Does familiarity affect transfer from an iconic to a short-term memory?*

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Six Ss discriminated seven-letter nonsense words from comparison words. Target and comparison words differed on randomly selected trials by one randomly chosen letter. Target words were displayed for 50, 55, 60, 70, 90, or 200 msec, and were preceded and followed by a masking field. In one condition the Ss were familiarized with the comparison words, and in another they were not. Discrimination was better for familiar words at all display durations. There was an interaction between familiarity and the letter position effect. For unfamiliar words the typical bow-shaped position effect occurred. For familiar words no marked position effect occurred. An identification condition using unfamiliar words found no interaction between letter position and display duration. The results are interpreted as evidence that familiarity removes a letter position effect that depends upon serial transfer from a nonmaskable mediating visual representation that is constructed from a maskable representation by nonserial processes.

The processing of briefly available visual displays has been described as involving a brief (Sperling, 1960), maskable (Sperling, 1963), visual memory, called the icon by Neisser (1967). A serial transfer process is thought to operate upon the icon to produce a verbal short-term memory (STM), which is not susceptible to visual masking and which can be maintained by rehearsal.

Two aspects of performance that have been taken to reflect properties of the transfer process are letter position effects and the backward masking effects produced by visual noise. If a sequence of letters is briefly displayed across the fixation point, accuracy of report is highest for letters on the left. It decreases regularly across the word and improves slightly for the rightmost letters (Crosland, 1931). There is a considerable amount of evidence that such position effects are related to the order in which material is transferred (Heron, 1957; Harcum, 1967). It is not clear, however, whether these effects occur because the transfer process fails to reach some material (Neisser, 1967) or because later loss is a function of transfer order (Harcum, 1967). If the display is followed by a visual noise field, performance rises from chance to about five letters as the duration between the onsets of target and noise rises from about 20 to 100 msec. Thereafter performance increases little with increases in duration (Sperling, 1963). The upper limit is explained as due to limitations of STM. Performance below this level at brief durations is explained as due to a reduction in the amount of material entered into STM. It is still not clear to what extent such reduction is due to interruption of transfer (Liss, 1968), and to what extent to degradation of the target display by integration (Eriksen & Steffy, 1964). In either case, however, the rising section of the backward masking function is taken to indicate the amount of material accurately transferred.

On the above account, characteristics close to the physical properties of the display, such as brightness distribution, are represented in the icon, whereas figural identity is represented in STM. Transfer thus includes pattern-recognition operations, and this suggests that transfer may depend upon the familiarity of the patterns displayed. Two specific predictions will be considered here. The first is that familiarity affects the size of the units transferred and, thus, the letter position effect. The second is that familiarity affects the rate at which information is transferred and, thus, performance on the rising section of the backward masking function.

Evidence for the latter prediction is given by Mewhort, Merikle, and Bryden (1969). Using pseudowords of eight letters, they showed that the rising section of the backward masking function depends upon the order of approximation to English of the words used. This evidence is not conclusive, however, as guessing was not controlled. It is important that it should be, because the case for taking the rising section of the backward masking function to show the efficiency of transfer is weakened if performance can be improved by guessing after transfer. The present experiment studies the effect of familiarity on the backward masking function and on the letter position effect when strict control is placed on the degree of visual resolution required to make a correct response.

METHOD

A word discrimination technique, similar to that of Earhard and Fullerton (1969), was used. The S's task was to discriminate a briefly presented word from a comparison word. All words were pronounceable nonsense words of seven letters, in which consonants (C) and vowels (V) alternated to give the form CVCVCVC. Target and comparison words differed on randomly selected trials, when one randomly chosen letter in the target word was changed to another chosen at random (with the restriction that the form CVCVCVC was maintained). The probability of a difference was .5. The comparator word was displayed soon after the brief display of the target word. This procedure has two advantages. First, the S can be told the comparator prior to the target display, but he need not be. Second, the S makes his judgment while looking at the comparator word. Performance is, therefore, likely to depend only on the S's knowledge of the target word. A typical display sequence for word discrimination is shown in Fig. 1. The S fixated a red

