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Short-term recognition memory for single letters and phonemic similarity of retroactive interference

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SHORT-TERM RECOGNITION MEMORY FOR SINGLE LETTERS AND PHONEMIC SIMILARITY OF RETROACTIVE INTERFERENCE

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Copying 12 letters produces more retroactive interference in recognition memory for a single letter when the interference letters possess a vowel sound in common with the letter to be remembered than when they do not. Compared to interference lists that do not include the presented letter, inclusion in the interference list of the letter to be remembered improves recognition memory when the other interference letters have no vowel sound in common with the letter to be remembered, but not otherwise. False recognition rates are greater when the test letter contains a vowel sound in common with the presented letter than when the vowel sounds of these two letters are different. The findings are in complete accord with analogous findings for short-term recall and indicate that short-term recognition memory uses the same phonemic-associative memory system as short-term recall.

Introduction

Recent evidence suggests that letters, digits and words are coded in short-term memory, not as atomic units, but as combinations of vowel and consonant phonemes. Conrad (1964) established that letters whose pronunciation ends in "ē" (B, C, P, T, V) tend to be confused with each other in recall and letters whose pronunciation begins with "ĕ" (F, M, N, S, X) tend to be confused with each other in recall. This was true even though the letters were presented visually at a rate of 0·75 sec./letter under conditions where the probability of perceptual error was known to be negligible. Wickelgren (1965*b*) replicated these findings for "ē" and "ĕ" letters under somewhat different conditions and found the same relationship between acoustic similarity and intrusion errors for other vowel and consonant similarities. The relationship between acoustic similarity and intrusions occurred not only in intrusions of letters for letters, but also in intrusions of letters for digits and digits for letters.

A second line of evidence in support of the functional importance of phonemic coding in short-term memory is a study by Conrad and Hull (1964) which found that lists of letters with a common vowel sound were more difficult to recall than lists of letters with different vowel sounds. Similar results were obtained with lists of words of similar versus dissimilar pronunciation (Conrad, 1963).

The functional significance of phonemic units in short-term memory is further supported by the finding that proactive and retroactive interference in short-term recall are affected by the acoustic similarity of the interfering material. Wickelgren (1965*a*, 1966) found that an interference list containing no letters in common with the correct letter(s) produced greater interference if the interference letters had the same vowel sound ("ē" or "ĕ") as the correct letter(s) than if the interference letters had a vowel sound different from the correct letter(s). The findings of these studies were interpreted in support of the hypothesis that there is only one internal representative of any particular phoneme in short-term memory, regardless of the number of times that phoneme is presented in the same or other letters. Thus, there is only one internal representative of "ē" and only one internal representative of "ĕ."

When any "ē" letter (B, C, D, E, G, etc.) is presented, this one internal representative of "ē" is activated, along with the internal representative of whatever consonant accompanied the vowel "ē."* According to this theory it is clear why an interference list composed of "ē" letters should produce more retroactive interference in the recall of other "ē" letters than an interference list composed of "ĕ" letters, and vice versa. If the interference list activates the same vowel representative as the original list, then associations will be formed between this vowel representative and consonant representatives in both the original and interference lists, and these associations will compete with each other. If the interference list activates other vowel representatives, this type of associative interference will not occur.

It seems difficult to account for the present findings and previous findings on phonemic similarity without assuming that items are coded in short-term memory as sequences of phonemes, at some level of analysis. Naturally, we cannot say from these data whether the phoneme is the ultimate unit of coding in short-term memory. The results of Miller (1956) and Miller and Nicely (1955) indicate that in auditory recognition of vowels and consonants there is a level of analysis beyond the phonemic level, namely distinctive feature analysis. It may be that the distinctive feature is also a more basic unit of coding in short-term memory, and perhaps there are levels of analysis even more basic than distinctive features. The present findings indicate only that, whatever the most basic units are, these basic units combine to represent phonemes, which in turn combine to represent letters, digits, words, etc.

