A tactile suffix effect*

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Evidence for a representational tactile memory was obtained from a tactile analogue of the auditory suffix effect. In two experiments, a short sequence of tactile stimuli applied to the fingers was followed by an acoustic (control) or tactile (suffix) recall signal. The serial position curves for the two conditions were compared. They revealed similar and strong primacy effects, but recall of the last few stimuli was higher in the control condition. This terminal control advantage was attributed to the retention of raw tactile information.

During the past two decades, short-term memory has been researched on a vast scale. However, only a minute proportion of this research has concerned the retention of tactile events, and many basic issues in tactile memory remain unresolved. In the present study, we will address one of these issues by asking whether tactile information can be retained in a relatively unencoded, representational form.

While a number of studies using masking procedures provide good evidence for tactile memory¹ for intervals up to 50 or 100 msec (e.g., Abramsky, Carmon, & Benton, 1971; Gilson, 1969), there is very little evidence that information may be retained in tactile form for longer periods of time. Bliss, Crane, Mansfield, and Townsend (1966), using Sperling's (1960) partial report technique, concluded that tactile memory persisted for 800 msec, but the advantage of partial report was very small, and it is at least possible that the effect was an artifact of constraints on the selection of the partial recall signal (cf. Holding, 1970).

Three recent studies (Gilson & Baddeley, 1969; Schurman, Bernstein, & Proctor, 1973; Sullivan & Turvey, 1972) have investigated retention of tactile events over intervals of several seconds, but the procedures used were inadequate for distinguishing between performance based on tactile memory and that based on a linguistic, spatial, or other relatively elaborate encoding of the stimuli. In each of these studies, the task was to remember the locus of a single stimulus applied to the forearm. The results were reasonably consistent, and showed performance to deteriorate at a decelerated rate over the first few seconds of the retention interval. While in all of these studies a verbal mode of retention was discounted, there was very little positive indication of the nature of the memory involved. Perhaps the strongest evidence for direct tactile retention comes from Gilson and Baddeley's experiment, in which Ss reported a tingling sensation persisting for up to 10 sec. However, not only are there dangers inherent in drawing inferences from introspective reports, but the retention functions lend no clear support to the notion of a

short-term tactile memory. Thus, performance remained above chance level for well beyond 10 sec, and hence there must have persisted some source of memory which did not correspond to the tingling sensation. In the absence of any clear discontinuity in the retention function, it would seem parsimonious to assume this latter, albeit unspecified, form of memory to underlie retention for all intervals.

The purpose of the present study was to seek more direct evidence for the use of tactile memory. The paradigm adopted was a tactile analogue of the stimulus suffix procedure used in verbal memory experiments (Crowder, 1967, 1969; Dallett, 1965). This technique involves the presentation of a short sequence of items (usually digits) for immediate serial recall. The redundant suffix refers to the addition of an extra stimulus item (such as "zero"), presented directly after the last to-be-remembered item. The findings of interest concern the shape of the serial position functions obtained both in the control and suffix conditions. When no suffix is presented, the serial position function depends on the modality in which the to-be-remembered items are presented. With auditory input, a strong primacy effect is obtained, together with a shorter but very marked recency effect; visual input yields a similar primacy effect but a very small recency effect confined to the last item (Conrad & Hull, 1968; Corballis, 1966; Madigan, 1971; Watkins & Watkins, 1973). When an auditory suffix follows auditory presentation of the to-be-remembered items, the recency effect is all but eliminated, so that the resulting serial position curve closely resembles that found with visual input. On the other hand, the effect of a visual suffix is small and nonselective with respect to serial position (Crowder & Morton, 1969; Morton & Holloway, 1970).

