Journal of Experimental Psychology:
Learning, Memory, and Cognition
1985, Vol. 11, No. 3, 596–604

0278-7393/85/$00.75

More Modality Effects in the Absence of Sound

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Two experiments examined serial recall of lists containing random orderings of the digits, 1, 2, 3, and 4. Our intention was to demonstrate active and passive modality effects with silently presented tactile input. In Experiment 1, recency recall was enhanced relative to a visual control when subjects received list input by placing their palms on wooden blocks containing 1, 2, 3, or 4 vertical pegs. In Experiment 2, subjects produced their own tactile input by pressing their thumb and first, second, third, or fourth finger together to signify visual digits presented on a CRT. Recency was enhanced with the added tactile input relative to a visual-only control. The relation between these results and current theories of the modality effect is discussed. A new interpretation of the modality effect is presented.

For a number of years, memory researchers have attempted to explain why auditory presentation produces better recency performance during immediate serial recall than visual presentation (Conrad & Hull, 1968). Explanations of this "modality effect" have typically appealed to the inherent superiority of auditory traces, most notably, the greater durability of auditory sensory memory compared with visual sensory memory (e.g., Crowder & Morton, 1969). However, recent data from a number of laboratories indicate that sensory memory theories of the modality effect are no longer capable of explaining the data pattern. This research has shown that there are a number of ways of producing the bow-shaped serial recall curves that are characteristic of auditory stimulation. For example, memory for silently lip-read input shows marked recency relative to the recall of static visual input (e.g., digits presented on cards or by a CRT; Campbell & Dodd, 1980; Gardiner, Gathercole, & Gregg, 1983; Greene & Crowder, 1984). Second, recency is improved when subjects silently mouth digits shown on a screen rather than merely read them (Greene & Crowder, 1984; Nairne & Walters, 1983). Third, for congenitally deaf subjects, recall of the last few items in a list is enhanced when the lists are signed via American Sign Language (ASL) instead of presented graphically (Shand & Klima, 1981). Because none of these manipulations directly involves sound, pure *sensory* memory cannot easily be invoked to explain the serial recall patterns that are produced.

In the present article, we demonstrate yet another manipulation that produces enhanced recency recall in the absence of auditory stimulation: *tactile presentation.* Our research was initiated, in part, to help specify the boundary conditions surrounding the production of modalitylike effects. Consider, for example, that each of the manipulations described earlier involves a form of presentation closely tied to speech or language perception. Lipreading and mouthing provide gestural information to the subject that may automatically activate the mechanisms involved in auditory memory. There is considerable evidence to support the idea that visual speech gestures interact with normal auditory perception (e.g., Dodd, 1977; MacDonald & McGurk, 1978). The presence of bowed-shaped serial recall patterns, then, may not depend on sound but rather on input that contributes to the general perception of spoken language. A similar kind of argument can be made concerning the perception of ASL by deaf subjects. Whenever list input is presented in a format that readily activates the mechanisms of normal language percep-

We would like to thank Calvin P. Garbin and Therese Migala for assistance in this project. We would also like to thank Ruth Campbell and H. L. Roediger, III for valuable comments on an earlier version of the manuscript.

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tion (ASL in the case of deaf subjects), recency recall is improved (Shand & Klima, 1981). For hearing subjects, we reasoned, a tactile modality effect would be difficult to explain because touch does not typically stimulate the information processing mechanisms involved in speech perception.

Although there have been no demonstrations of recency enhancement in the tactile domain, two previous studies investigated the role of touch in production of the stimulus suffix effect (Dallett, 1965). Watkins and Watkins (1974) showed that a tactile recall signal following a tactile input list (tapping each subject's fingers with a pen or paper clip) was more effective in reducing recency recall than an acoustic recall signal. Manning (1980) showed a similar result where touch information was presented by tracing letters in the palm of each subject's hand. This last report is of special interest because Manning (1980) found no differences in recency recall (or in the size of the suffix effect) between tactile input and a visual condition where the letters were traced on a card instead of in the subject's hand. Although such a finding suggests that tactile input may not produce the standard modality effect pattern, the Manning result is difficult to interpret because the visual input was presented in the form of *changing-state* stimuli (i.e., traced sequentially over time) rather than as static graphic input. As Campbell & Dodd (1980) suggested, the perception of changing-state, or movement, information may itself be a critical determinant of the modality effect (for some recent evidence on this position, see Campbell, Dodd, & Brasher, 1983).

