Modality-specific short-term storage for pressure*

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Trained Ss were required to report whether two consecutive tactile stimuli were delivered to the same or different parts of their arm. The main purpose of the study was to investigate modality-specific memory for pressure. Accuracy of recall was found to be a rapidly decaying function of the stimulus onset asynchrony between the two stimuli, reaching asymptote at about 4 sec. Performance was not affected by an interpolated verbal task. These data, in conjunction with tactile masking effects (Abramsky, Carmon, & Benton, 1971), are consistent with modality-specific sensory memory for pressure stimuli.

Various memory systems have been proposed for sensory storage. These storage systems are assumed to contain information in a relatively raw or "unprocessed" form compared to the symbols of short-term verbal memory (or long-term memory to the extent that these concepts are separable). The sensory storage concept implies a buffer system which allows the effective duration of a stimulus to exceed its physical duration.

Neisser (1967) proposed sensory storage systems for vision and audition which he termed "iconic" and "echoic" memories, respectively. His discussion provides three criteria by which sensory and short-term (verbal) memory systems may be differentiated. The first is that sensory memories decay quite rapidly over short time intervals (5-15 sec) during an unfilled retention interval in which S can rehearse. That is, forgetting is as rapid with unfilled intervals as with filled intervals where rehearsal is prevented. In contrast, short-term verbal memory does not decay appreciably over short time intervals except when rehearsal is prevented.

A second criterion is that events occurring in other sense modalities do not affect the sensory memory. Thus, sensory storage is *modality specific.* Interference occurs in short-term memory, on the other hand, from several modalities at once. This is because of the symbolic encoding that can occur to input from all modalities. The third criterion is essentially the converse of the second. Because sensory memory is modality specific, other events in the same modality, whether or not the task requires their encoding, will interact with the test material and interfere with recall accuracy. The most obvious example of this interaction is visual masking.

Recent research on sensory storage has concentrated upon the investigation of the properties of iconic and echoic memory systems rather than upon the possible existence of sensory storage in "lower" senses such as touch. Yet von Békésy (1967) has demonstrated that various phenomena, such as lateral inhibition, apparent movement, contour enhancement, and facilitation, occur in touch as well as in vision and audition. More recently, Abramsky, Carmon, & Benton (1971) found tactile masking effects with a time course similar to that previously found for visual masking.

The goal of the present studies was to investigate sensory storage for touch. The strategy was similar to that previously used for vision and audition. Pressure stimuli (Von Frey hairs) were used to control the size of the stimulated area and to keep stimulation confined to the touch modality (von Békésy, 1967). The S's accuracy in determining the spatial location of two successive stimuli (S1 and S2) was examined as a function of stimulus onset asynchrony (SOA)[1] and presence vs absence of an interpolated task. Despite the relative crudity of the stimuli, we felt that an orderly decrease in recall accuracy for both filled and unfilled intervals would demonstrate specific sensory storage for touch.

EXPERIMENT I

Method

Subjects

Eight undergraduate and graduate students at the University of Texas at Arlington served as paid volunteers. Three were male.

Apparatus

Ss were seated in front of a large wooden screen which had an approximately 6-in.-diam (15-cm) semicircle cut out of the bottom. Each S thrust his entire forearm to the elbow through this hole with the volar side upward. The forearm rested on a padded armrest, inclined 30 deg from the horizontal. The volar surface of the forearm was shaved from wrist to midpoint, about 2.5 cm on each side of the longitudinal midline. This area was thoroughly washed with isopropyl alcohol before and after shaving. Ss were given instructions while the forearm dried. Their forearm was then stamped with a 50-square grid using a 10 x 5 cm rubber stamp. The grid was centered on the midline latitudinally, with the lower edge against the bend in the wrist. The 50 squares were 1 cm on a side, with a dot in the center of each. Each square was numbered in order. The E used both the dot and the number to localize the touch stimuli. The Von Frey hairs were Weinstein log scale 5.08 (Shaw Laboratories) that provided 1.7 mg of force over a .13-cm^2 area. The touch durations were approximately ¼-½ sec—long enough to bend the hair and remove it quickly.

