The role of visual interference in producing the long-term modality effect

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Typically, recall of the last of a list of auditory items greatly exceeds recall of the last of a list of visual items. This modality effect is often referred to as the enhanced recall of items presented auditorily, as opposed to visually, near the end of the list of items.

This effect is not eliminated even when the retention interval is filled with overt verbal activity (Gardiner & Gregg, 1979; Glenberg, 1984). Areas based on the elaborative processes have been proposed for the modality effect (Frankish, 1985; Frankish & Turner, 1984), and for the LTME in particular (Gardiner, 1983; Glenberg, 1984; Glenberg & Swanson, 1986). In all of these accounts, it is proposed that the auditory items are in some way more distinctive than the visual items, and that this distinctiveness is good for learning. For example, Glenberg and Swanson (1986) expanded Gardner's (1983) proposal that auditory items are distinctive in the temporal domain. They proposed that the time of presentation is encoded more accurately (with a finer grain or resolution) for auditory items than for visual items. To retrieve information pre-

EXPERIMENT 1

Experiment 1 included two tests of the visual-interference hypothesis. The first test was performed by the very first list that subjects recalled. This list was learned un- der incidental learning instructions. The second test, the interference test, was to be tested on the list, we reasoned that they would not rehearse the to-be-remembered (TBR) items, and thus there was no need for a distractor task. Consequently, the interference test interval (ITI) and retention interval (RI) were unfilled, eliminating visual interference engendered by a distractor task. Unfor- tunately, in our instructions recall of the last item of the incidental list was close to 100%, and thus was un- informative. For this reason we will not describe in detail the procedures used or the results obtained from this incidental list.

A second test of the visual interference hypothesis was provided by a manipulation of the type of distractor task used subsequent to the incidental list. For half the sub- jects, a visually presented addition task filled the IPI and the RI. Every 2 sec the subject saw the computer mon- itor a three-digit addition problem as well as an answer that was equally often the correct or incorrect sum. The subject's task was to hit one key if the sum was correct and another key if it was incorrect (see Glenberg, 1984, for details of implementation of this task). This compo- nent of the distraction task was used to minimize re-hearing requiring capacity-demanding mechanisms. In ad- dition, the subjects engaged in articulatory suppression by saying "blah" three times per second through- out the distractor intervals. This component of the dis- tractor task was designed to minimize rehearsal by means of an articulatory loop.

The other half of the subjects engaged in an auditory tone task throughout the distractor intervals. Each tone task lasted for 2 sec. During the first second, a series of tones was presented through a loudspeaker located above and behind the computer monitor. Either the tone series was monotonically ascending or descending in pitch, or the pitches changed nonmonotonically. During the next second, the subject was required to press one button if the changes in pitch were monotonic and another button if the changes were nonmonotonous. As with the addition task, subjects engaged in articulatory suppress- ion throughout the distractor interval. (Subjects articu- lated "blah" slightly louder than a whisper, so that the articulation could be monitored by the experimenter. These articulations did not appear to interfere with per- ception of the tone in the RI, which was presented at a comfort- able volume.) With this tone task (and the other pre- cedence noted before), virtually all sources of visual interference were avoided. Thus the prediction based on the visual-interference hypothesis was that the LTME should also be eliminated.

Method

Subjects

The subjects were 48 men and women enrolled in intro- duction psychology courses at the University of Wisconsin—Madison. Participation in the experiment partially fulfilled a course requirement.

Materials

The TBR stimuli consisted of 87 pairs of common, concrete, on- and off-syllable nouns. When presented visually, each pair was displayed on the computer monitor for 3 sec. The pairs were also recorded on an intensity 2400 model FM tape recorder (General Electric, Naga- pheen, IL). This computer-controlled device allows rapid (within 400-500 msec) random access to the TBRs. Each pair was recorded within a 1,600-msec interval; however, an additional 1,600-msec interval was allotted so that the total presentation time was 4 sec. The RT was recorded for each tone task was also presented using the Intensity 2400.) Pairs were randomly as- signed (for each subject) to the 47-sec list, the 87-sec list, the incidental list, and 12 six-pair experimental lists.

Throughout the experiment, each subject's vision was restricted by a limited-vision mask. This mask consisted of a pair of narrow goggles strapped to the subject's head. The goggles were attached to a wooden rectangular box (the support) that was approximately 5 x 10 x 45 cm long, although the length was adjusted to suit in- dividual subjects. This mask was attached to the computer monitor to limit the subject's vision to a 5 x 10 cm area of the screen.