All of the previous studies of acoustic similarity and short-term memory have studied recall. The purpose of the present study is to determine if analogous effects of acoustic similarity can be established for short-term recognition memory. This is motivated by two hypotheses: first, the phonemic coding hypothesis just discussed and second, the hypothesis that recall and recognition are two different ways of using the same memory system.

Although it may seem natural to assume that the trace used in recognition is no different than the trace used in recall, this is not a logical necessity. There are at least two ways in which the underlying trace might differ for recognition and recall. First, if a subject knows prior to learning what the retention test will be, he may store items differently. Second, whether or not he knows the retention test in advance, traces may always be established in several different memory systems, one of which is used in recognition and another of which is used in recall.

Existing evidence supports the hypothesis that recognition and recall use the same memory system. Number of presentations, proactive interference and retroactive interference affect recognition memory in the same way that they affect recall (Egan, 1958; Peixotto, 1947; Postman, 1952; Florès, 1960; Shepard and Teghtsoonian, 1961). However, there are several, rather different, procedures for studying recognition, and one should be cautious in generalizing results from one procedure to another. It may make some difference whether one is asked: "Did you ever see this item before?", "Did you see this item in that list you saw at such and such a time?", "Which one of these *n* items was in that list you saw at such and such a time?". "Which ones of these *n* items were in that list you saw at such and such a time?", "Which of these two items did you see more recently?", etc.

The present experiment on recognition memory used the question, "Did you see this item in that list you saw before the interference list?", and the list before the interference list consisted of just one letter. In addition, subjects were required to indicate the confidence they had in their "yes-no" decision on a five-point rating

* Complex syllabic nuclei, such as ē (|iy|), will be called phonemes in this paper.

scale. This procedure enables one to compute nine points of a "memory operating characteristic" (MOC curve) for each recognition condition and thus control for differences in false recognition rate when studying correct recognition rate. Rather extensive discussions of the use of the operating characteristic in studies of recognition memory are to be found in Egan (1958) and Norman and Wickelgren (1965).

Method

Procedure

The procedure for each trial was as follows: One sec. after a ready signal, a single letter was presented, followed after 0·5 sec. by a tone and then the interference list of 12 letters presented at the rate of 0·5 sec./letter. The interference list was followed by a tone and, after 0·5 sec., by a single letter, to which subjects were to respond "yes," if they thought the test letter was identical to the originally presented letter, and "no," if they thought the test letter was different from the originally presented letter. Subjects were also instructed to indicate confidence in their decision on a five-point scale, where "5" meant "most confidence" and "1" meant "least confidence." The presented letter, the 12 interference letters, and the test letter were to be copied as they were being presented. The presented letter was to be covered immediately after being copied. Subjects were given 10 sec. in which to make their decision and indicate their confidence, so a trial required about 20 sec., followed immediately by the next trial. The entire experiment was recorded on tape and lasted approximately 50 min.

Design

There were 36 conditions in the experiment. Two types of presented letters were used, "ē" letters (B, C, D, E, G, P, T, V, Z-pronounced "zee") and "ĕ" letters (F, L, M, N, S, X). Three types of test letters were used: (1) the presented letter, (2) a different letter, from the same acoustic class as the presented letter, and (3) a different letter, from the other acoustic class (different class). Six types of interference letters were used: (1) same acoustic class as presented letter, presented letter not included; (2) different acoustic class from presented letter, presented letter not included; (3) both acoustic classes (six of the interference letters from the "ē" class and six from the "ĕ" class), presented letter not included; (4) same acoustic class as presented letter, presented letter included at least once; (5) different acoustic class from presented letter, except that the presented letter was included at least once; (6) both acoustic classes, presented letter included at least once. Subject to the above restrictions, the interference sequences were constructed by drawing randomly with replacement from the populations indicated in the definition of the conditions.