Procedure

On each trial, the S was touched at one of the numbered dot locations (S1). After a stimulus onset asynchrony (SOA) of 1, 2, 3, 4, 6, 8, or 10 sec, the E touched the S a second time (S2). The

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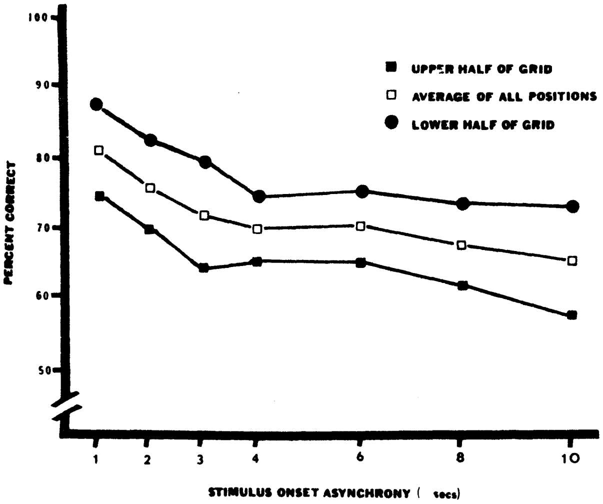

Fig. 1. Memory decay function averaged over eight Ss. Upper half and lower half of grid are shown separately.

S2 could be 2 cm above, 2 cm below, or at the same point as S1. As he delivered S2, E simultaneously said "now" as a signal for S to report whether S2 was at the same point as S1, above S1, or below S1. No simultaneous (0-sec) SOA was included because a pilot study indicated the 2-cm separation of S1 and S2 to be well within the 2-point limen for this touch intensity.

Half of the Ss were in the *no-counting* group. They were to respond as accurately as possible following an unfilled SOA. By contrast, the remaining Ss were in the *counting* group. For SOA of 2 sec or more, they were told that E would speak a number following S1 from which they were to count backward by ones. For the 1-sec SOA, the E simply said "one" to signal that the Ss should *not* count backward. This was suggested by the poor performance of pilot Ss required to count at this SOA who were often unaware that S2 had occurred at all.

All Ss received 40 trials per SOA: 20 same, 10 different up, and 10 different down. Direction (up, down, same) and SOA were randomized over trials, with the restriction that the proportionality of directions and equality of SOA be maintained. In addition, half of the S1-S2 pairings were delivered to the upper part of the arm and half to the lower.

Each S was run for three 1-h sessions. The first session consisted of 40 practice trials, during which Ss received feedback as to their accuracy, and 50 experimental trials, without feedback. The remaining two sessions consisted of 112 experimental trials each, also without feedback.

The Ss were given periodic short breaks upon request. During these breaks, they left their arms in the screen. Halfway through each session, they were given a 5-min break in which they could remove their arm from the apparatus. Several layers of gauze were taped over the S's forearm to keep S from seeing the grid impression. The grid impression was removed with isopropyl alcohol at the end of each session. The Ss chose a preferred arm for use throughout the experiment.

Results

An analysis of variance was first done upon a global accuracy measure, percentage correct. This was the relative frequency of times the S correctly reported the direction of movement (up, down, or same). Counting vs no-counting groups was a between-Ss variable. The SOA and upper vs lower part of arm were within-Ss variables. The results were that accuracy decreased as a function of SOA, $F(6,42) = 3.60$, $p < .01$, and accuracy in the lower arm was greater than accuracy in the upper arm, $F(1,91) = 44.99$, $p < .01$. The counting group mean of 74.2% was very close to the no-counting group mean of 70.1% ($F < 1$). No interactions were significant.