Procedure

Subjects participated individually. After signing a con- sent form, the subject listened to tape-recorded instructions charac- terizing the experiment as an investigation of the ability to solve word problems. Each word problem consisted of the presentation of two words. The subject was instructed to designate which of the two words referred to the larger object. For visual presentation, the subject pressed the left-hand button to designate the first word as referring to the larger object and the right-hand button to designate the second word. Subjects practiced responding on a button box with the practice list for the first trial were auditory, and those on the second trial were visual. Next, a six-pair list of 40 practice trials was presented. Each trial was 2 sec in length for each of the subjects, followed by an unexpected recall test. After this incidental list, half of the subjects (randomly assigned) prac- ticed the tone distractor task and half practiced the motion distractor task. Then another three-pair practice list was presented. For this list, the IPI and the RI were filled with the visual tone task and the subject attempted to recall the words orally. Recall was monitored by the experimenter and tape-recorded to ensure accurate scoring.

Finally, each subject studied and recalled 12 six-pair lists. Half of these lists (randomized in blocks of 6) used auditory pairs, and half used visual pairs. Before each list the subject was informed of the modality of the TBR pair. The practice list was used to determine the proper strategy. For the IPI preceding each TBR pair was 8 sec (i.e., four distractor problems) and the RI was 5 sec (i.e., two TBRs and four experimental problems). The RI was followed by a 45-sec recall interval.

To summarize, the intersubject learning part of the experiment was followed by an 8-sec distraction task (2 sec each of auditory and visual distractor tasks), the IPI preceding each TBR pair was 8 sec (four distractor problems) and the RI was 5 sec (two TBRs and four experimental problems).

Results

We scored the number of individual words recalled, regardless of order. 1 Statistical analyses were performed on the proportions of correct responses using the chi-square test. The data of major concern are presented in Figure 1.

The data from those subjects having the addition distrac- tor task (left-hand side of Figure 1) demonstrate the salient features of the LTME. At the end of the list, recall of audi- torial pairs greatly exceeded recall of the visual pairs. Also, as is often the case, recall of the visually presented recall of the auditory pairs at the beginning of the list.
The test of the visual-interference hypothesis is provided by the data from those subjects having the tone distractor task (right-hand side of Figure 1). According to the visual-interference hypothesis, the LTME effect should be eliminated when the tone distractor task is used, because all sources of visual interference are eliminated. Contrary to this prediction, a modest LTME is still apparent.

These observations were supported by the results of statistical analyses. An analysis of all six serial positions showed a main effect of serial position \(F(5,230) = 102.26, MSE = 0.03\). Also, there were significant interactions between distractor task and modality, \(F(1,46) = 4.61, MSE = 0.18\) and between modality and serial position \(F(5,230) = 15.37, MSE = 0.02\), as well as a significant three-way interaction among distractor task, modality, and serial position \(F(5,230) = 3.64, MSE = 0.02\).

Because our main concern was with the end of the list, a second analysis was performed on the data from the last serial position. This analysis showed main effects for distractor task \(F(1,46) = 8.68, MSE = 0.02\) and modality \(F(1,46) = 91.37, MSE = 0.01\), as well as a significant interaction between these factors \(F(1,46) = 22.84, MSE = 0.01\).

The clearest test of the visual-interference hypothesis is provided by a direct comparison between the level of recall of the last auditory and last visual items when the tone task was used. For this comparison, \(F(1,23) = 13.66, MSE = 0.03\), demonstrating a LTME even when the tone was used and visual interference was eliminated.

**Experiment 2**

Interpretation of the results of Experiment 1 may be compromised by the possible ceiling effect in recall of the auditory stimuli (see Figure 1). In Experiment 2, we made use of two related findings to reduce recall. The first finding, called the ratio rule, is that the size of the increments in recall over the last few items on a list is a positive function of the ratio of the length of the IP to the length of the RI (Brown & Whitten, 1974; Glenberg, Bradley, Kraus, & Renzaglia, 1983). Decreasing the RI will decrease the size of the recency effect. Second, the level of recall of the last item, after any RI, can be decreased by decreasing the IP. Thus, decreasing the IP and increasing the RI should reduce recall and provide a test of the visual-interference hypothesis that is free of any ceiling effects.

In Experiment 2, the IP was reduced to 2 sec (one distractor problem) and the RI was increased to 16 sec (eight distractor problems). The incidental list was eliminated, and subjects were aware of the recall requirement from the outset of the experiment. As in Experiment 1, modality of the TRB items was manipulated within subjects and type of distractor task was manipulated among subjects.