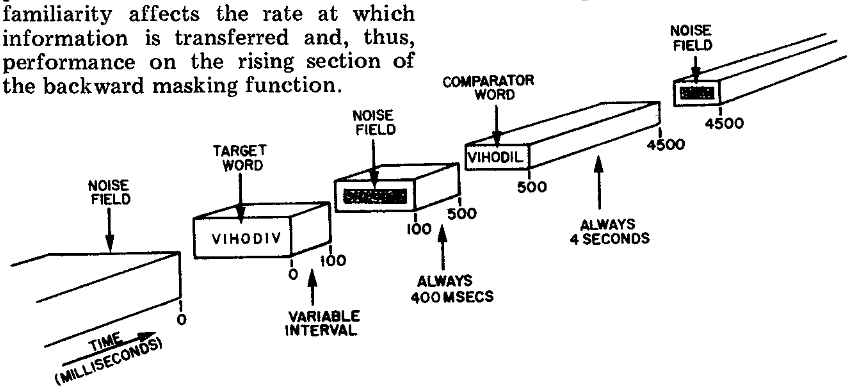

Fig. 1. The display sequence for word discrimination when the target display duration was 100 msec.

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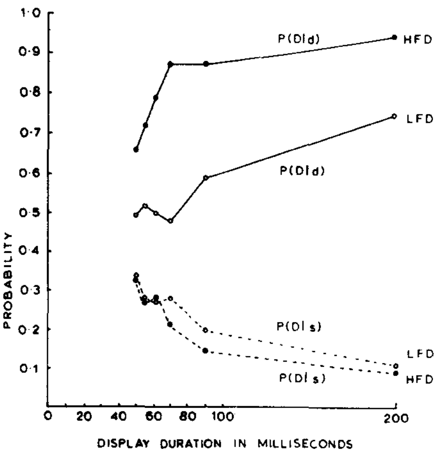

Fig. 2. Hit rate and false alarm rate as a function of target display duration for high- and low-familiarity discriminations.

dot at the center of a noise field and triggered the onset of the display sequence when ready. First, the target word was displayed across the fixation point for 50, 55, 60, 70, 90, or 200 msec. The visual noise field was then displayed for 400 msec. With no interstimulus interval, target display duration is synonymous with stimulus onset asynchrony, thought to be the important temporal variable in such tasks (Kahneman, 1968). Finally, the comparator word was displayed for 4 sec. The S was required to say either "same" or "different" on every trial. The response was recorded by E on a score sheet, which showed also whether the words were the same or different and, if different, by which letter.

Two conditions of familiarity were used. In the low-familiarity condition, the comparator word was selected at random from the $20^4 \times 5^3$ possible CVCVCVCs, and a new selection was made each trial. Thus, S knew only that the words would have the form CVCVCVC. In the high-familiarity condition, words with which the S had been familiarized were used. One comparator word was used each session. Before each session S was given the comparator word and seven variations on it, and was asked to learn them. The variations were formed by changing each of the letters of the comparator word in turn to another letter chosen at random (except that the form CVCVCVC was maintained). Thus, in this condition, the words used were familiar and the comparator word was known in advance.

A low-familiarity identification condition was also included. As previous studies have related the effects of duration and letter position to identification, it is important to determine whether or not identification and discrimination are comparable in these respects. Randomly selected words of the form CVCVCVC were displayed in the same way as were the target words in the discrimination conditions, except that the comparator word was omitted. The Ss identified the word by writing a letter in each of seven cells. They were required to write a letter in every cell on every trial, writing only consonants in Cells 1, 3, 5, and 7 and only vowels in Cells 2, 4, and 6.

The experiment, therefore, involved three conditions: low-familiarity discrimination (LFD), high-familiarity discrimination (HFD), and low-familiarity identification (LFI).