Figure 1 portrays percent correct as a function of SOA, with lower vs upper arm as the parameter. These data indicate that most of the forgetting had occurred by 4-msec SOA, although there is a slight further drop to 10 sec. The data further indicate that performance, even at 10 sec, was well above chance, suggesting that longer term encoding had occurred.

A further analysis was conducted to see whether accuracy varied as a function direction of the "different" stimulus (up/down) across SOA. In particular, we examined the data for the tau phenomenon (Helson & King, 1931). This phenomenon is the tendency for the memory of touches on the forearm, except those near the elbow, to drift toward the wrist as SOA increases. The tau phenomenon would be reflected by this change in the accuracy of up-different relative to down-different trials over SOA. No such effects were obtained, and the accuracy of up-different and down-different trials were almost identical at each SOA. Similar analyses, including attempts to separate accuracy and response bias effects using choice theory parameters (Luce, 1964), failed to add to the above findings.

None of these supplementary analyses, including the one for the tau phenomenon, indicated that there is anything but a nonselective decline in accuracy across SOA and that the lower arm is more sensitive than the upper.

The results of Experiment I are consistent with two of the properties to be expected of a sensory storage system: (a) the decline in accuracy during an unfilled interval, shown by the no-counting group, and (b) the failure of events occurring in other sensory modalities (the counting task with its auditory feedback) to affect performance. The finding that Ss were fairly close to asymptote by 4-sec SOA is also consistent with decay functions obtained for vision and audition in similar tasks (Neisser, 1967).

The data of Experiment I were somewhat noisy between and within Ss, which might have obscured a difference between groups. Likewise, the 2-cm separation and counting backward by ones may have made the task too easy to allow interference effects produced by the counting task to occur. Consequently, a second experiment was run.

EXPERIMENT II

The logic of Experiment II was the same as the logic of Experiment I. The major differences were as follows. First, counting and no counting were made within-S variables to increase the sensitivity of the test used to infer crossmodal interference effects, and Ss were asked to count backward by threes to increase the difficulty of the interpolated task. Second, a 1-cm rather than a 2-cm

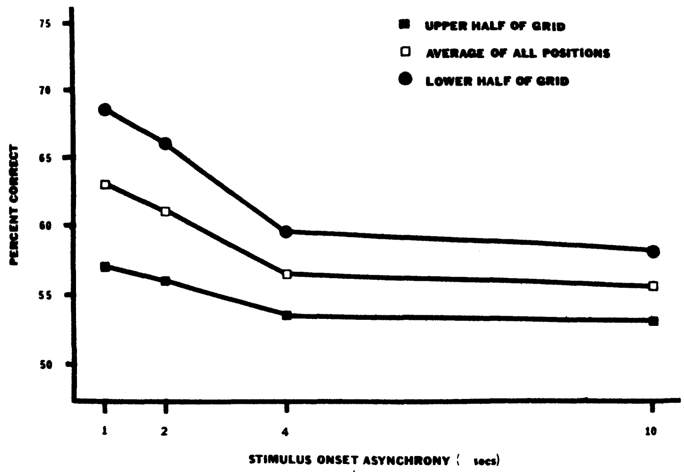

Fig. 2. Memory decay function averaged over four Ss. Upper half and lower half of grid are shown separately.

difference was used on up and down trials to increase task difficulty and create more optimal conditions for possible interference effects. Third, only four SOA (1, 2, 4, and 10 sec) were used, because the drop in accuracy had occurred by 4-sec SOA in Experiment I. Fourth, confidence ratings were obtained for each response in order to obtain a more sensitive response indicator. Finally, the number of observations per data point was increased to make the measures more stable.

Method

Subjects

Four students at the University of Texas at Arlington, three male, served as paid volunteers for 15 sessions each.

Apparatus

The apparatus was the same as that used in Experiment I.

Procedure

The same procedures were followed as in Experiment I, with the following exceptions: SOA values used were 1, 2, 4, and 10 sec; 1 cm was used rather than 2 cm as a difference in up or down trials. The no-counting and counting backward by threes tasks were run as within-Ss variables, counterbalanced between Ss. A total of 72 trials was run per upper vs lower part of arm by SOA by counting vs no-counting condition by S combination. These data were gathered in 3 practice and 12 experimental sessions per S.

