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An Auditory Analogue of the Sperling Partial Report Procedure: Evidence for Brief Auditory Storage[1]

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Three experiments are reported on the partial report of material presented auditorily over three spatially different channels. When partial report was required by spatial location, it was superior to whole report if the cue came less than four seconds after the end of the stimuli (Exp. I). When partial report was required by semantic category (letters/digits) the relation between it and whole report depended on whether the S was asked also to attribute each item to its correct spatial location. When location was required partial report was lower than whole report and showed no significant decay with delay of the partial report indicator (Exp. II), but when location was not required, partial report was superior to whole report for indicator delays of less than two seconds (Exp. III). This superiority was, however, much less than that found in Exp. I when partial report was required by spatial location. These results are compatible with a store which has a useful life of around two seconds and from which material may be retrieved more easily by spatial location than by semantic category.

The concept of brief sensory storage has played a central role in recent discourse on the nature of human information processing (e.g., Neisser, 1967; Haber, 1969; Hunt, 1971). The proposition is that sensory data is initially represented in a literal, labile form for a brief duration during the course of conversion into a relatively more persistent, categorized form.

The sensory store which has received the most attention and which

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consequently we know most about is in vision. The characteristics of this store, called iconic by Neisser (1967), have been isolated via the delayed partial-sampling procedure of Sperling (1960) and Averbach and Coriell (1961). Essentially this procedure involves presenting simultaneously an overload of items, usually letters or digits in a very brief tachistoscopic exposure which is followed by an indicator designating which element or subset of elements S has to report. If the indicator is given soon enough after the stimulus, S can report proportionately more with partial report than if asked for a report of the whole stimulus. This superiority declines rapidly with indicator delay, reaching zero between 250 msec and several seconds after the end of the stimulus, depending on the prevailing luminance conditions (Averbach & Coriell, 1961; Averbach & Sperling, 1961; Keele & Chase, 1967).

As well as showing a decline with indicator delay, the superiority of partial over whole report is sensitive to the selection criterion used to define the partial report subset. Partial report is superior to whole report (at suitable delays) if selection is made according to spatial location (Sperling, 1960; Averbach & Coriell, 1961), brightness, size (von Wright, 1968), color (Clark, 1969; von Wright, 1968) or shape (Turvey & Kravetz, 1970). Partial report is not superior to whole report, however, if it is selected according to whether the items are letters or digits (Sperling, 1960). This suggests that the information necessary for making such a complex distinction is not readily accessible in the iconic store, although the information necessary for distinguishing items along simple dimensions is accessible.

The investigation of the analogous sensory register in the auditory system has been conducted along somewhat different lines. The starting point for one approach (Crowder & Morton, 1969) has been the pronounced recency effect in the recall of auditorily presented serial lists. That the recency effect is tied to the auditory modality and not to a communal short-term store is shown by the fact that it is abolished by a redundant auditory suffix (Crowder & Morton, 1969) provided the suffix arrives within 2 sec of the end of the list (Crowder, 1969), but is not abolished by a redundant visual suffix (Morton & Holloway, 1970). These results define a brief auditory store. Moreover, it appears that only relatively crude attributes of the stimulus are distinguished in this store. Whereas the conceptual class to which the suffix belongs is unrelated to the size of the suffix effect (on recency), the physical channel on which the suffix occurs (voice quality, spatial location) is important. Nonspeech suffixes have no effect. These results suggest that the information is not stored in an alphanumerically categorized form.

An auditory analogue of the Sperling partial report procedure could provide a "converging operation" on the problem of the form of this auditory storage. Moray, Bates, and Barnett (1965) have shown that after multichannel auditory stimulation partial report of one channel is relatively superior to whole report. Their experiment used only one time delay and one mode of recall (spatial location), and so it is not clear whether the superiority they obtained for partial report is simply attributable to output interference and whether superior partial report could also have been obtained with other selection criteria.