Stimuli

All words were made by random selection of letters to give the form CVCVCVC. The letter "Y" was not used. Such words are pronounceable, but S cannot guess letters at rates better than chance. For the discrimination conditions, each S made 120 discriminations at each display duration. For the LFD condition this required 720 word pairs. The same 720 pairs of words were used for all Ss. For the HFD condition, one comparator word was used per S per session, thus requiring 36 randomly chosen comparator words and their variations. For the LFI condition, each S made 60 identifications at each duration; 360 words were constructed, and each S saw each word once. All words were printed in capitals by a Varityper Headliner, Model 840, and photographed. Typemaster ML-V1250 was used, giving high-contrast 12-point print.

The noise field was letters and parts of letters scattered across an area 1.8 in. wide and 1.3 in. high. The contrast ratio and density of letters was such that, when noise and target fields were shown concurrently for a few seconds, the target word could not be read. A small red dot at the center of the noise field served as the fixation point.

Apparatus

The optical system was that of a Takei three-channel tachistoscope, Model 202. The required display sequences were produced by an Iconix waveform generator, Model 5656. In two channels, material was seen in normal orientation and in the third—the noise field—in mirror reversal. Viewing was binocular through partially silvered glass. The stimulus in each of the channels was at the center of an illuminated white screen and at a distance of 31.5 in. from the viewing aperture. Illumination of the noise and comparator fields was 44 lumens/sq ft, as measured by a Weston photometer. Illumination of the target field was 22 lumens/sq ft.

Subjects and Procedure

The Ss were six undergraduates studying psychology at the Australian National University. They volunteered to act as paid Ss. All had normal or corrected vision. For each S there was one practice session and six experimental sessions. In the practice session, S was acquainted with the situation and with the specific tasks to be performed. The experimental sessions began with a 5-min practice period. In each session S made 120 discriminations in each of the discrimination conditions, and 60 identifications in the LFI condition. Conditions were counterbalanced across Ss; for each session each possible order of the three conditions occurred, with one order per S. For each S conditions were given in a balanced order (ABCCBA), both within and across sessions. Display durations within conditions were in either ascending or descending order, alternating on each change of condition. At the end of each block of 10 discriminations, S was told how many judgments had been correct. He was not told on which trials errors had occurred.

RESULTS

Backward Masking

Performance in the two discrimination conditions can be described by P(D | d), the proportion of times that S said, "Different," when the words were different, and by P(D | s), the proportion of times that S said, "Different," when the words were the same. The mean values of these proportions over all Ss are shown in Fig. 2. Each proportion is the result of about 60 trials per S. Performance clearly depends upon both display duration and familiarity. At every display duration, P(D | d) is significantly greater under the HFD condition, at least at the .001 level, as shown by tests for the significance of the difference between proportions. P(D | s) was less affected by familiarity but, across all durations combined, was significantly less under the HFD condition ($Z = 2.31$, $p < .05$).

Broadbent (1967) has suggested that the frequency effect for English words can be explained in terms of signal detection theory (Green & Swets, 1966). He suggests that the frequency effect is due to a lower criterion (β) for saying that the target is a frequent word, and not to a change in signal detectability (d'). This theory is often applied to complex stimuli, on the assumption that they

Table 1
The Mean Values of d′ and β Over All Ss

	Condition			
	LFD		HFD	
Duration	d′	β	d′	β
50	.40	1.11	.90	.98
55	.66	1.22	1.25	.98
60	.66	1.23	1.45	.91
70	.52	1.18	2.08	.77
90	1.12	1.51	2.36	1.24
200	1.90	1.96	3.14	.72

are mapped onto an axis monotonic with likelihood ratio. If this is so, and if the underlying distributions of signal (occurrence of a difference in the present case) and noise (no difference) are normal, then they will have equal variance. On these assumptions, values for d′ and β can be calculated from P(D | d) and P(D | s). Values of d′ and β were calculated for each S separately, and the means of these are given in Table 1. At every duration, d′ is significantly greater under the HFD condition, at the .05 level at least, as shown by t tests for the significance of the difference between means. Over all durations combined, β is significantly less under the HFD condition, at the .05 level. Thus, Ss had a lower criterion for saying that the target was not the comparator word in the HFD condition. Under the conditions of this experiment, therefore, Ss had a higher criterion for saying that the target was a comparator word with which they had been familiarized than for saying that it was a comparator word with which they were unfamiliar.