This pattern of results has been interpreted in broad terms as suggesting an auditory or echoic memory (Watkins & Watkins, 1973), and more specifically, a limited-capacity store of acoustic information analyzed to a level prior to verbal categorization (Crowder & Morton, 1969; Morton, 1970). Thus, recall is from an essentially verbal memory system, but in the case of auditory presentation recall of the last few items is augmented by information in echoic form. The effect of

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the auditory suffix is to selectively overwrite the echoic information.

In the two experiments to be reported here, we examined the effect of a tactile suffix on the serial position function obtained for the serial recall of a short sequence of tactile events. Specifically, the hypothesis under test was that the suffix would selectively impair recall of the last few tactile stimuli, just as an auditory suffix impairs recall of terminal auditory items. Such a result would provide strong support for the notion that recall of terminal items in the control condition was partly attributable to the retention of information in an essentially raw tactile form.

EXPERIMENT I

In the first experiment, a series of eight tactile stimuli was presented, one to each finger in random order. In order to render the paradigm as similar as possible to the verbal suffix paradigm, the Ss were trained to covertly respond to each stimulus with a number appropriate to the finger. The task was to recall the order of stimulus input. All Ss were tested under two conditions, operationally defined in terms of the recall signal. For the control condition, this was a nonverbal acoustic signal, while for the suffix condition, it took the form of a stroke across the stimulus regions of the fingers.

Method

Design

The Ss were first trained to respond with numerical labels upon stimulation of the fingers. They then received 10 practice followed by 20 experimental lists, with each list comprising all eight tactile stimuli in random order. These lists were presented in the same order for all Ss. The control and suffix conditions were arranged in six alternating blocks of 5 lists. Half the Ss began with the control, and half with the suffix condition.

Training

The fingers were numbered from 1 to 8, with the numbers written with a ball-point pen on the dorsal surface in the midphalangeal region. The numbers were arranged in natural order, with the little finger of the left hand labeled "1," the forefingers of the left and right hands "4" and "5," respectively, through to the little finger of the right hand, which was labeled "8." The S was requested to note the notation and also to keep his eyes closed during stimulus presentation. The fingers were outstretched, with only the heel of the hand and the thumbs in contact with the table. Training involved tapping the midphalangeal region of the fingers in haphazard order with the tip of a ball-point pen. The S responded orally with the appropriate number as rapidly as possible. The training continued until the S could code without error 10 successive stimuli presented at a 0.8-sec rate. This required between 5 and 20 min. Stimulus presentation was paced by a visual metronome.

Procedure

The Ss were tested individually. The task consisted of recalling the order of stimulus input. Instructions were given for covert labeling of the successive stimuli and for the eyes to remain

closed during input. Stimulus presentation was at a 1-sec rate, with the recall signal occurring 1 sec after the last stimulus. For the control condition, recall was signaled by tapping the pen on the table. For the suffix condition, a brisk stroke of the pen across the critical areas of all eight fingers served as the recall cue. Following Craik (1969), semiserial recall instructions were used, according to which the first four items were to be produced first. No time limit was imposed on recall, and successive lists were presented without a break.

Subjects

The Ss were 20 male and female undergraduate students, who were paid for their services.

Results and Discussion

The results are summarized in Fig. 1. The most important feature is the superior recall in the control condition for the last few serial positions. A Wilcoxon matched-pairs test applied to the last 1, 2, or 3 serial positions showed the control advantage to be significant at the .005 level or beyond. At no other position was there a significant difference between the conditions ($p > .1$). It may be concluded, therefore, that the tactile suffix selectively impaired recall of the last few tactile stimuli. This finding lends good support to the view that recall in the control condition was augmented by information retained in tactile form. That is, just as an auditory suffix is generally assumed to overwrite or displace echoic information available immediately after auditory presentation (Crowder & Morton, 1969; Morton, 1970), so it would seem reasonable to suppose that the tactile suffix in the present experiment destroyed, or at least reduced the effectiveness of, tactile information pertaining to the last few stimuli. In addition, the case for a tactile memory in the present paradigm is strengthened by the fact that most Ss reported that they could still "feel" the last one or two stimuli at the time of recall—an effect analogous to the echo effect following auditory presentation.

