Accessing lexical memory: The transfer of word repetition effects across task and modality

DON L. SCARBOROUGH, LINDA GERARD, and CHARLES CORTESE
Brooklyn College of the City University of New York, Brooklyn, New York 11210

Reading by literate adults is generally assumed to represent skill acquired years earlier. However, the present experiments show that aspects of that skill can be readily modified. In two experiments, pronunciation of visually presented common words speeded later recognition of those words. This facilitation of recognition occurred although subjects did not expect word repetition and the task was changed from pronunciation to recognition. In contrast, naming pictures did not facilitate later recognition of visually presented picture names. The occurrence of facilitation when the task was changed and the lack of facilitation when stimulus format was changed suggest that facilitation occurs in the processes of encoding and accessing memory, processes that may change little across tasks but may change substantially with stimulus format changes. This facilitation of recognition occurs automatically without mediation by subjects' expectations. A third experiment indicates that this facilitation of recognition shows little relation to episodic memory.

The importance of familiarity in word recognition is well known. For example, in the measurement of recognition thresholds for tachistoscopically or auditorily presented words, the typical finding is that common words have lower thresholds than rare words (Savin, 1963; Solomon & Howes, 1951). Generally, the distinction between common and rare words is made on the basis of samples of printed English, which are estimates of the normative frequency with which the various words occur in print. That such frequency counts predict threshold effects suggests that familiarity is a function of how often a person has encountered a particular word. However, several recent experiments indicate that a single presentation of words can produce substantial and persistent alterations in the speed with which the words can be recognized. For example, Kolers (1975) has reported that prior presentation of sentences or paragraphs facilitates oral reading speed on a later exposure. D. Scarborough, Cortese, and H. Scarborough (1977) studied the effect of repeated presentations of words, using the lexical decision task (Rubenstein, Garfield, & Millikan, 1970). On a typical trial in this task, subjects see a letter string and they indicate as quickly as possible whether or not the letter string is

a real English word. D. Scarborough et al. (1977) found that word recognition latencies were substantially shorter if the words had been presented earlier. Bartram (1973, 1974) has shown even larger repetition effects for picture naming latencies.

What is striking about these repetition effects is that they represent a kind of persistent one-trial learning phenomenon. For example, Kolers (1976) reported that subjects reread paragraphs faster as much as a year after the initial reading. D. Scarborough et al. (1977) found faster lexical decision latencies to words that had been seen several days earlier. Additionally, these repetition effects show little relation to contextual recognition or episodic memory. That is, paragraph reading speed, or lexical decision speed, can show reliable effects of prior exposure of the stimuli, even though subjects may show little ability to discriminate between repeated and nonrepeated stimuli (Kolers, 1976; D. Scarborough et al., 1977). Thus, a subject's behavior (speed) may show the effect of a single prior exposure of a stimulus, even though the subject cannot say whether the stimulus had been presented before. Such familiarity effects can provide important clues about the recognition process. The present experiments explore some of the limits under which these effects occur.

One possible account of these repetition effects is that they occur in the identification process, that is, the process by which current stimulus information makes contact with a prior representation of the stimulus in memory. When a stimulus is presented, recognition requires encoding and transformation of the stimulus information before memory can be accessed. Brooks (1977) has demonstrated the importance of perceptual coding processes in word recognition. For

This research was partially supported by Bell Laboratories, Murray Hill, New Jersey, and by a Faculty Research Award from the Research Foundation of the City University of New York. This research was conducted while the first author was a guest of the Human Information Processing Research department during a sabbatical leave from Brooklyn College. We wish to thank James Johnston and Saul Sternberg for many helpful comments on an earlier version of this paper. Requests for reprints should be sent to Don Scarborough, Psychology Department, Brooklyn College, Brooklyn, New York 11210.

