$, $MS_e = 12.6$, (4) letters drawn from a size 3 vocabulary (22%), $F(1,7) = 38.4$, $p < .01$, $MS_e = 12.6$.

In summary, results showed (1) recency effects occurred regardless of whether the stimuli were digits or letters, and, whether

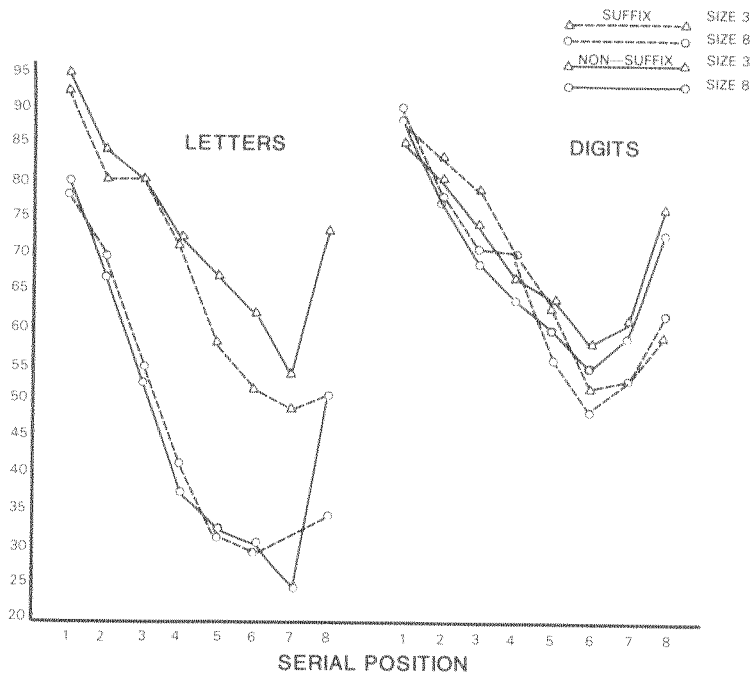

FIG. 6. Mean percentage correct as a function of Type of Stimulus Condition (letters/digits) by Suffix Condition (suffix/nonsuffix) by Vocabulary Size Condition (3/8) by Serial Position (1–8) with auditory presentation of digits and letters in Experiment 5.

the stimuli were drawn from a vocabulary of size 3 or 8, and (2) suffix effects occurred regardless of the type of stimuli or vocabulary size. Therefore, the results of this experiment showed that recency and suffix effects in the recall of auditorily presented items were independent of vocabulary size, while the results of Experiment 4 showed that recency and suffix effects in the recall of *mouthed* visually presented items depended on whether the size of the vocabulary was 3 or 8.

It is clear that vocabulary size is one variable that has given rise to differences between the findings of our second and third experiments with those of our first experiment and other researchers investigating mouthed recency and suffix effects (Greene & Crowder, 1984; Nairne & Crowder, 1982; Nairne & Walters, 1983). This one variable is enough to support the hypothesis that the recency and suffix effects found with auditorily presented stimuli and those found with mouthed visually presented stimuli are not mediated by a common structure or process.

General Discussion

The question that motivated this series of studies was whether two sets of effects that appear to be identical are mediated by the same mechanism. Are the suffix and recency effects found when visually presented stimuli are mouthed caused by the same psychological processes and/or structures that lead to these effects when presentation is auditory? If the two sets of effects are mediated by the same underlying mechanism, then they should be affected by the same variables. The demonstration of a single variable that differentially affects these two sets of phenomena would strongly suggest that they are mediated by different mechanisms.

The major question motivating our second and third experiments was whether the phonemic nature of the stimuli (vowel varied or consonant varied) affected the magnitude of mouthed recency and suffix effects in the same way as those effects obtained with auditory presentation. In order to explore the effect of that variable on mouthed recency and suffix effects, however, those effects must first be reliably obtained and our two experiments failed to do so. Experiment 2 clearly showed that recency and suffix effects with auditory presentation were only found with vowel-varied stimuli, not with consonant-varied stimuli. There was no convincing evidence for mouthed recency or suffix effects with visual presentation. The results of Experiment 3 essentially agreed with those of Experiment 2 in finding no evidence of recency or suffix effects with mouthed visually presented stimuli, much less that the phonemic nature of those stimuli interacted with the variables of serial position and suffix condition.