In seeking to demonstrate the presence of a tactile modality effect, the present experiments also distinguish between *active* and *passive* presentation of the touch information. Under passive presentation conditions, information about a to-be-remembered memory list is presented solely through the modality of interest; for example, in the studies of Watkins and Watkins (1974) and Manning (1980), list information was presented exclusively by touch. Active presentation, on the other hand, typically involves visual presentation of materials which the subject reproduces in a second modality. For auditory information, passive presentation usually involves the experimenter reading a list aloud; under active presentation, it is the subjects who produce the auditory input by repeating visually presented lists aloud. The distinction between the two types of presentation conditions can be important, as Nairne and Walters (1983) argued, because some theories of the modality effect appeal to the characteristics of the initial input as a way of predicting when recency performance will be enhanced. Lip-read input, in contrast to visual input, for example, may contain articulatory features that are especially compatible with the primary coding format of short-term memory; as a result, subjects may find it easier to discriminate among recently presented list items (see Shand & Klima, 1981). Because under active presentation conditions subjects are presented only with visual input, which is then required to be reproduced in a second modality, one might expect recency performance to be impaired. We felt that it was important, therefore, to produce tactile modality effects under both active and passive presentation conditions.

Experiment 1

Subjects in Experiment 1 were presented with 60 nine-item lists, containing random orderings of the digits 1, 2, 3, and 4, prior to immediate serial recall. The critical variable, which was manipulated within subjects, was the modality of presentation: For 30 of the lists, subjects received each list item by placing their palms on hidden boards containing 1, 2, 3, or 4 vertical pegs. The tactile stimulation produced from touching the pegs was the only source of information about each list item. For the remaining 30 lists, the same boards were presented in full view and subjects were instructed to count the pegs visually rather than to touch them. The question of interest asked whether recency recall would be different under the two presentation conditions. If recency is more pronounced in the tactile condition than in the visual condition, then we will have demonstrated the presence of a tactile modality effect.

Method

Subjects and apparatus. The subjects were 12 University of Texas undergraduates who participated for credit in an introductory psychology course. The stimuli were 4 × 4 in. (.10 × .10 m) flat wooden boards, painted black, containing 1, 2, 3, or 4 vertical 1 in. (.025 m) pegs. For the 3- and 4-digit boards, the pegs were arranged in the form of a triangle and square, respectively. Subjects could easily identify the digit represented by each board by viewing or touching the vertical pegs. The pegs were also black except for the tops which were painted purple to aid identification during visual presentation. The stimuli were presented either behind (Tactile) or in front (Visual) of a 18 × 26 in. (.46 × .66 m) flexible plastic screen containing a 4 in. (.10 m) gap at the bottom. The screen was placed on a table such that a subject, when seated, could easily slide his or her hand beneath it.

Design and procedure. Subjects, who were seated in front of the plastic screen, were given standard serial recall instructions. They were instructed to write down the 9 presented digits in the exact order of presentation, from left to right on the answer sheet, without returning to correct themselves. The design was within-subjects: Subjects received 20 trials in each presentation modality (tactile or visual) preceded by 10 practice trials. Everyone received the same 60 nine-item lists. Half of the subjects were given tactile presentation for the first 30 trials (10 practice trials plus 20 critical trials) followed by the visual trials; the remaining subjects received the reverse order.