A second feature of the results is the strong primacy effect, which is present to an equal extent in the two conditions. A strong primacy effect also characterizes recall following verbal presentation, and it is tempting to conclude that the bulk of recall in the present experiment derived from the retention of ordered verbal labels. Certainly, verbal encoding of the stimuli was encouraged, and indeed the Ss uniformly reported using this strategy. On the other hand, it is not clear to what extent the instructions and introspective reports corresponded to the nature of the memory actually used in performing the task, and hence we must regard the notion of a verbal memory system underlying the bulk of recall in Experiment I as no more than plausible.

EXPERIMENT II

Experiment II tests the generality of the finding that a tactile suffix selectively impairs recall of the last few of a

Fig. 1. Recall of tactile stimuli as a function of condition and serial position (Experiment I).

series of tactile stimuli. While the procedure adopted was substantially similar to that used in the first experiment, there were a number of differences. We have noted that there is a fair case for supposing that the bulk of the recall in Experiment I reflected the retention of verbal information. If so, the paradigm was highly analogous to that used in studies of the auditory suffix effect. In both cases, the suffix effect would be the result of a representational memory augmenting a fundamentally verbal mode of retention. In the present experiment, an attempt was made to induce spatial or spatio-temporal, rather than verbal, encoding. To this end, no verbal labeling was suggested to the S and the stimuli were applied to regions of just one hand, conducive to the formation of a visual image. Further, responses to each list were made on an outline drawing of the hand. Assuming that these measures were sufficient to induce a spatial encoding, the question of interest was whether the selective effect of the suffix observed in Experiment I would be replicated.

Apart from this substantial procedural change, there were several smaller differences between the two experiments. Experiment I did not require a strictly serial order of report, and therefore it is not completely meaningful to compare the resultant serial position curves with those from most auditory presentation studies. Hence, in Experiment II, the more conventional serial recall instructions were used. A second potential shortcoming of the first experiment concerns the blocking of the suffix and control conditions. It is possible that being able to predict condition may have

influenced the Ss' strategy. Also, the fact that the E knew the condition of a list during its presentation might have influenced the manner in which the stimuli were delivered. Although in neither case are the effects of these potential factors entirely obvious, it is conceivable that they may have influenced the pattern of results. In Experiment II, neither S nor E knew the list condition until after the last to-be-remembered item had been presented.

Method

Design

The Ss first received four practice lists, two in each of the suffix and control conditions. Twenty-four experimental lists were then presented in the same order to all Ss. For alternate Ss, a random half of the first, second, and third eight lists were allocated to the suffix condition, and the remainder to the control condition. For the other half of the Ss, the condition of each list was reversed. Each list comprised a random sequence of seven stimuli, selected from a possible eight.

Subjects

The Ss were 24 male and female undergraduates, who were paid for participating.

Procedure

The Ss were tested individually. The S placed his nonwriting hand so that only the heel was in contact with the table and the fingers were outstretched. He was told that he would receive a sequence of seven stimuli, with each stimulus presented to one of the eight distal and proximal phalanges. Eyes were to remain

Fig. 2. Recall of tactile stimuli as a function of condition and serial position (Experiment I).

closed until the recall signal was given; sometimes this would take the form of a brisk stroke across the midphalangeal regions of the stimulus fingers, while for other lists an auditory tap would signal recall. Presentation was paced by a visual metronome at a 1-sec rate, with the recall signal given 1 sec after the last list stimulus. The response sheets consisted of a series of schematic representations of four fingers, with the eight possible stimulus regions clearly marked. The task involved reporting the order in which the critical areas were stimulated, by writing "1" in the first area stimulated, "2" in the second, and so on, until seven responses had been made. Performance was monitored to ensure that a strictly serial order of report was adopted. Ss responded at their own rates, and typically required 10 to 15 sec. Lists were presented at about a 50-sec rate.