Sizable mouthing effects were obtained in our lab in Experiment 1 using digit lists, suggesting that the effects might only be found with certain types of stimuli. The final two experiments demonstrated that whether the stimuli were chosen from a vocabulary of size 8 or size 3 determined whether the mouthing effects would be obtained. Mouthing of visually presented stimuli led to demonstrable recency and suffix effects if the stimuli were either letters or digits chosen from a pool of eight items but not if the stimuli were chosen with replacement from a pool of three items. The final experiment showed that this variable did not affect the magnitude of recency or suffix effects with auditory presentation. Figure 6 shows quite clearly that with auditory presentation, the recency effect in the nonsuffix condition, and the decrement in that effect following a suffix, occur irrespective of the vocabulary size from which the lists are chosen. It is thus our contention that mouthed recency and suffix effects are *not* mediated by the same mechanisms as recency and suffix effects with auditory presentation.

This leaves the mouthing effects unexplained and, unfortunately, we can only offer vague speculation. We argue here that the recency effect and suffix effect found with auditory presentation are attributable to information directly resulting from auditory sensory input. The mouthing findings, among others, have contributed to an extensive battering of the earlier and revised PAS intepretation of the suffix effect. But the fact remains that there are several crucial results that seem to demand an explanation based on an information source directly based on or derivative of auditory input. Crowder (1982a, 1982b) showed that performance in an A–X matching task with synthesized vowel sounds declined as the delay between the A and X increased up to 3000 ms. He argued that performance at a short delay depended on a representation in echoic memory for the vowel but that the representation was lost by the long delay (3000 ms). In a task requiring immediate serial recall of a list of digits, performance in the Nonsuffix condition is theorized to depend on this same echoic representation while the echoic memory is not available for recall in the Suffix condition. If that is the case then performance in the Nonsuffix condition should correlate with performance in the A–X task at a short delay but performance in the Suffix condition should not correlate with performance in the long-delay A–X condition. That is exactly what Crowder (1982b) found. Performance in two very different tasks, saying same or different to two speech sounds and recalling a list of aurally presented digits, is correlated but only in those conditions theorized to depend on echoic memory.

Why then does mouthing of visually presented stimuli lead, under some conditions, to (1) enhanced performance generally, (2) increased recall over recency positions in particular, and (3) reduced recall over recency when a nonrecalled suffix is mouthed at the end of the list? One possibility is that while only auditory presentation leads to a true echoic representation of the type initially described by the Crowder and Morton (1969) PAS, both auditory presentation and mouthing of visually presented stimuli lead to the activation of articulatory or gestural codes of the type proposed by Greene and Crowder (1984). Another possibility is that mouthing increases the likelihood that visually presented stimuli receive the articulatory coding of the type described by Conrad (1964).

It is not clear, however, why mouthing would interact with vocabulary size in the manner demonstrated in Experiment 4. For letters, lists from three-letter vocabularies were recalled better, irrespective of mouthing condition, than were lists from eight-letter vocabularies. The letters for the three-letter vocabulary were chosen arbitrarily from the also arbitrarily chosen eight-letter vocabulary. In retrospect, this probably led to the two vocabularies differing somewhat in overall acoustic confusability. An analysis from Conrad's (1964) confusion matrix showed that the mean confusability of the eight-letter vocabulary was somewhat higher (.05) than that for the three-letter vocabulary (.023). While neither of these is very high (even compared to the low-confusability lists in Conrad and Hull (1964)), it is possible that this accounts for the better recall of the list from the three-letter vocabularies. Even if that is true, however, this does not explain why mouthing would only be found with the lists from the eight-letter vocabularies. Greene and Crowder (1984) showed that mouthing effects interacted with confusability of the stimulus items in the same way that the standard modality effect does. In other words, mouthing effects are reduced with stimuli that are high in acoustic confusability. Thus, we should find less of a mouthing effect with eight-letter than with three-letter vocabularies, but, of course, the reverse is true.

With the digits, there was not as much difference between the three- and the eight-digit lists, irrespective of mouthing, as with the letters. However, again, mouthing effects were only found with the lists chosen from the eight-letter vocabularies. This seems to rule out any explanation that mouthing effects occurred only with eight-item vocabulary lists because difficulty was confounded with vocabulary size.

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(Received April 4, 1986)
(Revision received August 26, 1986)