example, recognizing a visually presented word might require identification of the component letters and organization of the letters into clusters or spelling units (Spoehr & Smith, 1975). If these encoding operations are complex and sufficiently unique to a particular stimulus, the operations may occur more quickly upon a subsequent presentation of the stimulus. Hence, recognition could occur more quickly, although the subject might be unaware of the change (Kolars, 1975). On the other hand, D. Scarborough et al. (1977) proposed that both encoding and memory access are involved in word repetition effects. Their evidence was, in part, as follows. First, they found that pronounceable nonsense words, which have no prior representation in memory, show smaller repetition effects than do real words. Presumably, the initial encoding operations for pronounceable nonwords and words are similar. If the repetition effect occurred only at the encoding level, the repetition effects should have also been similar. Second, they found larger repetition effects for words in a lexical decision task than in a pronunciation task. The lexical decision task requires that the subject locate a word in long-term memory, but the D. Scarborough et al. pronunciation task only required that subjects pronounce the words in a phonologically plausible way, which could have been done without actually recognizing the words. The larger repetition effects that they found in the lexical decision task compared to the pronunciation task probably reflect the additional memory retrieval operations required by the lexical decision task. Finally, D. Scarborough et al. found that low-frequency words benefited more from repetition than did high-frequency words in the lexical decision task, and they proposed that this also reflected the effect of repetition on the process of retrieving specific words from memory. Taken together, D. Scarborough et al. suggested that their results show that the lexical decision task requires more and possibly different kinds of processing than does the pronunciation task, reflecting the difference in the memory requirements of the two tasks. Further, they proposed that the facilitation produced by repetition occurs both in encoding and in lexical access. One implication of this view is that the facilitation produced by repetition effects occur automatically. If so, such repetition effects might occur without awareness or intention on the part of the subject.

Morton (1969, 1970) has proposed one way in which word-frequency effects might occur in memory access. He proposed that each word is represented by a word detector (logogen) that is tuned to the perceptual features of the word. Further, he supposed that each logogen had a threshold that was a function both of the frequency and the recency of the word it represented. Logogens representing common words would generally have low thresholds, and, as a consequence, would be activated easily and quickly by a stimulus. Obviously,

if the threshold of a high-frequency logogen is not lowered as much by presentation of the word as is the threshold of a low-frequency logogen, Morton's hypothesis can provide an account of repetition effects in the lexical decision task.

One important aspect of Morton's (1969, 1970) hypothesis is that a logogen for a particular word is not tied to a specific sensory modality but, rather, sums relevant information in all forms (e.g., auditory, visual, pictorial, contextual; Morton, 1970, pp. 205-206). This characteristic of the logogen model suggests a test of the two-stage account of repetition effects given above. Suppose that presentation of a word modifies both the encoding processes for that word and the word's logogen threshold. Then, if a logogen is first activated by presentation of the word in one form and subsequently activated by presentation of the word in a different form, a repetition effect should be observed, reflecting the change in the logogen threshold produced by the first presentation; but the repetition effect should be smaller than if the form of the stimulus presentation had been kept the same. This follows from the idea that changing the form of the stimulus presentation should eliminate any facilitation in the encoding process, but should still reveal the effects of threshold changes at the logogen level. On the other hand, if the facilitation of lexical access hypothesized by D. Scarborough et al. (1977) occurs in the specific retrieval operations (e.g., search of the lexicon) rather than in terms of a threshold change of a logogen, a change in the stimulus form or modality between presentations should eliminate all repetition effects. The first two experiments reported below were designed to test this hypothesis. The general idea was to see how quickly subjects recognized visually presented words as a function of the prior exposure of the words. Some of the words were initially shown as printed words. For other words, subjects initially saw a picture whose name corresponded to the subsequently presented word. A third set of words had no initial exposure, and this set of words served as the baseline for evaluating the repetition effects. After the initial presentation, all words were then shown as printed words in a lexical decision task.