The experiments reported here extend Moray, Bates, and Barnett's paradigm and explore the effect of time delay on partial report and of requiring report by spatial location and/or by letter/digit category.

EXPERIMENT I

The general design of this experiment was to present simultaneously a different list of three consecutive items from each of three different spatial locations (left ear, middle, right ear), and then either require the subject to report, in their correct locations, all the items he could remember, or cue him with a visual indicator at zero, 1, 2, or 4 sec after the end of the stimulus to recall only the three items from one of the locations.

Method

The nine numbers 1–10 (omitting disyllabic seven) and the nine letters BFJLMQRUY were randomly assigned to 20 nine-item stimuli (one three-item list on each of three channels), with the following restrictions: (1) each three item list contained two items of one category and one of the other; (2) each stimulus had four items of one category and five of the other; (3) each category was equally represented over all 20 stimuli; (4) over all 20 stimuli, each position of each list contained each item at least once.

This gave a set of 20 main stimuli, each of which had three lists of three items. Each of these 60 lists was recorded separately as a single continuous utterance by a native British English speaker at a rate of 3 items/sec. These recordings were then assembled into an experimental tape using a computer controlled pulse-code modulation system (Cooper & Mattingly, 1969), which mixed appropriate lists and then output two channels simultaneously (one middle list being recorded on both left and right channels). Each of the 20 main stimuli occurred once with each of the 12 partial report cue conditions (4 delays $\times$ 3 locations) to give a set of 240 trials. This set was randomized into 10 blocks of 24 trials so that each half block had one of each tone condition and each block at least one and no more than two of the same stimulus. Allowance was made for the indicator delay in calculating each interstimulus interval so that 10 sec elapsed between the indicator and the next stimulus.

The indicator was a slide with a blank bar on the left, middle or right which was projected onto a screen in front of the subjects. The timing apparatus which controlled the projector was triggered by a tone ¾ sec before each stimulus. For whole report there was no visual indicator, and subjects responded in their own time. The subjects (12 Yale undergraduates) heard the stimuli over headphones. They had initial practice of one block of whole report followed by four blocks of partial report, and then took a total of five blocks of whole report and ten of partial in a balanced order. Only these last 15 blocks (360 trials) were scored. Subjects were tested in groups of 4 for one session of about 3 hr. Although repeated presentation of the same 20 stimuli doubtless led to some long-term memory for at least parts of each stimulus (Turvey, 1967), the experimental design was such that this would not differentially effect partial and whole report.

Results and Discussion

Two variables are interesting in the data: the effect of indicator delay and the position of an item within a particular list. Figure 1 shows the data as a function of these two variables. Observe first that for each item position the partial report curves descend towards the whole report level, but that the absolute level of each curve and its corresponding whole report varies. In the analysis of variance this was reflected in highly significant main terms for indicator delay ($F(3,99) = 9.16$, $p < .001$) and item position ($F(2,22) = 33.22$, $p < .001$). Individual t tests showed that the third item was recalled significantly better than the other two ($p < .001$) which did not differ between themselves ($p > .1$). The interaction between the two main variables was not significant ($F < 1.0$)—there was no change in decay with item position, so the three curves have been condensed into a single curve in the inset of Fig. 1. A separate analysis of variance with the 4-sec delay condition vs whole report as one factor, and item position as the other factor gave no significant main effect or interaction, so we are justified in including the average whole report bar on this figure.