**Method**

Subjects. Eighteen subjects were recruited from introductory psychology courses at the University of Wisconsin—Madison. Their participation partially fulfilled a course requirement. An additional 18 subjects were recruited from among the students enrolling in the summer session at the university. Each of these subjects was paid $3 for participating.

Materials. A total of 78 word pairs were randomly assigned (for each subject) to 2 three-pair practice lists and 12 six-pair experimental lists. In half of the lists the TRB items were auditory and in half they were visual. Timing, the orienting task for the word pairs, and other details of presentation were the same as in Experiment 1.

Procedure. Subjects were randomly assigned to distractor task conditions, with the constraint that 9 volunteer and 9 paid subjects be assigned to each condition. After signing consent forms, subjects listened to recorded auditions. Practice was provided on the appropriate distractor task and then on a three-pair list with visual presentation of the TRB items and a three-pair list with auditory presentation of the TRB items. For these lists, as well as for the 12 experimental lists that followed, the IP preceding each TRB item was 2 sec, the RI was 16 sec, and 45 sec was allowed for oral recall.

**Results**

The results of most concern are illustrated in Figure 2. Once again, a LTME was evident when the addition task was used (left-hand panel). Data from the tone-distractor condition (right-hand panel) were used to test the visual-interference hypothesis. As in Experiment 1, the LTME was reduced in the tone-distractor condition, but it was not eliminated. Note that this reduction in the size of the LTME cannot be attributed to a ceiling effect.

Again, the statistical analyses support these conclusions. The analysis of all six positions showed a main effect of serial position \(F(5,170) = 74.55, MSE = 0.02\) as well as a significant interaction between modality and serial position \(F(5,170) = 11.12, MSE = 0.02\). The three-way interaction among modality, serial position, and distractor conditions fell just short of statistical significance \(F(5,170) = 2.13, MSE = 0.01, p = .06\). This important interaction (it indicates whether or not the size of the LTME depends on the nature of the distractor task) was statistically significant in an analysis based on the last three positions \(F(2,68) = 3.72, MSE = 0.02\).

As in Experiment 1, it was important to determine if the LTME was found when the tone distractor task was used. For the 18 subjects performing the tone task in the distractor intervals, a comparison of recall of the auditory and visual items in the list serial position was significant \(F(1,17) = 6.72, MSE = 0.02\).

**Experiment 3**

One result from Experiments 1 and 2 is clear: Eliminating visual interference (as in the tone-distractor condition) does not eliminate modality differences in recall. What is not as clear is the extent to which visual interference contributes to the LTME. Judging from Figures 1 and 2, there is a sizable difference in the LTME depending on the type of task, but the causal factor cannot be uniquely identified as visual interference because modality of the distractor task was confounded with type of distractor task (addition or pitch judgments). In this experiment, we unconfounded modality of the distractor task and type of distractor task to determine the contribution of visual interference to the LTME.
Three distractor tasks were used. For the auditory-duration task, two tones of unequal durations were presented sequentially. The subject's task was to indicate the tone with the greater duration. This task, combined with the limited-vision mask and oral recall, should eliminate visual interference. For the visual-duration task, two lines were presented sequentially for unequal durations, and the subject was to indicate the line with the greater duration. This task introduced visual stimulation, but required the subject to make judgments in an auditory-duration task. For the visual-length task, two lines of unequal length were presented sequentially (for the same durations). The subject was to indicate the line with the greater spatial extent. This task introduced visual stimulation and forced the subject to attend to spatial information. If visual interference contributed to the LTME by reducing recall of visually presented words, then the two visual tasks should produce a larger LTME than that produced by the auditory task. Furthermore, if processing of spatial information contributed to the visual interference, then the LTME should be greatest in the visual-length task. The design of the experiment was similar to that of Experiment 2. Modality of the TBR items was manipulated within subjects and type of distractor task was manipulated between subjects. The IPI was fixed with one distractor problem and the RI was filled with eight distractor problems. In this experiment, however, each distractor problem required 2.5 sec. as opposed to the 2.0 sec used in the other experiments.

Pilot work using the three distractor tasks led us to believe that subjects were able to anticipate the end of the list and engage special rehearsal strategies. To discourage this, we manipulated (within subjects) the list length from four to six serial positions.

Method

Subjects: The 60 subjects were recruited from introductory psychology classes at the University of Wisconsin—Madison. Participation in the experiment partially fulfilled a course requirement.