The experiments below also provide a test of another aspect of the repetition effect. According to the views outlined above, the repetition effects in encoding and memory access should be automatic consequences of word recognition. However, in the experiments reported by D. Scarborough et al. (1977), subjects were aware that stimuli would be repeated. Thus, it is possible that the repetition effects they observed were mediated in some way by the subjects' awareness of the repetitions. For example, subjects might have rehearsed each word during the intertrial interval in an effort to remember it. The present experiments assess whether repetition effects occur automatically without anticipation on the part of the subjects. In the first part of the experiments,

words and pictures were presented without repetitions and subjects were unaware that there would be repetitions. Only after all priming items had been presented once were stimuli re-presented. In addition, the experiments tested whether the repetition effect occurs even if the task is changed between the first and second presentations of an item. The ideas outlined above suggest that repetition effects are a consequence of recognizing a word. However, the data reported by D. Scarborough et al. did not test this assumption, and this leaves the possibility that their repetition effects were task (and response) specific. In the present experiments, subjects simply pronounced words and named pictures upon their first exposure. Transfer of experience was then tested in a lexical decision task requiring manual responses.

EXPERIMENT 1

In outline, the experiment was as follows. There were three sets of concrete words and their corresponding pictures. In the first part of the experiment, a subject saw one of the three sets of stimuli as words to be pronounced aloud. A second set was presented as pictures to be named, and the remaining set of stimuli was not presented. The second part of the experiment was a lexical decision task in which all three sets of words were presented intermixed with nonwords. The principal question was how latencies in the lexical decision task would be affected by the prior presentation of the pictures and words in Part 1.

Method

Subjects. Fifteen paid volunteers from an undergraduate psychology class each served in a 1-h session.

Stimuli. The critical stimuli were 75 concrete, pictureable, four- and five-letter nouns, and simple black-on-white line drawings representing these nouns. Picture naming latencies are an increasing function of the uncertainty associated with the choice of a name for the picture (Lachman, 1973). For this reason, among others, most of the stimuli were taken from a developmental study of picture memory (H. Scarborough, 1977), in which the pictures were known to have very high consistency in naming. Other words and pictures were selected for use as practice and filler items. (Examples of the pictures are shown in H. Scarborough, 1977.) In addition, 84 four- and five-letter nonwords for the lexical decision task were constructed by changing a single letter in real words that were not used in the experiment.

The words and nonwords were each typed in uppercase Bulletin type with half-spaces between each character. The critical words and pictures along with additional filler words and pictures of similar frequency were then photographed with Kodak high-contrast copy film and mounted as white-on-black slides. When rear-projected in the experiment, the words subtended a vertical visual angle of about 1.4 deg and a horizontal visual angle of 4.7 deg for five-letter words. The pictures subtended an angle of about 6.6 deg.

Design. The 75 critical words and the corresponding pictures were divided into three sets that were matched in terms of the distributions of word lengths and word frequencies. Within each group of 25 stimuli, there were 13 high-frequency words and 12 low-frequency words. The high-frequency items all had

Thorndike-Lorge (1944) G-count frequencies of A or AA, and the low-frequency items had a median frequency of 22, with a range of 2-49.

In the first part of the experiment, one of the three sets of stimuli was presented as printed words to be pronounced aloud, and a second set was presented as pictures to be named. The 25 pictures and 25 words were intermixed pseudorandomly with an additional 22 filler pictures and words. There were no repetitions either within or across stimulus formats within the 72 stimuli. There were three versions of the Part 1 stimulus sequence such that each of the three sets of critical stimuli appeared in one version as words, in another version as pictures, and not at all in a third version. Each of the three stimulus sequences was presented to 5 of the 15 subjects in a counterbalanced order.

Part 2 of the experiment was the lexical decision task, and this was identical for all subjects. It consisted of 50 practice trials and 160 test trials. In both practice and test, 40% of the items were nonwords. In the practice block, 13 of the words were new, while 17 had been presented as filler pictures or words in Part 1 of the experiment. The 96 words in the test block included the 75 critical words plus 21 additional nonrepeated filler words. The items in the test block were pseudorandomized so that words of each frequency from each of the three sets were distributed uniformly throughout the trials.