Each trial began with the word *ready,* spoken aloud by the experimenter, followed by presentation of the 9 numbers. Each list contained only the digits 1, 2, 3, and 4 presented in a random order with the exception that the same digit could not be presented twice in a row. During tactile presentation, the subject was prevented from viewing the stimulus boards by the flexible plastic screen. Each subject was instructed to slide his or her nondominant hand beneath the plastic screen and to attend to a timing device placed adjacent to the screen. The timing device flashed a small light every 2 s. Subjects were told to raise or lower their hand onto a stimulus board in sequence with each flash of the timer. Thus, the trial would begin with the experimenter voicing the word *ready* on the first flash of the timer. On the second flash, the subject would lower his or her hand onto the stimulus board representing the first item on the list. Based on the number of vertical pegs, subjects encoded the first to-be-remembered digit. On the third flash, the subject would raise his or her hand while the experimenter replaced the first stimulus board with the second. On the fourth flash, the subject's hand would be lowered again and so on. Subjects were asked only to place their palms on the pegs and not to whisper or say anything aloud. Following the ninth list item, the subjects began their written recall with the dominant hand. Recall continued until the experimenter perceived that the subject had recalled the ninth number or given up. For visual presentation trials, the experimenter simply slid the same stimulus boards under the screen into view of the subject. Subjects were instructed not to touch the stimuli in this condition, but only to view them in preparation for recall. The stimulus boards were presented with the same timing parameters (2-s stimulus presentation and 2-s interstimulus interval) in the visual and tactile conditions.

Results and Discussion

The results of main interest are shown in Figure 1. The left side of the figure displays the mean recall errors for each condition as a function of serial position. An error occurred if an item was not recalled, or if it appeared in an incorrect serial position. Because we are concerned primarily with condition differences in recency recall, we used two standard measures of recency for each subject: (a) the difference in raw errors between the eighth and ninth serial positions and (b) the normalized errors on the last serial position. Normalized errors represent the proportion of all errors made by a subject, for a given condition, that fall on a particular serial position. This measure is considered to be an index of relative recency, or the advantage given to the last item relative to the other items in the list. The normalized data for each of the nine serial positions are shown on the right side of Figure 1.

The data displayed in Figure 1 show all of the important characteristics of the standard modality effect, despite the fact that no auditory stimulation was used in the experiment. An overall analysis of variance (ANOVA) on the raw errors revealed significant effects of serial position, $F(8, 88) = 27.00$, $MS_e = 10.52$, $p < .01$, and the interaction of presentation modality (tactile vs. visual) with serial position, $F(8, 88) = 3.86$, $MS_e = 4.67$, $p < .01$; the main effect of presentation condition was not reliable, $F(1, 11) = 2.87$, $MS_e = 10.59$, $p > .05$. Our first measure of recency confirmed that subjects showed a greater drop in raw errors from positions eight to nine in the tactile presentation condition—an ANOVA on the last two serial positions revealed a significant main effect of serial position, $F(1, 11) = 11.30$, $MS_e = 10.93$, $p < .01$, and, more importantly, a significant interaction of presentation modality with serial position, $F(1, 11) = 6.73$, $MS_e = 8.05$, $p < .03$. For the individual data, 10 subjects showed a greater drop in raw errors from position eight to nine during tactile presentation, 1 subject showed more recency in the visual condition, and there was 1 tie ($p < .01$, by a sign test). Our second measure of recency, which indexed the proportion of errors that occurred