To determine whether or not the slope of the backward masking function is affected by familiarity, two measures of performance at the four briefest durations were analyzed. A two-way analysis of variance (Duration by Condition, with Ss as replications) was performed on P(D | d) − P(D | s) and on d′. In both of these analyses, the main effects of duration and condition were all significant at the .01 level. For the measure P(D | d) − P(D | s), the interaction of Condition by Duration was significant [$F(3,40) = 4.04$, $p < .05$]. This interaction was also significant for d′ [$F(3,40) = 5.73$, $p < .01$]. Discrimination performance, thus, increases at a faster rate with increases in display duration for familiar than for unfamiliar material.

For the LFI condition, the number of letters correctly identified, position not being taken into account, was determined and corrected for chance. The means of these scores over all Ss are shown in Fig. 3. Comparison of discrimination and identification performance indicates that both methods agree in locating the rising

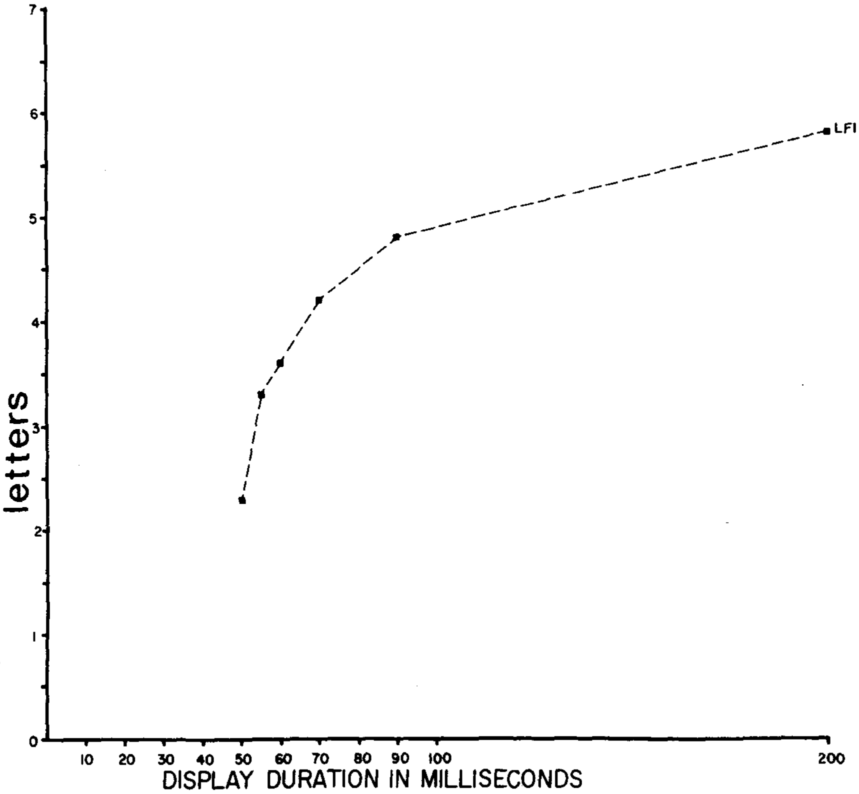

Fig. 3. The number of letters identified as a function of target display duration in the low-familiarity identification condition.

section of the backward masking function at between 40 and 100 msec.

Letter Position

Letter position effects were examined at the display durations of 50, 55, and 60 msec. Probabilities of identification (IPr) or discrimination (DPr) at each letter position were calculated from performance over the three durations combined. For the discrimination conditions, this probability was calculated from $P(D \mid d_i)$, the proportion of times that S said, "Different," when a change occurred at the i^{th} position, corrected for chance success by the formula

$$DPr = [P(D \mid d_i) - P(D \mid s)]/[1 - P(D \mid s)].$$

For the identification condition, $P(I_i)$, the proportion of correct identifications at the i^{th} position, was calculated and corrected for chance success by the formula

$$IPr = [N_i \cdot P(I_i) - 1]/(N_i - 1),$$

where N_i is 20 for the consonant positions and 5 for the vowel positions.