Procedure. The stimuli were rear-projected for 1 sec onto a ground glass screen mounted in one wall of a small booth. A second projector provided a 1-sec prefield immediately prior to each stimulus presentation. The words and pictures appeared in the middle of the predisplay field. The luminance of the fixation field was about .6 fL, while the average display luminance was about 1 fL. The display time was controlled by electromechanical shutters placed in front of each projector. Response times were recorded from a millisecond timer that started with the onset of the display. The timer was stopped by operation of a Grason-Stadler voice-operated relay in Part 1. In Part 2, the subject pulled one of two levers to indicate whether a stimulus was a word or a nonword.

A subject sat in the dimly lit booth facing the rear-projection screen and initiated each trial by stepping on a foot pedal. This turned on the fixation field, and the display appeared about 1 sec later. In Part 1 of the experiment, a microphone was placed on the table in front of the subject. Subjects were told that the experiment was to measure reading times for words and naming times for pictures. There was no mention of the subsequent lexical decision task. After the naming trials were over, the microphone was removed and replaced by a box with two levers, one actuated by each hand. All subjects pulled the right lever in response to words and the left lever in response to nonwords. Subjects were given a break between the two parts of the experiment and at intervals during slide tray changes.

Results

For six of the pictures, fewer than half the subjects responded with the name expected. These six items were eliminated from the analysis. For the remaining items, errors were low and naming consistency was high. For the remaining pictures, subjects responded correctly (gave the expected name without false starts) on 92% of the trials. The error rate due to hesitations, extraneous noise, and so on, on word pronunciation trials was about 1%. The mean error rates for words and nonwords in the lexical decision task were 3% and 4%, respectively. Stimulus items in Part 1 for which a subject made a pronunciation error in reading a word or gave other than the expected name to a picture were excluded from the

Figure 1. Effect of the type of prior exposure of high- and low-frequency words on recognition latencies in the lexical decision task: Experiment 1.

analysis of the Part 2 lexical decision latencies for that subject.

The principal question is how latencies in the lexical decision task were affected by exposure to either the pictures or the words in Part 1. Figure 1 shows mean latencies for correct responses to high- and low-frequency words in the lexical decision task as a function of the type of prior exposure in Part 1.

In order to deal with problems of missing data and with the lack of normality in the latency distributions, the results were analyzed using the min F' analysis suggested by Clark (1973). That is, the data were analyzed twice in an analysis of variance (ANOVA). In one analysis, the correct response latencies were averaged over the stimuli within each condition and the error term in the ANOVA was the appropriate Subjects by Treatment interaction. In the second analysis, the data were averaged over subjects for each word within each condition, and the error term was the appropriate Words by Treatment interaction. The results were then combined by the min F' analysis to give an estimate of the robustness of treatment effects with respect to both subject and stimulus variability. This analysis of the Part 2 lexical decision latencies indicated significant effects of the type of prior exposure [$\min F'(2,94) = 5.07, p < .01$] and a marginally significant effect of word frequency [$\min F'(1,48) = 3.06, p < .10$]. The frequency effect was significant both in the analysis by subjects and the analysis by words ($p < .05$ in both cases). Although Figure 1 suggests an interaction of word frequency and the type of prior exposure, it was not significant [$\min F'(2,59) = .4$], and the interaction was not significant in either of the two analyses leading to the min F' . Although the min F' analysis is conservative, the results of each of the separate analyses were consistent with the min F' results. The mean latencies for the three types of prior

presentation were compared using Fisher's least-significant difference method. For both the ANOVA by words and the ANOVA by subjects, the mean latency for words shown as words in Part 1 differed from the mean latencies for the other two types of prior exposure ($p < .01$), which themselves did not differ significantly ($p > .30$).

