Paired associate and sequential probes in dichotic memory

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Paired associate (PA) and sequential (SQ) probes were compared in two experiments in which lists of four (Experiment I) or five (Experiment II) pairs were presented dichotically. The SQ probe gave higher recall for early list items while the PA probe was superior for the last serial position. The effects of presentation rate and a nonredundant suffix were typical in the PA probe conditions but were not systematic in the SQ conditions. The data were discussed in terms of the sequential association hypothesis and the importance of considering the subject's processing strategies in interpreting rate and interference effects in memory.

A number of apparently disparate findings from experiments on short-term memory and attention have proven somewhat difficult to explain. For example, there is presently no completely satisfactory theoretical account of Broadbent's (1954, 1956) finding of an ear-by-ear report order of dichotically presented stimuli. A second problematical finding was reported by Murdock (1967) who found that, in a sequential probe task where auditory and visual items are mixed within a list, performance is highest when both probe and target items were presented auditorily in the list. For the other three conditions (visual probe and target, auditory probe and visual target, and visual probe and auditory target) there were no systematic differences.

Penney (1975) has suggested one explanation for both of these phenomena. In auditory short-term memory, strong associations are hypothesized to exist between successive items. These auditory associations are much stronger than the analogous associations between successive visual stimuli or associations between stimuli presented in random alternation to different sensory modalities. In a dichotic split-span task, subjects are hypothesized to divide their attention approximately equally between the two simultaneous inputs such that the sequential associations may also exist between items presented in different ears. These associations do not exist between auditory items presented simultaneously.

Weak evidence for these associations was presented by Penney (1974a) who used a four-channel (Murdock, 1971) audio-visual presentation and a probe technique. The subjects were asked to report either the item that had occurred at the same time in the list or the word that had occurred before or after the probe in the same ear. For auditory items, the same-time probe was found to give poorer recall. Evidence relating to the hypothesis

that subjects divide their attention equally between the two ears was reported by Penney (1974b) in which subjects were tested on recognition of the order of the list items. It made no difference whether the two items tested had been presented to the same or to different ears.

In the present experiments, a probe task was used to test recall of a single item from a dichotically presented list of either 8 or 10 words. One group of subjects was asked to recall the word that had occurred at the same time as the probe word in the other ear (PA probe) while the second group of subjects recalled the word that came after the probe word in the same ear (sequential or SQ probe). If the sequential associations are as strong as hypothesized, the SQ probe ought to give better recall than the PA probe, particularly at faster presentation rates. In an unpublished pilot study, a large recency effect was found in the PA probe condition which may have masked the predicted superiority of the SQ probe. Therefore, an interference condition was included with the purpose of reducing this recency effect. Earlier unpublished work suggested that the recency effect in the SQ condition would only be reduced slightly by the interference. This possibility was considered to be of sufficient importance to merit further investigation.

The experiment was conducted with two list lengths and two presentation rates. Presentation rate has been shown to influence the preferred order of recall in a dichotic split-span task (e.g., Bryden, 1964) and may well influence the relative effectiveness of the SQ and PA probes. Pilot work indicated that the superiority of the SQ probe was found only in the second serial position of a four-pair list. Five-pair lists were included in the present experiment in the hope that more than one serial position would show the effect.

In contrast to the prediction from the sequential association hypothesis, a description of possible rehearsal strategies would suggest that performance should be consistently higher in the PA probe condition. In the SQ condition, the optimal rehearsal strategy is not

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obvious. It is conceivable that subjects attend selectively to one ear on any trial. However, this strategy would practically guarantee that the subject is unable to recall anything on half the trials since he would not have been attending to critical stimuli. If, on the other hand, the subject chooses to rehearse the simultaneous items as pairs and decode the successive items at retrieval, performance should be higher in the PA condition. The extra processing necessary in the SQ condition should undoubtedly lower recall.