The mean probabilities of identification and discrimination over all Ss are shown in Fig. 4. An analysis of variance (Condition by Position by S) was performed on these probabilities. The condition and position effects are significant at the .01 level. The S effect is not significant. The Condition by Position interaction is significant at the .01 level. For unfamiliar words the typical bow-shaped position effect occurred under both identification and discrimination conditions. For familiar words, however, no marked letter position effect occurred.

The results given in Fig. 4 show performance under the LFI and LFD conditions to be at about the same

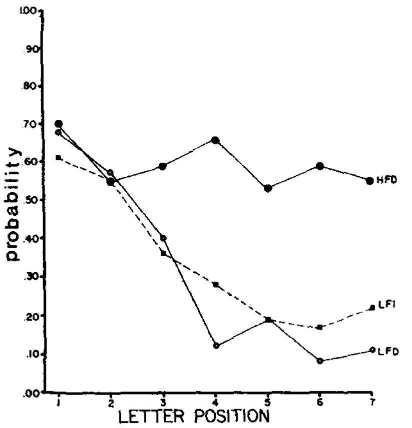

Fig. 4. Probability of identification (LFI) or discrimination (LFD and HFD) as a function of letter position.

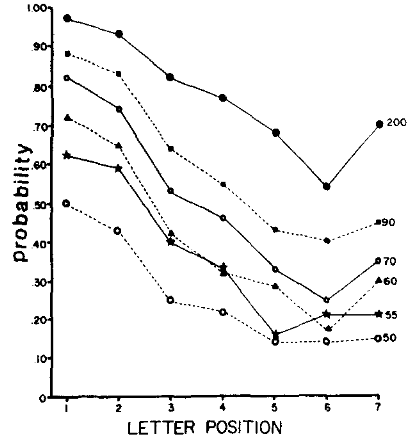

Fig. 5. Probability of identification in the LFI condition, with target display duration in milliseconds as the parameter.

level. It is unclear what conclusions can be drawn from this, because comparison of absolute levels of performance across these conditions depends upon the guessing corrections used, and the status of the various possible corrections in relation to the tasks used has not yet been satisfactorily clarified. This does not obscure the significance of the Position by Condition interaction, as the guessing corrections used affect all positions equally.

Performance at the three shortest durations was combined for the above analysis because there was insufficient data in the HFD and LFD conditions for analysis of position effects at each duration separately. There might, however, be important changes in the position effect as a function of display duration. The interaction of position and duration was, therefore, examined for the LFI condition, for which sufficient data was available. The mean scores over all Ss for each duration and position are shown in Fig. 5. There appears to be no interaction between display duration and position over the range of durations studied. An analysis of variance performed on the LFI data showed that, while the effects of duration and position are highly significant, their interaction does not approach significance [$F(30,210) = 0.796$, $p > .05$]. This result, which is similar to a finding reported by Sperling (1967), seems to have important implications for interpretations of backward masking.

DISCUSSION

The two discrimination conditions differed only in what the Ss knew about the stimulus words prior to presentation. Performance was far better under the HFD condition. There seems to be no way in which this improvement can be due to guessing. No change in guessing strategy, response bias, or criterion would seem able to produce both an increase in hit rates and a decrease in false-alarm rates. Earhard and Fullerton (1969), using a similar word discrimination technique, found no substantial effect of prior experience. They concluded that repetition has only a slight effect on perception when control is placed on the degree of visual resolution required to make a correct response. A possible reason for the difference between the two studies is that Earhard and Fullerton's Ss were given far less experience of the comparator word than were Ss in the present experiment. Further evidence on the prior knowledge required for the effect to occur is reported in Phillips.[1]

The difference in prior experience between familiar words and unfamiliar words in the present experiment is not the same as that between frequent and infrequent English words. Broadbent's suggestion that prior experience changes only the criterion may therefore hold for the frequency effect, though not for the effect studied here.