The stimuli consisted of light taps made with an ordinary paper clip. During list presentation, neither S nor E knew the list condition. In order that the stimuli could be presented at an even rate, E was trained to numerically code the eight stimulus areas, and then hold the appropriate digits in mind during input. Before presenting a list, E took a card in her left hand and turned it over immediately after the last stimulus to determine the recall signal to be used.

Results and Discussion

The results are summarized in Fig. 2. They are clearly comparable to those obtained in Experiment I, with both conditions showing a similar and strong primacy effect, while a control advantage is evident over the last few positions. Wilcoxon tests revealed the control advantage to be significant at the last ($p < .005$) and last but one ($p < .02$) serial positions. There were no significant differences ($p > .1$) between conditions at any other positions.

In short, the selective effect of the tactile suffix found in Experiment I was replicated under the somewhat different conditions of Experiment II. This suggests the

tactile suffix effect to have at least a reasonable degree of generality. Introspective reports obtained immediately after testing almost always revealed a strategy of constructing a spatio-temporal image by mentally drawing a line from the first region stimulated to the second, from there to the third, and so on. However, there is danger in assuming that introspective reports accurately reflect the functional processes of memory. Moreover, apart from the fact that performance in Experiment II was rather lower than in Experiment I, the pattern of results for the two experiments was very similar, and hence there is very little firm basis for concluding that the major component of recall derived from fundamentally different types of memory.

GENERAL DISCUSSION

In two experiments, a tactile suffix has been shown to impair recall of the last few of a sequence of tactile stimuli in a fashion remarkably similar to that observed when an auditory suffix follows presentation of a series of auditory items. It has been suggested that this effect derives from a raw tactile memory—an interpretation analogous to that usually held for the auditory suffix effect. While it is conceivable that this interpretation may prove inappropriate in the light of subsequent research, there is considerably more justification for identifying the terminal control advantage with tactile memory than there is for using this term to describe the forgetting function found for the locus of a single stimulus (e.g., Gilson & Baddeley, 1969).

The characteristics of the proposed tactile memory

are at present largely unknown. However, one property which does appear to be established is that tactile memory is limited in terms of capacity, with information subject to displacement or interference by subsequent tactile events. Tactile information could not have merely decayed over time, for if this were the case the results for the control and suffix conditions should have been identical. In fact, the results show that the suffix served to reduce the recall of terminal items, and it would seem reasonable to suppose that these terminal items were to some extent, or with some probability, still represented in tactile memory at the time of suffix presentation. It should be noted that little can be concluded about the durability of tactile information in the absence of further tactile events. Perhaps the Ss recalled the first few items before utilizing the information available in tactile memory. In this case, terminal items must have been retained in tactile form for several seconds. On the other hand, the Ss could have utilized the available tactile information after the recall signal and before beginning recall by encoding this information into a more durable form; this possibility is essentially equivalent to that usually held for the terminal auditory-over-visual advantage. The only conclusion which the present results do permit regarding the persistence of the tactile information suggested to underlie the terminal control advantage is that it remained available until at least the time of the recall signal.

The relation between the proposed tactile memory and the memory system (or systems) responsible in the present experiments for the major part of recall is also speculative. Perhaps the simplest possibility is that the tactile and the more deeply encoded records function independently. This is analogous to the most popular interpretation of the auditory suffix effect, according to which precategorical acoustic information (that is, information analyzed to a level prior to verbal identification) is retained in a limited-capacity store, which is quite distinct from postcategorical memory (Craik, 1969; Crowder & Morton, 1969; Madigan, 1971; Morton, 1970; Morton, Crowder, & Prussin, 1971). However, Watkins and Watkins (1973) found that the number of items involved in the auditory modality effect is independent of the acoustic length of the items, and thus concluded that the effect arises at a level of analysis beyond verbal identification. If analogous results should be obtained for the tactile suffix effect, then it would be apt to conceive of tactile information as being retained in the same memory trace as a verbal, spatial, or other encoded representation of the stimulus, rather than in a distinct and independent store.