Materials: A total of 64 word pairs, a subset of those used in Experiments 1 and 2, were randomly assigned (for each subject) to a 2-place list with 3 pairs and one with 2 pairs) and 12 experimental lists (four at each list length of 4, 5, and 6 pairs). In half of the lists, the list length of the TBR items was auditory, and in half they were visual. The 12 experimental lists were randomized, with the constraint that each block of 6 lists contain one example of each combination of list length and modality. The presentation modality of the pairs was indicated before each block began, but subjects were unaware of the list length. Timing, the orienting task for the word pairs, and other details of presentation were the same as in Experiments 1 and 2.

Each distractor problem consisted of a pair of stimuli presented sequentially for a judgment. The stimuli varied on two dimensions. One dimension was relevant to the judgment and differentiated the stimuli presented as a problem. The other dimension was irrelevant to the judgment and differentiated the stimuli presented as a problem, but changed randomly between problems. The two stimuli were presented during a 1250-msec interval and they were followed by a 1250-500-msec response interval. Subjects overread the syllable "Yah" three to four times per second during the distractor problems.

For the auditory-duration task the stimuli were two tones, and the relevant dimension was duration of the tones. Except for one constraint noted below, the duration of the shorter tone was randomly chosen from among 50 equally spaced durations in the interval (approximately) 100 msec to (approximately) 400 msec. The duration of the other tone was determined by multiplying the duration of the first tone by a multiplier greater than 1.0. The value of this multiplier was adjusted after every few problems in an attempt to keep performance at 80% correct. For example, if performance fell below 80% correct, the multiplier was increased to increase the difference in the durations of the tones. The one constraint on the randomly chosen duration was that it must be less than the longest duration used (with a duration of the randomly chosen duration times the multiplier) would have a duration of less than 400 msec. The two tones were presented in random order. Following presentation of the tones, the subject pressed a button to indicate which tone had the greater duration. For the auditory-duration problems, the irrelevant dimension was pitch. Although the two tones in any given problem had the same pitch (differing only in duration), for each problem the pitch was randomly chosen from among 40 values between approximately 150 and 300 Hz.

The stimuli for a duration problem were two lines presented for unequal amounts of time, so that the relevant dimension was again duration. Except for one constraint, the duration of the shorter duration line was chosen from the interval 100 to 400 msec (in 1-msec increments). The duration of the other line was determined by multiplying the duration of the first line by a multiplier greater than 1.0, and this multiplier was adjusted to keep performance at 80% correct. The one constraint in choosing the shorter-duration line was that the duration of the other line be less than 400 msec. The two lines were presented in random order, and the subject pressed a button to indicate the line with the greater duration. The irrelevant dimension was length of the lines. Although the two lines in any given problem had the same length (differing only in duration), for each problem the length was randomly chosen from among 145 values, equally spread from approximately 0.36 to 1.34 cm.

The stimuli for the visual-length problems were identical to those for the visual-duration problems, except that the relevant and irrelevant dimensions were interchanged. Thus, in a given problem, the lengths of the lines varied (and the difference was adjusted to keep performance at 80% correct), and their durations were constant (and irrelevant). Across problems, the durations varied randomly. The subject's task was to judge which line was longer.

Procedure: Subjects were randomly assigned to distractor-task conditions. After listening to recorded instructions, each subject practiced on the appropriate distractor task, a three-pair list with visual presentation of the TBR stimuli, and a five-pair list with auditory presentation of the TBR stimuli. For these lists, as well as for the 12 experimental lists that followed, the IPI preceding each TBR item was 2.5 sec (one distractor problem), the RI following the last TBR item was 20 sec (eight distractor problems), and 45 sec was allowed for oral recall.

Results

The distractor tasks differed in modality of presentation, and they may have differed in difficulty. To rule out this potential confound, it is necessary to demonstrate that the performance on the three distractor tasks was comparable. In fact, percent correct responding was 76.6, 76.5, and 74.8 in the visual-duration, visual-length, and auditory-duration tasks, respectively. These percentages were not statistically different [F(2, 57) = 1.64, MSE = 26.05]. Equality in the percent correct measure was achieved by differences in the multiplier that controlled the difference in duration or length between the two stimuli in a problem. The average multipliers were 2.49, 1.49, and 2.00 for the visual-duration, visual-length, and auditory-duration tasks, respectively [F(2, 57) = 3.07, MSE = 1.55].