Separate t tests on the difference between the average values of the four delay conditions and the average whole report value gave highly significant differences for 0-, 1-, and 2-sec delay ($p < .001$), all 12 subjects showing the effect for all three conditions. As suggested above there was no significant difference between the 4-sec delay condition and whole report ($t(11) = 1.6$, $.1 > p > .05$), eight subjects showing su-

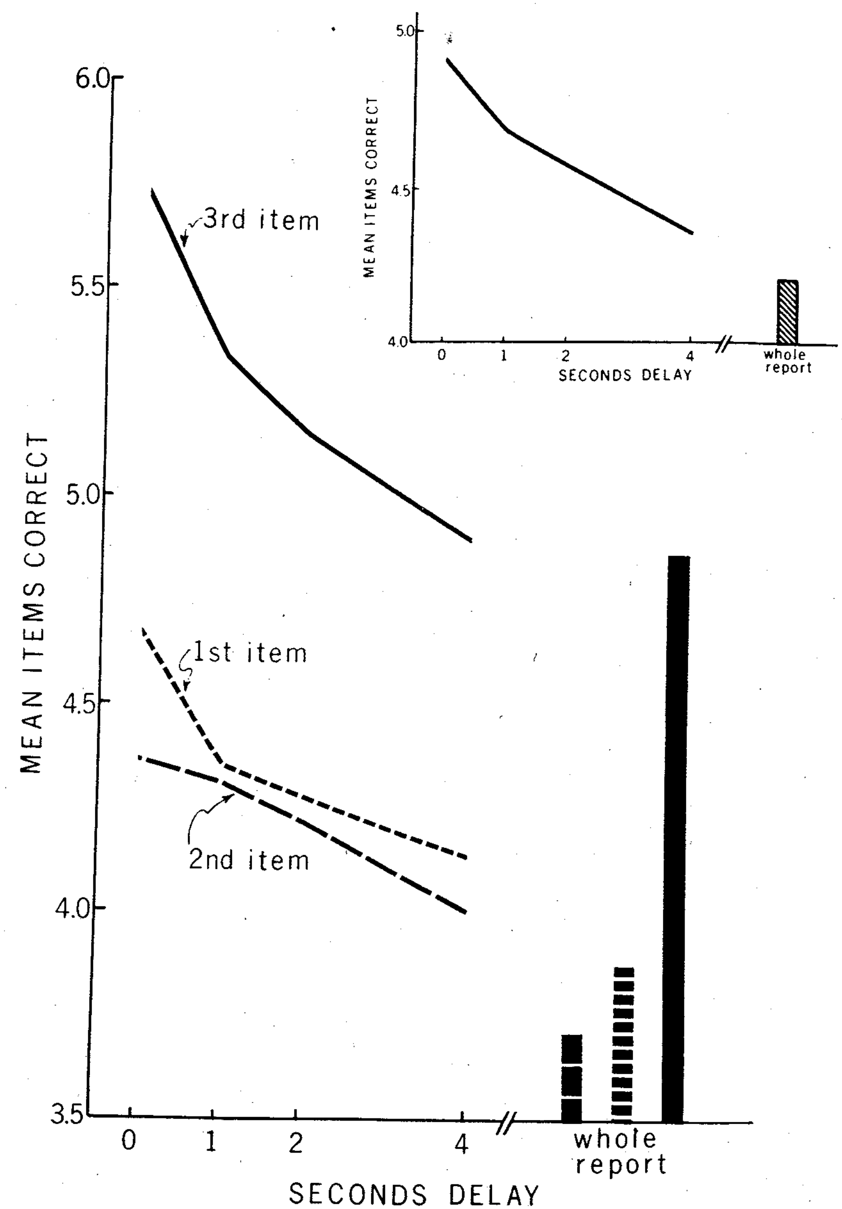

FIG. 1. Partial report by spatial location as a function of visual indicator delay in Exp. I. The three curves correspond to the temporal order of the three items on a channel. The bars on the right are the whole reports, made with no indicator. The inset is the average of the three curves together with the average whole report. Maximum possible score is nine items.

perior partial report, and four showing superior whole report. Whatever, then, is responsible for superior partial over whole report loses its effect if the indicator is given 4 sec after the end of the stimulus.