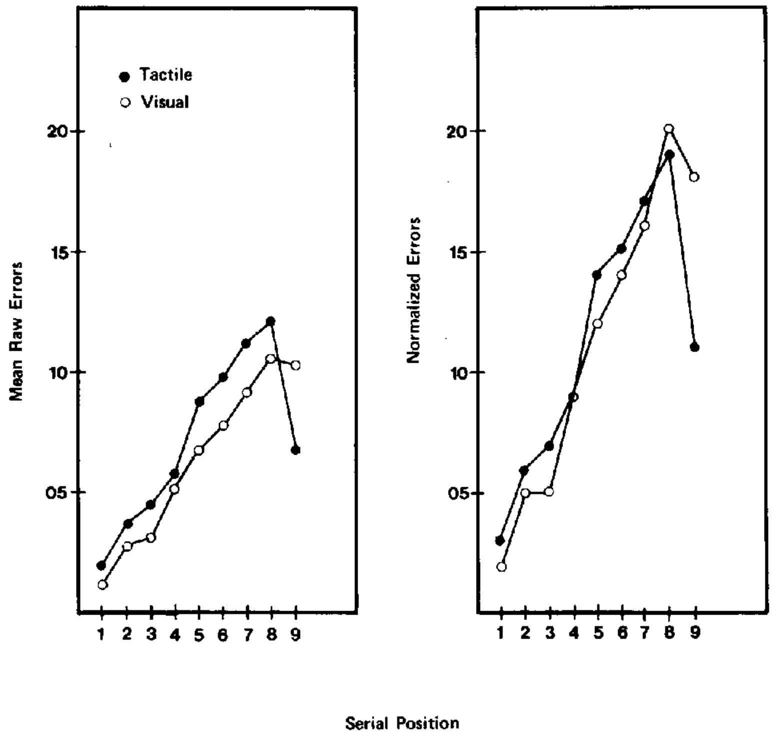

Figure 1. Raw and normalized errors for the tactile and visual conditions as a function of serial position.

at the end of the list, produced a similar conclusion: there were significantly fewer normalized errors on the last serial position in the tactile condition, $t(11) = -2.16$, $p < .05$. Clearly, tactile presentation produced better end-of-the-list performance than visual presentation. In addition, as in many modality effect experiments, the improvement in recency performance was restricted to the last serial position (see Baddeley & Hull, 1979; Engle, 1980).

The results of Experiment 1 show once again that bow-shaped serial position curves (that is, relative to visual presentation) are not exclusive to auditory stimulation during immediate serial recall. Tactile presentation, although perhaps not as efficient a vehicle for producing recency as auditory presentation, nevertheless is a sufficient manipulation to improve recency when compared with standard visual controls. Consequently, this demonstration of a tactile modality effect suggests that enhanced recency is not an exclusive by-product of presentation conditions that use sound, or activate the information processing mechanisms involved in speech or language perception; it is unlikely, for hearing subjects, that touch plays much of a role in the general perception of spoken language. The present results also allow us to comment on Campbell and Dodd's (1980) hypothesis that the standard modality effect results from input containing movement, or *changing-state,* information (a characteristic of mouthing, lipreading, and ASL presentation conditions but less so of visual presentation). Encoding of the tactile input in Experiment 1 appeared, at least nominally, to be relatively simultaneous rather than spread out over time: subjects received the input by placing their outstretched palm onto vertical pegs. Although one cannot rule out that this input was perceived, in some fashion, sequentially, the present data do not appear to be consistent with the Campbell and Dodd (1980) position.

Experiment 2

The purpose of Experiment 2 was to demonstrate a tactile modality effect under conditions where the subjects themselves generated the touch information (i.e., active presentation). In Experiment 1, the presentation conditions were passive in the sense that the experimenter provided tactile input as the sole source of information about the to-be-recalled memory list. During active presentation conditions, subjects are typically presented with visual input which they have to reproduce in a second modality. In Experiment 2, subjects received 60 nine-item lists presented visually on a CRT. For 30 of the lists, the subjects merely silently encoded the visual input in preparation for immediate serial recall. For the remaining 30 lists, however, subjects were required to produce concurrent tactile input by pressing their thumb and first, second, third, or fourth finger together as the digits 1, 2, 3, or 4 appeared on the CRT screen. The empirical question of interest asked whether this added tactile input would be sufficient to produce improved recency.

Method

Subjects and apparatus. The subjects were 20 University of Texas undergraduates who participated for course credit. All stimulus materials were presented on a Televideo 950 terminal which was controlled by a Northstar Horizon microcomputer.

Design and procedure. The design was similar to the one used in Experiment 1: All subjects received the same 60 nine-item lists, divided into two blocks of 30 trials. Each block contained 20 critical trials and 10 practice trials, presented visually on the CRT either with or without concurrent tactile input. The particular order of presentation conditions (tactile vs. visual) was counterbalanced across subjects. The general serial recall instructions also resembled those used in the previous experiment. Subjects were told to recall the items in order, from left to right on their answer sheet, without returning to correct themselves.