After removing the variability associated with the significant main effects and interactions, the standard error of the points shown in Figure 1 is 9.9 msec for the analysis collapsing over words, and 8.2 msec for the analysis collapsing over subjects.

The arcsin-transformed error proportions for each subject within each condition in the lexical decision task were also analyzed in an ANOVA. There was a significant effect of frequency [$F(1,24) = 14.00, p < .01$], with more errors made on low-frequency words than on high-frequency words (11% vs. 3%). No other effects were significant ($p > .10$).

Of subsidiary interest are the naming and pronunciation latencies for Part 1. The latencies to pronounce high- and low-frequency words were 671 and 692 msec, respectively. For pictures with the corresponding high- and low-frequency names, the latencies were 873 and 1,058 msec, respectively. A min F' analysis of these results indicated that word frequency [$\min F'(1,56) = 13.3$], type of presentation [$\min F'(1,36) = 120$], and the interaction between these variables [$\min F'(1,41) = 7.71$] were significant (all $ps < .01$). The standard error of the data after removing variability associated with significant main effects and interactions was 16 msec both for the analysis by subjects and the analysis by stimuli.

Discussion

The mean lexical decision latency for words previously shown and named as pictures was 630 msec, virtually the same as the latency for words encountered for the first time (631 msec). In contrast, lexical decision latencies for words that were pronounced in Part 1 were about 32 msec faster (599 msec) than the control items. Thus, recognition of a word was facilitated by having pronounced that word about 170 trials earlier, on the average, a time lag of about 25 min. This result replicates the existence and persistence of the word repetition effects reported by D. Scarborough et al. (1977) and extends their findings by showing that the effect transfers across tasks. That is, recognition of a word in the lexical decision task is facilitated by prior pronunciation of the word. On the other hand, there was no evidence of a repetition effect across stimulus modality. That is, naming a picture did not facilitate subsequent recognition of the picture name in the lexical decision task, even though the picture naming latencies in Part 1 were substantially longer than the pronunciation latencies, indicating that picture naming required more extensive processing. It is possible

that the power of the present experiment was insufficient to detect transfer from picture naming. In fact, any effect whose expected value was less than about 30 msec would be difficult to detect statistically. However, the failure to find a repetition effect across modalities suggests that repetition effects occur primarily at the level of processes specific to the stimulus format and not at the level of word detectors that are independent of format.

The 27-msec effect of word frequency on the lexical decision latencies was small. However, the difference in the frequencies of the high- and low-frequency words was also relatively small because of the need to have corresponding pictures that would be consistently named. However, the small effect of frequency on lexical decision latency to words not previously seen was smaller than expected on the basis of previous data (Rubenstein et al., 1970; D. Scarborough et al., 1977), and two aspects of the experiment may have been responsible. First, word frequency had been defined in terms of the Thorndike-Lorge (1944) count. A subsequent check of the words against the Kučera and Francis (1967) frequency count indicated that several of the words classified as high frequency in terms of the Thorndike-Lorge count would be assigned to the low-frequency group on the basis of the Kučera and Francis count, and vice versa, for words initially assigned to the low-frequency group. A second possible explanation is that although the nonwords were generally pronounceable, we later noticed that a number of them seemed to be orthographically irregular. If subjects were able to make the word-nonword response consistently on the basis of an evaluation of orthography (Rubenstein, Richter, & Kay, 1975), then frequency effects due to memory access would be nonexistent. Also, if subjects could make the word-nonword decision solely on the basis of an examination of the orthographic properties of the display, this could explain the failure to find cross-modality repetition effects: That is, only repetition effects at the encoding level would affect the response latency.

It seemed unlikely that the presence of orthographic irregularities in the nonwords could completely explain the failure to find transfer from picture naming to word recognition because the irregularities were not common enough to provide a reliable basis for making the word-nonword decisions. However, it seemed important to check on this possibility before concluding that there was no transfer, and this was the impetus behind the second experiment. A second goal was to reexamine the role of word frequency with respect to repetition.