Yntema and Trask (1963) have suggested that at presentation the subject tags the items according to either ear of arrival or time of arrival and then at retrieval uses the appropriate tags as a basis for a retrieval plan. If, as Mewhort's (1973) data suggest, more information is transmitted about the time of arrival than ear of arrival, the time tags should be more effective, giving consistently higher recall in the PA condition.

METHOD

Subjects

The subjects were 160 male and female volunteers from the introductory psychology course who were paid \$2.00 for taking part in the experiment. No subject was aware of having any hearing impairment. One subject was unable to do the task and was replaced by another subject. All subjects were tested individually. The subjects were randomly assigned to conditions with the restriction that the number of males and females in each group was equal.

Stimulus Materials

For each experiment, four sets of stimulus materials were constructed, one set for each of the rate and interference treatment combinations. For each set, the words were randomly selected without replacement from a pool of 1430 common English words of one syllable. An attempt was made to ensure that the two words to be presented simultaneously did not rhyme.

In Experiment I, four pairs of words were presented at each trial, with the two words of each pair presented simultaneously to different ears. One of the eight words was repeated at the end of the list as a probe. The probe word was always repeated in the same ear as the initial presentation. In the interference conditions, a random number was presented monaurally after the last list word and before the probe. The ear of presentation of the interference changed after every second trial. The subject was instructed to ignore the interfering number. In the no interference condition, a silent interval replaced the interfering number. The stimulus material for Experiment II was generated in the same manner except that there were 10 words per trial instead of eight.

For construction of the dichotic tapes, a Uher diaphonot driven by a Lafayette interval timer recorded signals at successive intervals on an unused track of the tape. These signals were used by the experimenter as timing signals when he recorded the words independently on the two channels of the tape. If the experimenter could detect any asynchrony in the onset of any pairs, the entire list of 8 or 10 pairs was rerecorded. The same male experimenter recorded both channels.

Design

For both Experiments I and II a factorial design was used with two instruction conditions (PA and SQ), two presentation rates (.8 sec and 1.2 sec per pair), two interference conditions (interference present or absent). Ten subjects were tested on each of these eight treatment combinations with five males and five females in each group. Four sets of stimulus materials were used in each experiment, one set for each rate and interference combination, but the same set of materials was used in the two instruction conditions. In Experiment I there were eight possible probe positions with every position tested once in each block of eight trials. There were 10 blocks of trials, giving a total of 80 experimental trials. In Experiment II, there were 10 possible probe positions and 10 replications for a total of 100 experimental trials. Therefore, for both experiments the design is a complete factorial design with instructions, presentation rate, and interference as between-subject variables, replication, and serial position tested as within-subject variables.

Procedure

The subject was given a sheet of instructions describing the type of list he or she would hear and explaining the task. In the PA instruction condition, the subject was asked to recall the word that had occurred at the same time in the list as the probe word. In the SQ condition, the subject was asked to recall the word that had been presented after the probe word and in the same ear. If the probe word had been in the last pair, the subject was asked to recall the first word presented to the same ear as the probe.

When subjects felt they understood the task, they were given the 16 (Experiment I) or 20 (Experiment II) practice trials, during which they were allowed to ask questions and were given some feedback on their performance. After the practice trials, the experimenter reviewed the instructions, and the 80 or 100 experimental trials proceeded with only sufficient time between trials for the subject to respond orally and for the experimenter to record his or her response.

RESULTS

The results of each experiment were subjected to an analysis of variance with instructions, presentation rate, and interference conditions as between-subject factors and serial position and ear of presentation of the target item as within-subject factors. The dependent variable was the arcsin transformed proportion of words recalled out of 10 replications. The within-subject main effects were tested against the interaction with subjects, as in most cases this happened to provide a more conservative test than using the pooled error term. Higher order within-subject interactions and mixed between-within interactions were tested against a pooled within-subject error term (Experiment I, Error $W = .176$, $df = 504$; Experiment II, Error $W = .181$, $df = 567$). All between-subject main effects and interactions were tested against a pooled error term (Experiment I, Error $B = .435$, $df = 72$; Experiment II, Error $B = .326$, $df = 72$).