Each of the 60 stimulus lists was a random permutation of the digits 1, 2, 3, and 4 without adjacent repetition. A trial began with a 250-ms warning tone presented simultaneously with the word *ready*, centered and displayed for 3 s on the terminal screen. The 9 digits were then presented in succession, in the same location, for 1 s each. A 12-s recall interval was signaled by the presence of a row of asterisks. During the visual trial block, subjects were asked simply to read each number silently as it appeared on the computer screen. For the tactile trial block, subjects were told to signify each number (that is, either the number 1, 2, 3, or 4), as it appeared on the screen, by "pressing your thumb firmly onto your first, second, third, or fourth finger." Subjects were taught that their index finger meant 1; their next finger meant 2; their third finger meant 3; and their fourth finger (pinky) meant 4. It was emphasized that the experimenter should be able to tell what number had been presented visually by watching the subject press his or her fingers together. A short practice session, where the experimenter called out numbers for the subject to signify by pressing a thumb and finger together, preceded the trial block. Subjects always produced the tactile input with their nondominant hand and recalled the lists with their dominant hand.

Results and Discussion

The main results of interest are plotted in Figure 2, which show the raw and normalized errors for each condition as a function of serial position. As in Experiment 1, an item had to be reproduced in its correct serial position in order to be counted correct. The overall ANOVA on the raw errors revealed a main effect of serial position, $F(8,\ 152) = 30.71$, $MS_e = 7.47$, $p < .01$; an ANOVA on the last two serial positions revealed a marginally significant interaction of Serial Position × Input Modality, $F(1,\ 19) = 4.00$, $MS_e = 6.61$, $p < .06$, in addition to a main effect of serial position, $F(1,\ 19) = 19.47$, $MS_e = 6.42$, $p < .01$. Inspection of the individual raw error data confirmed that concurrent tactile input produced greater recency than the visual-only control: Out of 20 subjects, 14 showed a larger drop in raw errors from positions eight to nine in the tactile condition, 5 subjects showed the reverse pattern, and there was 1 tie ($p = .032$, by a sign test). Our second measure of recency, the normalized errors on the last serial position, also indicated that concurrent tactile input enhanced end-of-the-list performance: there were fewer normalized errors on the last serial position in the tactile condition than in the visual control, $t(19) = -1.99$, $p < .05$. For the individual data, out of 20 subjects, 15 showed fewer normalized errors on the ninth serial position in the tactile condition and 5 subjects showed the reverse pattern ($p < .03$, by a sign test). Thus, as in Experiment 1, tactile input helped the subject's recall, but only at the end of the list. As a result, these data confirm that active presentation of tactile input produces a pattern of serial recall that resembles the one found for passive presentation. Because a similar cor-

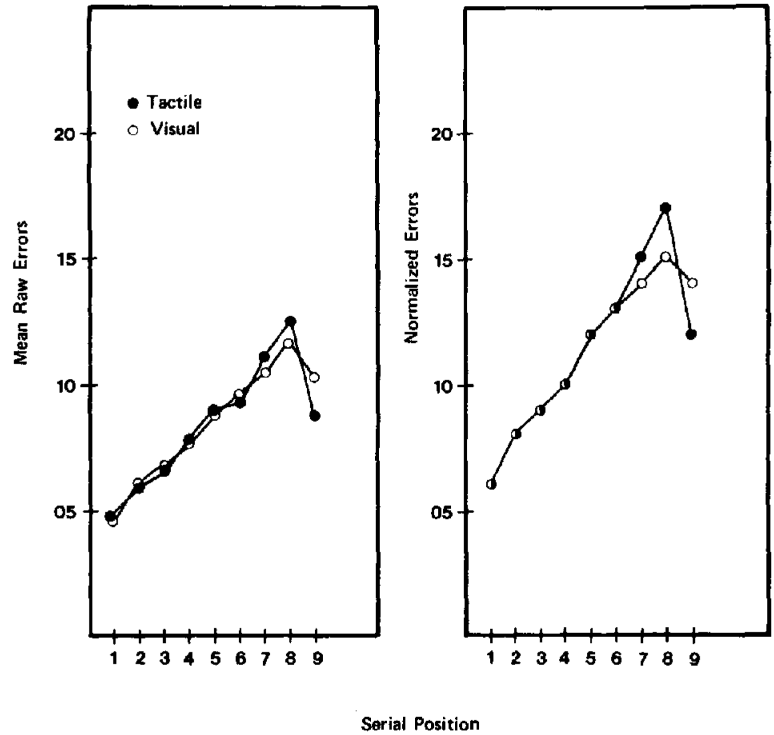

Figure 2. Raw and normalized errors for the tactile and visual conditions in Experiment 2.

respondence is found for active and passive auditory presentation and lipreading and mouthing, support for the existence of tactile modality effects is clearly evidenced in these experiments.