EXPERIMENT 2

Experiment 2 was quite similar to Experiment 1 except that there were more subjects. Also, changes were made in the stimuli to eliminate pictures that were

named inconsistently and to provide a more robust frequency effect in the lexical decision task. Finally, all nonwords were constructed from common spelling patterns and were quite pronounceable.

Method

Subjects. Thirty-three undergraduates (13 males) from an introductory psychology course each received course credit for serving in a 1-h session. Three subjects were lost due to apparatus failures. Three more were eliminated because of high error rates in the lexical decision task (14%, 20%, and 22% errors). All subjects were right-handed.

Stimuli. The critical stimuli were 72 four- and five-letter concrete nouns and their corresponding pictures, plus additional filler words and pictures. Many of the stimuli were drawn from Experiment 1. However, pictures that were inconsistently named were replaced. In addition, several words that had inconsistent frequency ratings based on the Carroll, Davies, and Richman (1971) American Heritage "U" count, Kučera and Francis (1967), and Thorndike and Lorge (1944) were eliminated or replaced. As in Experiment 1, the critical stimuli were partitioned into three sets that were closely matched in terms of word length and word frequency. Each set of 24 items was further subdivided into three groups of items by frequency. Based on the Kučera and Francis count, the median frequency for the high-, medium-, and low-frequency words was 104, 28, and 11 occurrences per million, respectively.

New nonwords were prepared for Experiment 2, as before, by changing a single letter in real words. Care was taken to insure that all such nonwords were pronounceable and orthographically regular.

All stimuli were prepared and mounted as 35-mm slides, as in Experiment 1.

Design. The design was similar to that of Experiment 1. As before, there were two parts to the experiment, and the versions of Part 1 were such that each set of stimuli appeared as pictures, as words, or not at all across subjects. Part 2 was again the lexical task. There were three different orders of the stimuli in Parts 1 and 2, in order to counterbalance for practice effects across stimuli and for the effects of the interval between the presentation of a stimulus in Part 1 and its reoccurrence in Part 2.

There were 78 trials in Part 1, consisting of 24 critical words, 24 critical pictures, and 30 filler stimuli (half pictures). In Part 2 there were 40 lexical decision practice trials that included 16 words that corresponded to filler pictures and words in Part 1. There were 171 lexical decision test trials (approximately 46% nonwords), including the 72 critical words.

The assignment of the subjects to conditions was counterbalanced such that each version of the Part 1 pronunciation and naming task was shown to nine subjects. With each group of nine subjects, three were assigned to each of the three stimulus presentation orders.

Procedure. The apparatus and procedure were the same as for Experiment 1. As before, subjects were given no indication prior to Part 2 that any stimuli would be repeated.

Results

The mean error rates for the Part 1 naming and pronunciation trials was 1%, with a range of 0%-4% over subjects. The mean error rate in the lexical decision task was 3%, with a range of 0%-7%. The latency data for the lexical decision task are shown in Figure 2.

The analysis of these data followed the pattern outlined for Experiment 1. In the lexical decision task, there were significant main effects of frequency

Figure 2. Effect of the type of prior exposure of words on recognition latencies in the lexical decision task: Experiment 2.

[$\min F'(2,107) = 9.60, p < .01$] and of type of presentation in Part 1 [$\min F'(2,150) = 4.70, p \approx .01$]. The interaction between frequency and type of presentation was not significant [$\min F'(4,205) = 1.37, p > .10$]. This interaction was significant in the ANOVA in which the error term was the interaction with subjects ($p < .01$), but did not reach significance in the ANOVA in which the error term was the interaction with words ($p < .10$). No other effects approached significance in the analyses. The mean latencies for the three types of prior presentation were compared using Fisher's least-significant difference method. For both the ANOVA by words and the ANOVA by subjects, the mean latency for words shown as words in Part 1 differed from the mean latencies for the other two types of prior exposure ($p < .05$), which themselves did not differ significantly ($p > .30$). The standard error for the data shown in Figure 2 was 6 msec for the analysis collapsing over stimuli, and 10 msec for the analysis collapsing over subjects.