As predicted, familiarity affects both the letter position function and the backward masking function. The results, however, cast doubt on the view that this is to be interpreted in terms of transfer directly from an iconic to a short-term memory. Assume that transfer does involve a process scanning a visual representation, and consider the effect of masking this representation, after various durations, by a visual noise field. As the display duration decreases, there will come a time, dependent on the scan rate, when the representation will be masked just before the scanning process reaches the last letters. At this duration recognition of the letters scanned last would deteriorate, but recognition of the letters scanned first would be unaffected. With further decreases in display duration there would be a progressive change in the positions affected, and this change would be in the reverse direction of the scan sequence. Even if the position effect is not due to transfer interruption, but does depend upon transfer order, a position-duration interaction would occur if the noise acts by interfering with the representation from which material is being transferred. The results shown in Fig. 5, and those of Sperling (1967), give no indication of such an interaction. They therefore cast doubt on the view that the representation that is masked is also the representation from which transfer is serial.

The results thus suggest at least two kinds of information loss in word recognition under backward masking: a loss that depends on letter position and a loss that does not depend upon letter position but does depend on display duration prior to masking. These considerations seem to imply that transfer from iconic to short-term memory is mediated by a nonmaskable visual representation. The evidence for both backward masking (Kahneman, 1968) and serial transfer (Harcum, 1967) is strong. If they cannot operate upon the same visual representation, then two distinct visual representations must be assumed. The duration-dependent loss is then explained as due to interference with information in the icon. The processes that operate upon the icon to construct a nonmaskable visual representation are assumed to operate in a nonserial manner. Masking therefore affects all letter positions equally. The letter position effect is explained as depending on a serial order imposed at transfer from the mediating representation. It could be due either to loss of information from the mediating representation or to subsequent events. Further evidence for a nonmaskable visual memory is reported by Phillips and Baddeley (1971) and by Posner, Boies, Eichelman, and Taylor (1969). Their evidence suggests that information in such a memory may be lost within a few seconds.

Returning to the effect of familiarity, the results indicate that one of the ways in which it operates is by removing the letter position effect. Whether the duration-dependent loss is also affected by familiarity is unclear. Both $P(D \mid d) - P(D \mid s)$ and d' increase more rapidly with increases in duration for familiar than for unfamiliar words. On the interpretation just given, this indicates that the mediating representation is set up faster for familiar material. However, the irregularity of performance under the LFD condition weakens this evidence. In addition, Fig. 4 shows that performance on Letter Positions 1 and 2 was no better for familiar than for unfamiliar words. This suggests that familiarity removes only the position-dependent loss.

As the position-dependent loss is assumed to result from treatment of the letters as independent units, these results support the view that familiarity alters the units of processing. This recoding must occur prior to the position-dependent loss, but where that is, is still unclear. As already mentioned, the above results conflict with the view that the loss is due to the interruption of transfer by masking. The similarity of the position effect in the LFI and LFD conditions indicates that the effect is not due to the processes of reproduction. In word identification tasks, reproduction is always sequential, and usually from left to right. The possibility that this might account for the position effect has often been noted (e.g., Crosland, 1931; Hershenson, 1969). This explanation is clearly weakened by the occurrence of the effect in the LFD condition, because in this condition no order of reproduction is involved. The similarity of the LFD and LFI conditions also suggests that the loss occurs soon after presentation. In the LFD condition the comparator word is seen only 400 msec after the target word, but this did not alter the effect. On the other hand, the absence of the effect in the HFD condition suggests that it does not depend upon relatively peripheral input processes such as mutual masking. Lastly, the effect was found to occur at very brief display durations, when less than 2.5 letters were correctly reported on average. This seems to suggest that either the effect is not due to exceeding a capacity limit or the amount of information stored is relatively independent of the amount correct.

In summary, the results provide evidency that familiarity removes a letter position effect that depends upon serial transfer from a nonmaskable mediating visual representation. This mediating representation appears to be constructed from a maskable representation, the icon, by processes which are not serial across letter positions. The position effect appears to occur soon after presentation and appears not to depend upon relatively peripheral input and output processes.

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NOTE

1. W. A. Phillips. Familiarity and predictability in word discrimination tasks. In preparation.

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