Subjects were 38 M.I.T. undergraduates taking psychology courses who participated in the experiment as part of their course requirements. Subjects were run in three approximately equal groups; every subject being tested in all 36 conditions. Conditions were randomly ordered in blocks of 36 trials, and there were four blocks in the experiment, for a total of 144 trials.

Analysis

Let us consider a rather general two-stage model of the recognition process in which both a memory and a decision system operate to determine the response. All items, presented or not presented, are assumed to be characterized by a real-valued strength in memory. The decision system maps these strengths on to responses by comparing the strength of the test item with some criterion value. Items that exceed the criterion receive a response of "yes," otherwise they are assumed to be non-presented items and receive a "no" response. According to this reasoning, false recognitions contain valuable information. By forcing the subject to vary his bias (and thereby his criterion strength) while holding the presentation conditions constant (and, hopefully, holding constant his memory of the items), one can trace out the relative strengths of the distributions of presented and non-presented items. The relation between correct and false recognition rates will be referred to as the memory operating characteristic (MOC curve), which is directly analogous to the receiver operating characteristic (ROC curve) in signal detection theory.

In the binary choice experiment just described each point must be obtained in what is essentially a separate experiment in which the subject's bias to say "yes" is manipulated by changing his instructions or pay-offs. Fortunately, a more economical technique has been developed (Egan, Schulman and Greenberg, 1959; Pollack and Decker, 1958). After making his binary decision a subject can indicate his confidence in that decision on a rating scale. We interpret his confidence as a direct reflection of the strength of the item along a unidimensional scale from a "most confident yes" to a "most confident no." This permits us to get several points of the operating characteristic in one experiment.

To each test item a subject must respond with one of ten decision-confidence pairs. Let $i = 1, 2, \ldots, 5, 6, \ldots, 10$ represent "yes" with confidence "5" (greatest confidence), "yes" with confidence "4," ..., "yes" with confidence "1" (least confidence), "no" with confidence "1," ..., "no" with confidence "5." Let $f_i(x)$ represent the total frequency (over all four blocks and all 38 subjects) with which response i occurred in condition x. Let $r_i(x) = f_i(x)/\sum_{i=1}^{10} f_i(x)$ represent the relative frequency with which response i occurred in condition x. Let $R_i(x) = \sum_{j=1}^{i} r_j(x)$ represent the cumulative relative frequency with which responses 1 through i occurred in condition x. The MOC curve is a plot of $R_i(x)$, the (correct) recognition rate for some condition in which the test item is the same as the presented item, against $R_i(y)$, the (false) recognition rate for some condition in which the test item is different from the presented item.

In common sense terms, it is relatively meaningless to compare conditions with respect to correct recognition rate (correct "yes" responses) unless you also compare the conditions with respect to false recognition rate (incorrect "yes" responses). If one can obtain correct recognition rates for several different values of the false recognition rate, then one can plot an MOC curve for a condition and compare that curve to the MOC curve for another condition. If one curve lies above the other curve, then recognition memory is better in the condition with the higher MOC curve. The confidence judgement technique allows one to determine one point on the MOC curve for each possible cut-off along the decision-confidence continuum. In this experiment there are ten decision-confidence pairs, hence nine cut-offs and nine points on the MOC curve for each condition.