The arcsin-transformed error proportions for each subject within each condition in the lexical decision task were analyzed in an ANOVA. There was a marginally significant effect of the type of trial [$F(2,48) = 3.05, p \approx .06$], suggesting a tendency for more errors to be made on words not previously presented as pictures or words (1.4% vs. about .3% errors for words seen before as pictures or as words). No other effects approached significance ($p > .10$).

Pronunciation latencies in Part 1 for high-, medium-, and low-frequency words were 590, 587, and 631 msec, respectively. The corresponding picture naming latencies were 818, 887, and 974 msec. Analysis of variance of these data revealed significant effects of frequency [$\min F'(2,92) = 8.62, p < .01$], type of presentation (word vs. picture) [$\min F'(1,44) = 101, p < .01$], and their interaction [$\min F'(2,100) = 3.52, p < .05$]. No other effects approached significance. The standard

error for the pronunciation latencies was 11 msec for the analysis collapsing over stimuli, and 19 msec for the analysis collapsing over subjects.

Discussion

Experiment 2 replicates the main result of Experiment 1. There was little evidence of any transfer from picture naming to subsequent recognition of the picture name in the lexical decision task. The mean lexical decision latency for low-frequency words without prior exposure was 660 msec, and 655 msec for words that were preceded by pictures, a difference of only 5 msec. In contrast, as in Experiment 1, pronunciation of the low-frequency words in Part 1 speeded the Part 2 lexical decision latencies by an average of 50 msec. This experiment also showed a significant effect of word frequency, primarily in terms of slower responses to low-frequency words. Although not significant in the $\min F'$ analysis, the data also show evidence of an interaction between word frequency and word repetition, reflecting a tendency for transfer to occur primarily for low-frequency words. Such a tendency is seen in the mean data for Experiment 1 and has been observed in other experiments (D. Scarborough et al., 1977). Thus, it seems reasonable to conclude that the current data do show that the transfer or repetition effect is dependent on word frequency.

The interaction between frequency and repetition in the present experiments might have been more robust if a priming task that required word recognition had been used in Part 1. The idea here is that repetition effects may reflect the reoccurrence of processes (or the reuse of pathways) that were employed in responding to an earlier occurrence of a stimulus. The size of the repetition effect represents, in part, the consistency or overlap in processing upon the two occurrences of the stimulus. Although the processes involved in pronunciation of a word in Part 1 and recognition of the word in the lexical decision task may overlap to some extent (e.g., in terms of initial perceptual and encoding operations), other processes may overlap little. As suggested in the introduction, word-frequency effects in the lexical decision task may occur primarily in the process of locating a long-term memory representation of a word based on an encoded stimulus representation. However, subjects might occasionally have pronounced a word without recognizing it. If so, pronunciation of a word would affect encoding, but could have no effect on processes involved in subsequent retrieval from long-term lexical memory. Hence, differences in processing latency attributable to word frequency that occurred in lexical retrieval would be unaffected by prior pronunciation of the word. On the other hand, a priming task that always required word recognition might have demonstrated repetition effects that were more consistently dependent on word frequency.

Although characteristics of the Part 1 priming task

may control repetition effects, other factors may account for some of the results. In several unpublished experiments, we have found, generally, a consistent and reasonably linear relationship between log word frequency and response latency. Furthermore, repetition effects have been reasonably well predicted by word frequency. However, in one of our experiments (D. Scarborough et al., 1977, Experiment 4) that used many of the same stimuli as in the present experiments, we also failed to find a significant interaction between frequency and the size of the repetition effect. Thus, some property of the highly constrained set of words we sampled from in the present experiments may be responsible for the results. Additionally, there are other factors besides frequency that influence the observed repetition effects (e.g., stimulus degradation, semantic complexity, verbal ability of the subjects). Some of these other factors may account for aspects of the current results. For example, the first two experiments drew subjects from slightly different populations. Additionally, the quality of our slide making improved from Experiment 1 to Experiment 2, and the sharper word slides in the latter experiment may have reduced any general repetition effects not tied to word frequency.