It is interesting to note a recent study by Reisberg, Rappaport, and O'Shaughnessy (1984) which contains data relevant to Experiment 2: Subjects were taught to use a "finger loop" strategy for serial recall in which they tapped their fingers, as if on an imaginary typewriter, to signify visual digits presented on a CRT. The finger-tapping technique dramatically improved overall recall, by as much as 50%. Unfortunately, those authors do not present their data as a function of serial position in the lists, so conclusions about recency performance cannot be made. In addition, their subjects received considerably more practice than the subjects of our Experiment 2. Whether the finger-pressing technique of the present experiment would, with extended practice, produce similar gains in overall performance remains unknown.

General Discussion

The preceding two experiments were designed to examine the role that tactile information can play in enhancing recency performance relative to a visual-only control. In Experiment 1, where subjects either looked at or felt boards containing one or more pegs, tactile input produced a sharp gain in end-of-the-list performance relative to visual input. In Experiment 2, subjects simply pressed their thumb and a finger together to signify static visual digits presented on a CRT. This manipulation also produced better recency for the tactile condition. Because improved recency relative to a visual control is the characteristic feature of a modality effect, these experiments provide strong demonstrations of modality effects in the tactile domain.

Consequently, these data allow us to fine-tune current theoretical accounts of the modality effect: First, tactile presentation represents yet another manipulation that produces bow-shaped serial position curves, in the absence of auditory stimulation, during immediate serial recall. As a result, these data further limit the generality of theories that rely exclusively on sound as the mechanism behind recency in immediate serial recall (e.g., Crowder & Morton, 1969; Watkins & Watkins, 1980). Second, the present experiments indicate that list input does not need to be presented in a format that readily activates the mechanisms of normal language perception in order to produce better recency than a visual control. Touch, unlike the gestural features of mouthing and lipreading, is not a usual component of language perception, nor is touch likely to be especially compatible with the coding characteristics of short-term memory (for such an account of the modality effect, see Shand & Klima, 1981). Third, the results of Experiment 1 suggest that list input does not have to be presented as *movement* information (that is, spread-out over time), in order to improve recency (see Campbell & Dodd, 1980). Fourth, the results of Experiment 2 cannot be explained by attributing recency effects to the ease of initial encoding by the subject of the presented material; it was necessary for the subjects to encode fully the visual input prior to adding the tactile information. The demonstration of tactile modality effects, therefore, are quite difficult for current theories of the modality effect to explain.

Of course, one could argue that these results, although suggestive of modalitylike effects, are not relevant to theories that have been designed to handle the advantages of auditory over visual presentation (that is, the "standard" modality effect). If this position is taken, however, it is also necessary to question the relevancy of the mouthing (Greene & Crowder, 1984; Nairne & Crowder, 1982; Nairne & Walters, 1983), lipreading (Campbell & Dodd, 1980; Greene & Crowder, 1984), and ASL (Shand & Klima, 1981) data. Because all of these manipulations produce recall patterns that resemble auditory recall patterns, it would seem parsimonious to design a theory that encompasses all the data. It is also possible to argue that the demonstration of a tactile modality effect reflects nothing more than the operation of a tactile sensory memory system resembling Crowder and Morton's (1969) precategorical acoustic storage system. That is, we could argue that tactile presentation produces a more durable memory trace than visual presentation because of some special properties of tactile sensory memory. In fact, there may be some basis in the literature for assuming that tactile stimuli show greater durability than visual stimuli (see, for example, Gilson & Baddeley, 1969). However, such an account again fails to explain the range of manipulations that enhance recency relative to visual input (i.e., mouthing, lipreading, ASL). What is needed is a theoretical framework to explain how recency, in the most general sense, varies during immediate serial recall. Appealing to specialized sensory memory systems no longer seems to be a very intellectually satisfying course to take.