The other interesting feature of the data is the effect of item position in each list. The last item was better recalled than the first two. This advantage for the last item cannot be attributed simply to a shorter time elapsing between the item being presented and the indicator appearing since, for example, performance on the third item at 1-sec delay (5.34 items) is superior to that on the second item with zero delay (4.36 items). Here the time elapsing between stimulus and indicator is greater for the condition that shows better recall. The relevant difference appears to be that in the case of the second item there is another item presented immediately after it, while for the third item there is a helpful silence (Aaronson, 1968). By contrast, the second item does not exert a similar effect on the first item, which is in fact recalled insignificantly better than the second.

Others have reported marked recency effects in the recall of the unattended channel in dichotic listening experiments (Bryden, 1971; Murray & Hitchcock, 1969). Murray and Hitchcock find, using a probe technique, that recall of the last item on the unattended ear is markedly superior to that of previous items. We would, however, doubt the validity of inferring a specific decay time for auditory memory from this result since, as we have shown here, an interpolated item is more detrimental to recall than a delay of two seconds. Both interference and decay are potent factors in the temporal degradation of auditorily input material.

Why was the magnitude of the advantage for partial report so small compared with the large advantages found in vision? The most plausible reason is that the subjects found it difficult to separate the three different input channels. Many of the errors were intrusion errors from different channels and a number of the subjects said that they had difficulty distinguishing the middle channel. This suggests that subjects would have performed rather poorly if they had been precued to select one channel. By contrast, in the visual modality performance is very good with precueing by location (Eriksen & Johnson, 1969). It may be possible to improve the separation of the three channels by using a different voice on each channel.

EXPERIMENT II

The results of Exp. I functionally define a store in which material is held for about 2 sec, though the form in which the material is held remains unclear. From the data presented here there is in fact no direct evidence that the store is specific to auditorily presented material. Averbach and Sperling (1961) report for example that partial report of visual material remains superior to whole report for longer than 2 sec if dark pre- and postfields are used. With light fields they find a much more rapid decay of the order of 250 msec, so the store that they identify must have some component which is sensitive to the purely visual parameters of the stimulus situation. Unfortunately, we have no evidence that the store we have identified for auditorily presented material is similarly restricted by auditory stimulus parameters.

A lever that has been applied to the question of the form of the stored material in vision can also be applied here. Partial report is only superior to whole report in the visual case when report is cued along some simple dimension of the stimulus. Recall by higher order categories shows very little advantage for partial over whole report, and this, as noted above, has been taken to imply that the items are not classified by higher order categories in the iconic store. We can ask a similar question in the auditory case. Does recall by category give an advantage for partial over whole report similar to that obtained for recall by spatial location? The next two experiments provide some data on this question.

Method

The first two-thirds of the tape for Experiment I was used with 11 new subjects, but with only two different indicators. A vertical bar to the left indicated that only the numbers were to be recalled and a bar to the right only the letters. The subjects were given five blocks of practice as before.

In this partial report condition they were told to write down in their correct location items of the particular category denoted by the indicator, effectively answering the question "What were the numbers, and where were they?" In the whole report condition they were given identical instructions to those of the previous experiment. They did not have to recall the items in any particular order, so long as they attributed each item to its correct location.

Results

The analysis of variance showed a significant main effect of item position in a list as in the previous experiment ($F(2,20) = 19.16$, $p < .001$) (again with #3 superior to #1 and #2), but no main effect of indicator delay ($F(3,30) = 2.18$, $p > .1$), nor any significant interaction between it and item position ($F(6,60) = 2.20$, $.1 > p > .05$). Figure 2A shows the data averaged over item position. The striking difference between this figure and Fig. 1 is that although the whole report was