Results

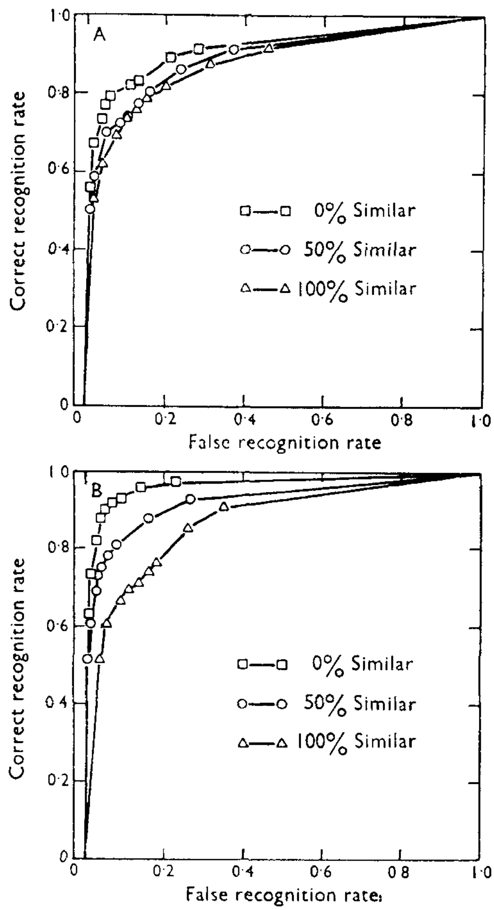
Similarity of interference letters

The most appropriate estimate of the false recognition rate for each of the interference conditions comes from the condition in which the test item is different from the presented item, but from the same acoustic class. Using the condition in which the test item is from a different acoustic class would be confounded by possible differences in the false recognition rate for different classes of letters. Therefore, throughout this section "false recognition rate" will mean the "false recognition rate for the condition in which the test item is different from the presented item, but from the same acoustic class."

Figures 1A and 1B plot the correct recognition rate against the false recognition rate (MOC curve) for each of the six interference conditions averaged over the two presented letter conditions. Figure 1A contains the MOC curves for the three conditions in which the presented letter never occurred in the interference list; Figure 1B contains the MOC curves for the three conditions in which the presented letter occurred at least once in the interference list. In both Figures 1A and 1B recognition memory is superior when the retroactive interference is composed of acoustically different letters than when it is composed of acoustically similar letters. In both cases the condition with half similar and half different letters is intermediate in recognition memory performance. Retroactive interference in short-term recognition memory is clearly a function of the acoustic similarity of the interfering materials, the relationship being greater interference with more similar material.

Unfortunately, no statistical test has been developed to determine if two operating characteristics are significantly different. However, it is possible to give an approximate idea of the reliability of the difference between two operating characteristics by applying the Kolmogorov-Smirnov two-sample test to the correct recognition rates at equal false recognition rates. This is not completely valid since it does not take into account the error in estimating the false recognition rates. Fortunately, all the paired comparisons are in the same direction, and many of them are highly significant by this test. In Figure 1A, the 0 per cent. similar condition has a significantly greater correct recognition rate than the 100 per cent. similar condition at equal false recognition rates ($D = 0{\cdot}14$, $p < 0{\cdot}01$, two-tailed), but the other two paired comparisons are not significant. In Figure 1B, the 0 per cent. similar condition is significantly superior to the 50 per cent. condition ($D = 0{\cdot}13$, $p < 0{\cdot}01$, two-tailed), the 50 per cent. condition is significantly superior to the 100 per cent. similar condition ($D = 0{\cdot}24$, $p < 0{\cdot}001$, two-tailed), and of course, the 0 per cent. versus 100 per cent. comparison is significant at well beyond the 0·001 level.

FIGURE 1



MOC curves for single letters after copying 12 interference letters that were 0 per cent., 50 per cent. or 100 per cent. similar to the letter to be remembered. In A the letter-to-be-remembered never appeared in the interference list. In B the letter-to-be-remembered appeared at least once in the interference list and was counted as a "similar" letter. "Similar" letters had a vowel phoneme (ē or ĕ) in common with the letter-to-be-remembered; "different" letters had no phoneme in common with the letter-to-be-remembered.

Comparing the curves in Figure 1A with those in Figure 1B demonstrates that including the presented letter in an interference list composed of acoustically different letters improves later recognition memory, but including the presented letter in an interference list composed of acoustically similar letters is of little or no benefit to later recognition memory. The mixed interference is again intermediate. These results may be explained as follows. First, the occurrence of the presented item in the interference list very likely aids later recognition memory only when subjects recognize it as the presented letter at the time of its occurrence in the interference list. Second, recognition of the presented letter is more likely after different letters than after similar letters, as already established. Viewed in this manner, the comparison of Figures 1A and 1B provides further support for the hypothesis that retroactive interference in recognition memory is a direct function of acoustic similarity.