Figures 1 and 2 show percentage recall as a function of serial position of the target item for the two

Figure 1. Experiment I: The effectiveness of PA and SQ probes as a function of serial position of the target item. The separate panels show recall of left- and right-ear items separately at the fast and slow presentation rates.

experiments. The two dotted lines represent recall of left and right ear items in the SQ condition while the solid lines are for the PA condition. The main effect of instructions was not significant in either experiment, but instructions did interact with serial position: Experiment I [$F(3/504) = 17.2$, $p < .005$], Experiment II [$F(4/567) = 6.99$, $p < .005$]. The main effect of serial position was also significant [$F(3/27) = 107$, $p < .005$; $F(4/36) = 70.8$, $p < .005$]. Figures 1 and 2 show that recall was higher in the early serial positions in the SQ instruction condition, but higher in the last serial position in the PA condition. In Experiment II, the effect is much weaker, with the superiority of the SQ condition in early serial positions appearing only when the presentation rate was fast. For items in the last serial position in both experiments, recall was either higher in the PA condition or there was no difference.

In Experiment I, the main effect of presentation rate and all interactions with rate were not significant. In Experiment II, however, presentation rate did interact with other factors; in particular, the Rate by Instructions and the Rate by Serial Position interactions were significant [$F(1/72) = 8.82$, $p < .005$ and $F(4/567) = 5.16$, $p < .005$, respectively]. In the PA condition, the slow rate resulted in better recall with the largest difference occurring at the last serial position. For the SQ condition, a fast rate resulted in higher recall of early list items, but lower recall of the last item when compared to the slow rate.

In Experiment II, but not in Experiment I, the four-way interaction between instructions, rate, serial position, and ear was significant [$F(4/567) = 3.77$, $p < .005$]. It would appear from Figure 2 that recall of

the right-ear item in the last serial position is unusually high in the PA condition if the rate is slow and that recall of the left ear item is unusually low in the SQ condition if the rate was fast. An alternate interpretation is that the SQ superiority depends on serial position, presentation rate, and ear of presentation, occurring chiefly for items in the first and second serial positions at the fast rate and being more reliable for the right ear than the left. In Experiment II, the SQ superiority was not found at all with a slow presentation rate.

The main effect of interference was significant in Experiment I [$F(1/72) = 5.01$, $p < .05$], as was the interaction with serial position [$F(3/504) = 4.15$, $p < .01$]. Recall of the last list item was lowered when the interference was present, a finding that has frequently been demonstrated (e.g. Crowder & Morton, 1969). In Experiment I, the triple interaction between interference, instructions, and ear of presentation was also significant [$F(1/504) = 4.10$, $p < .05$]. In the SQ instruction condition, there was virtually no effect of the interference upon recall of items presented to the left ear. Interference did lower recall of terminal right ear items in the SQ condition and both left and right ear items in the PA condition.

In Experiment II, the pattern of results for interference effects was slightly different. The main effect of interference and the interaction with serial position were not statistically significant, but the following interactions were significant: Interference by Rate by Ear [$F(1/567) = 3.86$, $p < .05$] and Interference by Instructions by Rate by Ear [$F(1/567) = 6.51$, $p < .05$]. Interference consistently reduced recall of the terminal items in the PA condition, but had somewhat unsystematic effects in the SQ condition. When the data are summed over serial position in the SQ condition, interference was found to have, if anything, a facilitating effect on recall of left-ear

Figure 2. Experiment II: The effectiveness of PA and SQ probes as a function of serial position of the target item.

Table 1
Interference Effects as a Function of Ear of Presentation
of Interference and Target Items

Ear of Inter- ference	Instruction Condition			
	PA		SQ	
	Left	Ear of Target Item Right	Left	Right
Experiment I				
Left	16.9	20.8	20.8	19.8
Right	16.5	19.1	17.9	26.1
Experiment II				
Left	12.6	15.4	16.4	14.4
Right	22.0	13.9	15.9	23.4

Note—Entries are the percentages of items recalled.

target items presented at a fast rate and of right-ear items at a slow rate. When the data are summed over instruction condition, the effect of interference disappears for left-ear items at the fast rate and right-ear items at the slow rate, resulting in the significant triple interaction.