We scored the number of words recalled from the first serial position, the last serial position, and the whole list for each task (after oral recall), and from the recall task (by using oral recall), but the LTME remained.

Experiment 3 provides the clearest demonstration of the limited role of visual interference. Adding visual (and spatial) information to the distractor task, while holding other characteristics of the task constant, had little or no effect on the size of auditory superiority at the end of the list. In Experiments 1 and 2, the size of the modal difference varied greatly between the tone task and the addition task. Given the results of Experiment 3, it seems unlikely that visual characteristics of the distractor tasks produced a large role in determining the size of the modality effect. Two factors that may have controlled the size of the modality effect are difficulty of the distractor task and meaningfulness of the stimulus features (tones vs. numbers). In fact, Glenberg et al. (1980) demonstrated that more difficult distractor tasks produced greater long-term recency than did easier tasks. And Greene (1985) suggested that grouping based on meaningful features plays a role in the LTME.
An adult model of preschool children's speech memory

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In previous work, it has been demonstrated that phonetic similarity among the items in a spoken list interferes with recall much more in school-aged children than in preschool children. The basis of this developmental difference, however, is unclear. In the present study we examined the possibility that a developmental increase in the use of covert verbal rehearsal accounts for the change in the effects of phonetic similarity. Adults who recalled lists of spoken words during articulatory suppression tasks that blocked overt rehearsal were found to display patterns of recall that resembled those ordinarily found in 5-year-old children. The specific aspects of rehearsal responsible for these effects also were investigated.

There are developmental changes during childhood in various processing mechanisms that assist in memory for speech. Our knowledge of these processes often is not extensive enough to determine which mechanisms account for the developmental changes observed in a particular memory task. An important example is the phonetic similarity effect first observed by Conrad (1971), who presented children with series of pictures with names that sounded similar (e.g., bat, bar, car, etc.) or dissimilar (e.g., fish, clock, spoon, etc.). School-aged children remembered series of pictures with dissimilar names much better than series with similar names, whereas for preschool children the similarity of the names made much less difference. (Younger children's memory performance also was poorer overall, so the developmental change was primarily an increase in memory for dissimilar lists.) Conrad suggested that the observed age differences resulted from the development of some form of covert verbal labeling of the pictures, which presumably is more mnemonic value when the items' names are dissimilar. Conrad's results were replicated by Holme (1984) in an experiment in which the stimuli were spoken without accompanying pictures. These experiments, however, provided no direct support for the suspected role of covert speech.

A study conducted by Hayes and Rosner (1975) with 4- and 5-year-old children suggested that the developmental change in the effects of phonetic similarity might result from an increase with age in the amount of cumulative rehearsal of list items (i.e., a particular type of covert speech). Hayes and Rosner used a procedure similar to that used by Conrad (1971), except that two verbal training conditions were included. In one of these, the child learned to name each picture only once as it was presented. In the other, the child learned to rehearse the items cumulatively; all of the items already presented were named whenever a new item was presented. A phonetic similarity effect was observed in the rehearsal condition, but not in the label-once or control conditions.

Although these results suggest that the development of rehearsal may underlie increases with age in the phonetic similarity effect, the observed effect of rehearsal training conceivably could be misleading. It is possible that young children are deficient in some other memory mechanism but that trained rehearsal somehow compensates for the true deficiency. Alternative memory mechanisms are not entirely hypothetical: developmental changes have been observed in studies of auditory memory (Cowan, Suomi, & Morse, 1982; Irwin, Ball, Kay, & Stillman, 1985; Sipe & Engle, 1986) and speech representation (Cowan, Braine, & Leavitt, 1985; Cowan & Kibbés, 1986; Morais, Carey, Alegria, & Bertelson, 1979; Read, 1978; Treiman, 1985). The trained rehearsal may act to strengthen the representation in one of these passive types of memory, even if older subjects would not need to rehearse in order for a stronger speech representation to be formed.

Convergent evidence on the role of covert speech in memory within older subjects would help to resolve this question, and in the present study we examined one such source of evidence. Covert speech processes in adults can be blocked with a technique termed "articulatory suppression" (Murray, 1967). In this technique, the subject repeats a single word or phrase while trying to learn a list of words. In the most relevant of these studies, Murray (1968) and Peterson and Johnson (1971) presented visual and auditory series of rhyming or nonrhyming letters for serial recall, with or without articulatory suppression concurrent to the presentation. They found that there was a detrimental effect of phonetic similarity with either visual or auditory presentation of the letters. This effect was eliminated by articulatory suppression when the lists were