Similarity of test letter

Table I presents the cumulative false recognition rates for the similar and different test letter conditions, averaged over the two presented letter conditions and the six interference conditions. A chi-square test on the frequency of "yes" versus "no" responses in the two false recognition conditions is significant at the 0·01 level ($\chi^2 = 9{\cdot}27$). Since all letters are equally probable in the two conditions, when

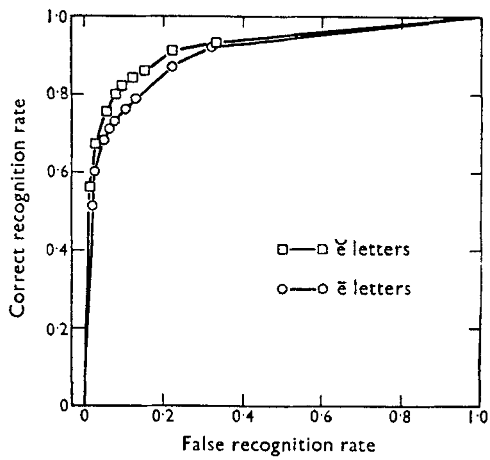
TABLE I

Cumulative False Recognition Rates for Similar and Different Test Letters

($R_i(x)$ in percentage)

	Y5	*Y4*	*Y3*	*Y2*	*Y1*	*N1*	*N2*	*N3*	*N4*	*N5*	N
Similar	1·6	2·8	5·2	7·0	8·6	11·3	14·1	22·0	32·8	100	1740
Different	0·6	1·7	3·2	4·4	5·9	7·8	11·5	18·6	28·9	100	1793

FIGURE 2



MOC curves for "ē" letters and "ĕ" letters.

averaged over all values of the other two variables in the experiment, we cannot attribute this result to intrinsic differences in false recognition rate for different letter classes. Thus we conclude that a test letter possessing a vowel phoneme in common with the presented letter is more likely to be falsely recognized than a test letter possessing no phoneme in common with the presented letter.

Nature of the presented letter

Figure 2 presents the MOC curves for "ē" letters and "ĕ" letters, averaged over the six interference letter conditions and using test letters from the same acoustic class to estimate the false recognition rate. Recognition memory for "ĕ" letters is clearly better than recognition memory for "ē" letters. This is in line with the finding of Wickelgren (1965*a*) that free recall is better for "ĕ" letters than for "ē" letters. This result might be due to the size of the confusion class or countless other factors, and nothing more definite can be said.

Discussion

In recall, the memory system, acting on whatever cues are given, must produce the test item. In recognition, the memory system, acting on the test item, must produce a "yes-no" decision. The stimulus conditions of the original presentation can be identical in the two cases. The stimulus conditions at the time of retrieval are obviously different in the two cases. The question presently at issue is whether the same memory system is used to produce above-chance performance in both cases. To the extent that recall and recognition memory are affected in the same manner by the same variables, it is parsimonious to assume that both use the same system.

The present experiment establishes that the acoustic similarity of retroactive interference affects short-term recognition memory in the same way that it affects short-term recall, namely, greater interference from similar material than from different material.

Finding that an acoustically similar test item produces more false recognitions than an acoustically different test item is analogous to the finding in recall experiments that intrusions tend to be acoustically similar to the correct item (Conrad, 1964; Wickelgren, 1965*b*). One could say for both recall and recognition memory that false positives tend to be acoustically similar to the correct item.

Finally, "ĕ" letters are remembered better than "ē" letters under either the recall or recognition testing procedures. Every possible comparison between the results of this experiment and previous experiments on recall supports the hypothesis that short-term recall and recognition use the same memory system.

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