In summary, the results of the two experiments indicate that the effects of the interfering number in the PA condition are quite predictable. In the SQ instruction conditions, there are several cases where the interference actually seems to *improve* recall. This point will be taken up in the discussion.

The only other significant effect was ear of presentation, Experiment I [$F(1/9) = 39.5$, $p < .005$], Experiment II [$F(1/9) = 14.0$, $p < .005$], with the usual right-ear superiority being found.

Because of the interactions between interference, instruction condition, and ear of presentation, a further analysis was undertaken to discover whether the ear in which the interference occurred had any effect. The four combinations of ear of interference and ear of the target item were not tested an equal number of times, so recall is presented as a percentage. Table 1 shows the percentage recall in Experiments I and II for both instruction conditions as a function of ear of interference and ear of the target item. In the PA condition in Experiment II, recall is slightly better if the target and interference are in different ears. In Experiment I there seems to be no effect in the PA condition. However, in the SQ instruction condition of both experiments, performance is slightly better if both target and interference are in the same ear. This is a rather unexpected finding.

DISCUSSION

The results of the present experiments provide some support for the hypothesis outlined in the introduction. For early list items recall was generally better in the SQ than in the PA condition. In Experiment II, this difference was not found with a slow presentation rate, but this may be due to a very low level of recall in both

instruction conditions for early list items. According to any prediction based on attentional or rehearsal strategies, the PA probe ought to be a far more efficient retrieval cue than the SQ probe. The finding that the SQ probe was more effective under any circumstances is strong evidence that in dichotic memory, simultaneous items are not associated and that it is the forward and backward associations that determine performance on retention tests.

Recall of the last list item was consistently higher in the PA than in the SQ condition. This is consistent with the idea that both of the simultaneously presented items enter memory at the same time, not separately as Broadbent (1958) suggested. In other words, the subject is able to divide attention between the simultaneous items and does not necessarily reject one in favor of the other.

Another possible interpretation, not inconsistent with the above, is that, when recall of one item of the last pair is tested, encoding or recognition of the probe is faster in the PA condition. In the PA condition both the probe and the target items are in the last pair and the subject can probably make use of this information. However, in the SQ condition, the probe was initially presented in the penultimate pair. Upon hearing the probe item, the subject must decide in which pair it was originally presented before attempting to retrieve the succeeding item. Information about the serial position of the probe is probably less available in the latter case than in the former.

Presentation rate and interference were both shown to interact with instruction conditions, and certain higher order interactions were significant as well. The effect of both interference and presentation rate in the PA condition are straightforward. Interference decreases recall, the effect occurring mainly for the last pair, and a slow presentation rate is beneficial. If the subject adopts the most likely strategy of rehearsing items as pairs, a fast rate is going to reduce the time available for this rehearsal. The interference will affect recall of the last pair most as this will probably be the pair being rehearsed at the time the interfering number is presented.

In both experiments, the effect of rate and interference were somewhat inconsistent in the SQ condition. A possible interpretation of the rather confusing results in the SQ condition is that the effects of both interference and rate depend upon the subject's rehearsal and attentional strategies which, in this experiment, were not controlled.

It is difficult to imagine a strategy which would allow a fast presentation rate to be superior to a slow rate; nevertheless a number of investigators have reported such results (see Penney, 1975, for a review). Hockey (1973) presented evidence to indicate that a fast presentation rate was beneficial if the subjects adopted a passive

strategy and did not attempt to code or organize the input. In Experiment I, neither the main effect of presentation rate nor any interactions with rate were significant. On the other hand, in Experiment II, a fast rate was beneficial for early list items. The longer lists of Experiment II may have overloaded memory to the extent that subjects simply gave up trying to rehearse and therefore allowed a decay factor to operate.