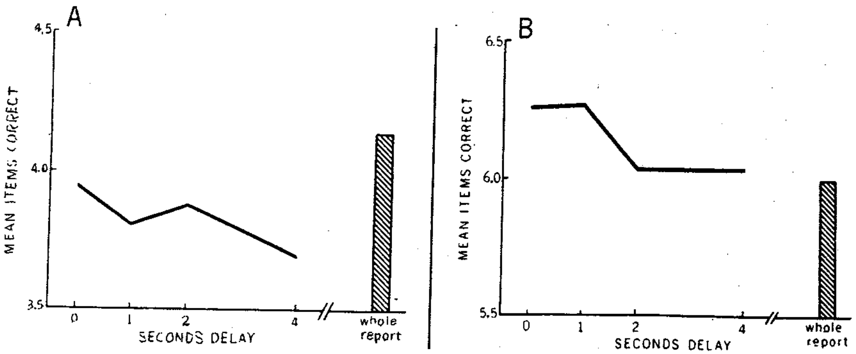

FIG. 2. (A) Partial and whole report by letter/digit category when location is required in Exp. II. (B) Partial and whole report by letter/digit category when location is not required in Exp. III. Maximum possible score is nine items.

almost identical to that of Exp. I (4.2 items) partial report tended to be *lower* than the whole report. This is significant for the average of the partial report conditions ($t(10) = 2.36$, $p < .025$). Clearly report by category is, in this situation, an inefficient mode of recall, and one that shows little variation with indicator delay.

Discussion

These results raise two questions: why was there no change in partial report with time? and why was partial report less efficient than whole report? The absence of decay with time of course supports the hypothesis that semantic category information is not available in the store whose decay leads to the decline in partial report. But, unfortunately, other reasons could be advanced for the absence of temporal decay. It could be that since the transformation between the indicator and the particular selection required is more complex in this experiment than in the previous one, the subject requires more time to perform it and consequently can tap the transient memory only after it has suffered considerable decay (cf. Eriksen & Collins, 1969). Against this we can offer informal observations on the subjects; they generally started to make their response at least within a second of the indicator appearing on the screen, and when questioned after the experiment on the difficulty of identifying the required category considered it a trivial imposition. Doubtless it required time and effort in the early stages of the experiment, but it probably became automatic by the end of the practice period of 120 trials. Almost no errors were made in deciphering the indicator, and they were scored as if the chosen category was the correct one. Comparison of visual partial report procedures (Averbach & Coriell, 1961; Sperling, 1960) shows that for trained subjects the estimate of iconic storage decay does not depend on whether the indicator used is visual or auditory although undoubtedly the auditory indicator involves a more complex transformation than the visual and the estimated decay time is very much shorter than here. A logical objection to the problem of when the indicator information is used must remain, but we doubt that it is of great practical significance.

A more substantial objection is that partial report by category required recall of more material (4.5 items) than recall by channel (3 items). To see the effect of this increase in partial report size, consider the extreme case of "partial" report of all nine items. Here of course there would be no advantage for partial report over whole since they are identical. Neither, by analogy with the visual case (Averbach & Sperling, 1961), would there be any decay with time. The absence of any significant decay in partial report in this experiment could be attributed to this factor. As a counter to this argument, we can compare the partial report curves obtained by Sperling (1960) and Averbach and Coriell (1961); the former required partial report of three or four letters, respectively, from a nine or eight letter array, whereas the latter required report of only one letter from a 16 item array. Despite this large difference in the fraction of material required in the partial report, similar estimates of the useful life of iconic memory were derived. This comparison with vision, however, may not be valid since readout times from the transient store into a more permanent form may be more rapid in vision than audition.

Why was partial report worse than whole report? In both conditions subjects had to assign items to their correct spatial location, all nine items in the whole report, but only those of a particular category in the partial. For the partial condition, an explicit decision is required of an item's category, which is not necessary for the whole report. This extra cognitive load could influence the decay of partial report since items would be output at a slower rate (cf. Posner & Mitchell, 1967). Perhaps, then, this extra interrogation of an item's category is responsible for the absence of a decline in partial report with time, not because category information is not available in the store responsible for the decline, but because readout from that store is slower when information on two attributes of an item (location and category) is required rather than information on just one (location). If this were in fact the case, and category information were as accessible as location information, we would expect to find decay of partial report when cued by category with the location of an item irrelevant. Accordingly the next experiment looks at recall by category when location is not required.