Instead, we would like to suggest that differences in recency recall simply reflect differences in the discriminability or distinctiveness of the last several items in the memory list. Such a hypothesis is, or course, not new—the critical question is what produces these differences in item discriminability as a function of input condition? One possibility, as suggested by Gardiner (1983) and Glenberg (1984), is that certain kinds of input are just inherently more discriminable than others: If one assumes, for example, that temporal distinctiveness is enhanced in the auditory mode, then it follows that a backward scanning retrieval strategy might be more effective in the auditory case (cf. Gardiner, 1983, p. 271). Although some published data support this idea (e.g., Metcalfe, Glavanov, & Murdock, 1981), it leaves unexplained the mouthing, lipreading, ASL, and current tactile data. If it is necessary to appeal to enhanced discriminability everytime a new presentation mode improves recency, then we have explained very little. Rather, given the increasing variety of presentation modes that produce recency, we feel that the first question that needs to be addressed is why doesn't one normally find much recency for *visual* presentation?

We consider the subject's task during serial recall to be one of simple discrimination: It is necessary for the subject to distinguish a given list item from other list items in memory as well as from traces tied to the background activities of short-term memory. By these latter activities, we are simply referring to the fact that memory traces do not exist in a mental *vacuum*—there is constant cognitive activity occuring during and immediately after list presentation. The subject is not only rehearsing items, but he or she is also formulating strategies for retrieval, thinking about the difficulty of the task, wondering when the end of the session will occur, and so on. Traces which result from these internal activities may potentially interfere with recall in much the same way that externally presented events produce interference (see Johnson & Raye, 1981). Importantly, if one assumes that the format of these internally produced events resembles the format of traces formed from the encoding of visually presented lists (both presumably reflect the operation of the *inner voice*), then one might predict interference based on similarity, or feature overlap. Following Broadbent and Broadbent (1981), we assume that the probability of recall of an event is reduced whenever its features recur in a later event. However, rather than relying only on subsequent "sensory-overwriting" (Broadbent & Broadbent, 1981), we suggest that other nonsensory events, like the background activities of short-term memory, may also produce selective interference with recent list items.

According to this reasoning, one can expect recency whenever the traces for list items contain features that are distinctive relative to subsequent sensory events and to the features formed from the workings of the inner voice. In the case of auditory, mouthed, lipread, signed, or tactile input, such distinctive features should clearly be present unless the list is followed by a suffix in the same mode of presentation. Visual presentation of events does not typically produce recency because the list is followed by salient visual events and by cognitive activities which are exclusively in the inner voice mode—these activities serve to overwrite or interfere with recently formed list traces (that is, they act like a suffix). Similarly, inner voice activities should not interfere with traces containing unique features like those produced from sound, mouthing, or touch. Even though traces formed from inner voice activities presumably contain auditory, or articulatory, features, one can assume that these features differ significantly from those present in traces formed from externally presented auditory input; this should be true even if the overt auditory input is produced by the subject's own outer voice (note, for example, how different a recording of one's own voice sounds from the subjective experience of the inner voice). Such reasoning explains the finding of Nairne and Crowder (1982) that fully encoded and recalled visual suffixes fail to reduce recency for auditory lists. Visual suffixes encoded via the inner voice should not interact significantly with the auditory features formed via the outer voice (for other data relevant to the distinction between inner and outer voices, see Nairne & Pusen, 1984).

These speculations, of course, need to be developed on empirical grounds. Prior to this advancement, however, it is important to stress the need to consider theoretical accounts of the modality effect that do not rely uniquely on the characteristics of sensory events. The past several years has seen a dramatic rise in the documentation of input manipulations that affect recency during serial recall—it is difficult to imagine how any theory that appeals simply to the sensory qualities present in auditory, or tactile, events can explain these outcomes.

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Received January 7, 1985
Revision received January 25, 1985 ■