It is a little more difficult to interpret the data on interference effects in the SQ condition. In Experiment II, the presence of a distracting number did not seem to have any consistent effect upon recall, although the interference did reduce recall of the last two pairs in the first experiment. Furthermore, in both experiments, recall was actually better in the SQ instruction condition if the interference was in the same ear as the probe than if it were in the other ear. This is in clear contradiction to the results of Morton, Crowder, and Prussin (1971) who found that a contralateral suffix interfered less than did an ipsilateral suffix with retention of monaurally presented items.

Recently Engle (1974) reported some rather anomalous suffix effects in a running digit span task and in free recall. In both tasks, he reported a more extensive suffix effect than Crowder and Morton (1969) found in that approximately four serial positions were affected. Contrary to Crowder and Morton's (1969) prediction, Engle (1974) also found in the digit span task that the suffix reduced recall of terminal items in a visual list. It would appear that the size and extent of the suffix effect depends on the task, which suggests that it is also dependent upon the subject's strategies. If this is so, Crowder and Morton's (1969) model will have to be revised somewhat. The next step is to perform experiments on the suffix effect in serial recall and serial probe tasks with rehearsal strategies controlled.

One problem in the interpretation of the data from the present experiments, the second experiment in particular, is the large number of higher order

interactions all of which involve ear of presentation. Right ear superiority in dichotic memory is well documented (e.g., Bartz, Satz, Fennell, & Lally, 1967) and was shown in both experiments. The higher order interactions seem to result from an extraordinarily large ear difference for certain serial positions in certain experimental conditions. The interpretation of these interactions will await replication and further research.

REFERENCES

- Bartz, W. H., Satz, P., Fennell, E., & Lally, J. R. Meaningfulness and laterality in dichotic listening. *Journal of Experimental Psychology*, 1967, 73, 204-210.
- Broadbent, D. E. The role of auditory localization in attention and memory span. *Journal of Experimental Psychology*, 1954, 47, 191-196.
- Broadbent, D. E. Successive responses to simultaneous stimuli. *Quarterly Journal of Experimental Psychology*, 1956, 8, 145-152.
- Broadbent, D. E. *Perception and communication*. New York: Pergamon Press, 1958.
- Bryden, M. P. The manipulation of strategies of report in dichotic listening. *Canadian Journal of Psychology*, 1964, 18, 126-138.
- Crowder, R. G., & Morton, J. Precategorical acoustic storage (PAS). *Perception & Psychophysics*, 1969, 5, 365-373.
- Engle, R. W. The modality effect: Is precategorical acoustic storage responsible? *Journal of Experimental Psychology*, 1974, 102, 824-829.
- Hockey, R. Rate of presentation in running memory and direct manipulation of input processing strategies. *Quarterly Journal of Experimental Psychology*, 1973, 25, 104-111.
- Mewhort, D. J. K. Retrieval tags and order of report in dichotic listening. *Canadian Journal of Psychology*, 1973, 27, 119-126.
- Morton, J., Crowder, R. G. and Prussin, H. A. Experiments with the stimulus suffix effect. *Journal of Experimental Psychology*, 1971, 91, 169-190.
- Murdock, B. B. Auditory and visual stores in short-term memory. *Acta Psychologica*, 1967, 27, 316-324.
- Murdock, B. B. Four-channel effects in short-term memory. *Psychonomic Science*, 1971, 24, 197-8.
- Penney, C. G. Dichotic listening and sequential associations in auditory short-term memory. *Journal of Experimental Psychology*, 1974, 102, 142-150. (a)
- Penney, C. G. Order information in dichotic memory. Paper read at the annual meeting of the Canadian Psychological Association, Windsor, 1974. (b)
- Penney, C. G. Modality effects in short-term verbal memory. *Psychological Bulletin*, 1975, 82, 68-84.
- Yntema, D. B. & Trask, F. P. Recall as a search process. *Journal of Verbal Learning and Verbal Behavior*, 1963, 2, 65-74.

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