The Ss were first shown three up, three down, and three same movements at the 1-sec SOA, using a 2-cm separation on "different" (up or down) trials. The Ss were then given 48 practice trials at the SOA and separation, followed by an additional 48 trials at this SOA with a 1-cm separation. This SOA and separation was continued for the remaining two practice sessions. Feedback was given on all trials.

No feedback was used during the remaining 12 experimental sessions. The SOA was held constant for a block of 12 trials. Each SOA occurred equally often. A mandatory 1-min rest break was given after the second and sixth block of each session during which S's arm was covered, as in Experiment I, so that he could remove his arm from the apparatus and move about.

Results

The first variable analyzed was the global percentage correct measure, as in Experiment I. In the present experiment, part of arm (lower vs upper), SOA, and condition (counting vs no counting) were all within-Ss variables. A decline in accuracy with SOA was again found, $F(3,9) = 4.03$, $p < .05$. The difference previously found favoring accuracy in the lower arm approached, but did not reach, statistical significance, $F(1,6) = 4.38$, $.05 < p < .10$. As in Experiment I, means for counting and no counting did not differ; in fact, they were identical (58.9%).

Figure 2 portrays percentage correct as a function of SOA. To maintain comparability with Fig. 1, upper vs lower part of the arm is again the parameter, even though the present difference is not significant. As can be seen in this figure, reducing the difference between S1 and S2 for "different" movements from 2 cm to 1 cm reduced accuracy at 1-sec SOA to about 63%. Maximum accuracy at this SOA was more than 80% in Experiment I. Despite the difference in level of performance, the rate of decline is about the same as it was in Experiment I; most of the forgetting has taken place by 4-sec SOA. Here the drop between 1- and 4-sec SOA is 6% rather than the 11% obtained in Experiment I. Although experimental error was a good deal less than it was in Experiment I, there also seems to be a floor effect, produced by the lower accuracy, that attenuated the decline.

As in Experiment I, information theory and choice theory parameters were obtained and analyzed. The results were consistent with, but failed to add to, the above conclusions. Specifically, no evidence was found for the tau phenomenon.

DISCUSSION

Both studies provide evidence for a decline in accuracy that occurs over an unfilled retention interval in a modified same-different task. Likewise, both studies failed to suggest that interpolated verbal material impaired performance. The latter conclusion needs to be interpreted with caution, as it rests upon null hypothesis-acceptance logic. However, the two main findings, coupled with the Abramsky et al (1971) masking data, seem to provide the converging operations necessary to postulate a modality-specific sensory memory for touch.

Both studies further indicate that the modality-specific forgetting was largely complete at 4 sec. This is comparable to the forgetting curve found by Eriksen & Johnson (1964) in a similar study that employed auditory stimuli. In addition, our data, unlike theirs, provides evidence for a longer term storage. This is evidenced by the finding that performance at 10-sec SOA remained well above chance. In no case did performance ever deteriorate to chance.

Our Ss reported that they began by trying to use verbal encoding, but soon gave that up as a bad strategy. When Ss were allowed to see the grid impression (after the last session), they unanimously expressed surprise at the small size and low location of the grid. Thus, it is hard to see how the longer term storage evident in our data could have been due to verbal encoding or visualization of the stimuli.

The question of central or peripheral storage remains open, of course. However, the Abramsky et al (1971) data, along with our data, imply a central storage system. A tactile afterimage, providing peripheral storage, should have been stronger for stimuli on the lower arm, since it was the more sensitive region. There would have been an Upper-Lower Arm by SOA interaction, therefore. No interaction was suggested in these data.

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NOTE

1. The term "stimulus onset asynchrony" is used rather than interstimulus interval, since stimulus duration was not precise. SOA is more meaningful in this context.

(Received for publication October 31, 1972.)