It will be obvious from the tentative nature of this discussion that any adequate understanding of the tactile suffix effect will require identification of the relevant experimental variables, and a knowledge of their interactive effects. A few of the more obvious candidates for study are presentation rate, delay before the suffix, locus of the stimuli, and locus of the suffix.

Unfortunately, much of this research may require apparatus somewhat more sophisticated than the ball-point pen and paper clip used in the present experiments.

REFERENCES

- Abramsky, O., Carmon, A., & Benton, A. L. Masking of and by tactile pressure stimuli. *Perception & Psychophysics*, 1971, 10, 353-355.
- Bliss, J. C., Crane, H. D., Mansfield, P. K., & Townsend, J. T. Information available in brief tactile presentations. *Perception & Psychophysics*, 1966, 1, 273-283.
- Conrad, R., & Hull, A. J. Input modality and the serial position curve in short-term memory. *Psychonomic Science*, 1968, 10, 135-136.
- Corballis, M. C. Rehearsal and decay in immediate recall of visually and aurally presented items. *Canadian Journal of Psychology*, 1966, 20, 43-51.
- Craik, F. I. M. Modality effects in short-term storage. *Journal of Verbal Learning & Verbal Behavior*, 1969, 8, 658-664.
- Crowder, R. G. Prefix effects in immediate memory. *Canadian Journal of Psychology*, 1967, 21, 450-461.
- Crowder, R. G. Improved recall for digits with delayed recall cues. *Journal of Experimental Psychology*, 1969, 82, 258-262.
- Crowder, R. G., & Morton, J. Precategorical acoustic storage (PAS). *Perception & Psychophysics*, 1969, 5, 365-373.
- Dallett, K. Primary memory: The effects of redundancy upon digit repetition. *Psychonomic Science*, 1965, 3, 237-238.
- Gilson, R. D. Vibrotactile masking: Some spatial and temporal aspects. *Perception & Psychophysics*, 1969, 5, 176-180.
- Gilson, E. Q., & Baddeley, A. D. Tactile short-term memory. *Quarterly Journal of Experimental Psychology*, 1969, 21, 180-184.
- Holding, D. H. Guessing behaviour and the Sperling store. *Quarterly Journal of Experimental Psychology*, 1970, 22, 248-256.
- Madigan, S. A. Modality and recall order interactions in short-term memory for serial order. *Journal of Experimental Psychology*, 1971, 87, 294-296.
- Morton, J. A functional model for memory. In D. A. Norman (Ed.), *Models of human memory*. New York: Academic Press, 1970.
- Morton, J., Crowder, R. G., & Prussin, H. A. Experiments with the stimulus suffix effect. *Journal of Experimental Psychology*, 1971, 91, 169-190.
- Morton, J., & Holloway, C. M. Absence of a cross-modal suffix effect in short-term memory. *Quarterly Journal of Experimental Psychology*, 1970, 22, 167-176.
- Schurman, D. L., Bernstein, I. H., & Proctor, R. W. Modality-specific short-term storage for pressure. *Bulletin of the Psychonomic Society*, 1973, 1, 71-74.
- Sperling, G. The information available in brief visual presentations. *Psychological Monographs*, 1960, 74, No. 11.
- Sullivan, E. V., & Turvey, M. T. Short-term retention tactile stimulation. *Quarterly Journal of Experimental Psychology*, 1972, 24, 253-261.
- Watkins, M. J., & Watkins, O. C. The postcategorical status of the modality effect in serial recall. *Journal of Experimental Psychology*, 1973, 99, 226-230.

NOTE

1. We use the term "tactile memory" to refer to the retention of raw (unencoded) tactile information; its meaning is thus more specific than memory of tactile events.

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