EXPERIMENT III

Method

The same tape and slides were used as in the last experiment. Eight new subjects were given instructions and practice similar to those of the previous experiment, the only difference being that they were not told to remember or report the location of a particular item. Their answer sheets were divided into two columns; for the whole report they wrote the numbers on the left and the letters on the right, for the partial they wrote the cued category in the left-hand column. They were told to average about 4½ responses per trial for the partial report, and to write all nine items for the whole report, guessing if necessary.

Results

Partial report is now at approximately the same level as whole report. No breakdown of the scores was made in terms of item position, and the average of the three positions is shown as a function of indicator delay in Fig. 2B. The analysis of variance showed a significant effect of indicator delay ($F(3,21) = 3.97$, $p < .025$). However the magnitude of the effect was very small; the difference between the whole report and the zero delay partial condition was only 0.25 items. This was significantly smaller than the 0.71 items found in Exp. I for partial recall of the same material by location rather than by category ($t(18) = 5.73$, $p < .001$). Partial report was significantly greater than whole report for the zero and 1-sec delay conditions ($p < .01$) but not for the 2- and 4-sec conditions ($p > .1$).

Discussion

When partial report was required by semantic category, there was some advantage over whole report for indicator delays of a second or less. However, this advantage was significantly less than when partial report was required by spatial location. As we suggested in the discussion of the previous experiment, the magnitude of the partial report advantage over whole report depends in part on the relative number of items required for partial report. We cannot tell on the evidence presented here, whether the much smaller advantage under recall by category is due to the larger number of partial response items, or to the relative ease of withdrawing items from a decaying store according to different stimulus attributes.

The lower partial report over whole report obtained in Exp. II is clearly not attributable simply to the fact that recall was cued by category. Rather it must be due to the fact that recall required memory for two attributes of the stimulus rather than one. The small though significant decay found in this experiment suggests that this may also have been responsible for the absence of any decay in Exp. II.

GENERAL DISCUSSION

The evidence presented in these three experiments demonstrates some transient memory for auditorily presented material, from which we have reason to believe retrieval is more easily made according to the dimension of spatial location than according to that of an item's semantic category. The time limit on the store identified in these experiments is similar to that reported from other experiments in audition. Treisman (1964) reports that the identity of two messages dichotically presented is only noticed when the nonshadowed message leads if the temporal disparity is less than about 1.5 sec. When the shadowed message leads, the critical time is around 4 sec. One disadvantage of the design of our experiments is that there is no attempt to control, as in Treisman's experiments, the attentional strategy of the subject. Nevertheless our figure of something greater than 2 sec but less than 4 is conveniently bracketed by Treisman's two estimates. Our store probably has more in common with Treisman's 1.5-sec store since there was a silent interval after our to-be-remembered sounds which perhaps extended its useful life. Glucksberg and Cowen (1970) give a figure of less than 5 sec for memory for digits embedded in prose on the rejected channel of a shadowing task, a figure compatible with a similar experiment by Norman (1969), which used a string of six digits rather than an embedded digit. They comment also that their subjects were never aware that a digit had occurred unless they could name the particular digit. This absence of any awareness of the occurrence of a nonspecific member of the class of items required and the absence of any context effects in detection correspond well with Treisman's findings, and with our own findings of less efficient partial report by semantic category than by spatial location.

The presumed absence of semantic attributes, however, cannot serve to distinguish between material held in some articulatory/phonetic code, and material held in some less processed auditory form. The only argument in favor of the latter, and it is not a strong one, is that the lower limit on the detection of periodicity for repeating white noise is of the order of 1 sec (Guttman & Julesz, 1963), a time which is not incompatible with our estimate considering the continuous nature of the stimulus, and the finer auditory resolution required to distinguish two sections of statistically identical white noise compared with that required to distinguish between 18 acoustically grossly different items.

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