In any case, the first two experiments demonstrate that pronunciation of a word affects, in some way, a subject's memory for that word many trials later. In contrast, naming a picture seems to have no effect on later word recognition. However, the dependent variable in these experiments was recognition latency. Most experiments investigating memory for pictures and words have tested how accurately subjects can recognize whether or not a picture or word occurred before in the experiment. In this task, picture recognition memory is generally much better than word recognition memory (e.g., Shepard, 1967). In the third experiment, we asked whether the conditions used in Experiments 1 and 2 would show evidence of transfer across modality and task if we used a more traditional recognition memory task.

EXPERIMENT 3

Method

Subjects. Seventeen right-handed volunteers from an undergraduate psychology course (11 females) each served in a session of about 1 h. One subject was discarded because of apparatus failure. A second subject was discarded because he showed approximately chance performance on the memory test.

Design and Procedure. The stimuli and the design were identical to those of Experiment 1. The procedure was identical to that of Experiment 1, with the single exception that, in Part 2, subjects were told to pull the right-hand lever if they saw an "old" item (i.e., a word or the name of a picture that they had seen in Part 1) and to pull the left-hand lever for new names or nonwords. Subjects were not given feedback regarding accuracy during Part 2.

Results

As in Experiment 1, several items were eliminated because they were inconsistently named as pictures. For the remaining items, error rates in Part 1 for picture naming and pronunciation averaged 4% and less than 1%, respectively. The naming and pronunciation latencies were faster, but quite similar in pattern to those observed in Experiment 1. The latencies for pronouncing high- and low-frequency words were 609 and 636 msec, and the mean latencies for naming the corresponding pictures were 811 and 930 msec.

In Part 2 of the experiment, the prime interest was on the accuracy with which subjects recognized words that they had seen before and words corresponding to the names of pictures seen in Part 1. The results were absolutely clear-cut. The average false alarm rate (i.e., responding "old" to real words that had not been presented before either as words or as pictures) was approximately .15. The hit rate (responding "old" to a word that was shown in Part 1 as a word or a picture) was .51 for repeated words. For the names of pictures seen in Part 1, the hit rate was .92, much better than the .51 hit rate for the repeated words. The hit rate for picture name recognition was better than for repeated word recognition for all subjects, except one who showed superior picture name recognition for high-frequency items but slightly better performance in recognizing old low-frequency words than in recognizing old low-frequency picture names. Mean false alarm rates for high- and low-frequency new words were .17 and .12, respectively.

Because there was considerable variability in the false alarm rate across subjects, d' 's (Banks, 1970) were estimated for each subject. This analysis assumed that subjects made recognition responses on the basis of some underlying familiarity distribution, with equal variance but different means assumed for the familiarity distributions of the picture names, the old words, and the new words. The ANOVA for the d' data indicated a significant main effect of whether the words were presented as pictures or as words in Part 1 [$F(1,12) = 90.1$, $p < .01$] and a main effect of frequency [$F(1,12) = 12.9$, $p < .01$]. The interaction between these variables was not significant [$F(1,12) = 1.41$, $p \cong .25$]. Mean d' 's for high- and low-frequency words pronounced in Part 1 were .95 and 1.52, respectively, with 12 of the 15 subjects showing superior performance for the low-frequency words. The mean d' 's for high- and low-frequency words that had been seen as pictures were 2.36 and 2.74, with 10 subjects showing better performance for the low-frequency names.

Discussion

Experiment 3 demonstrates the usual superiority of pictures over words in recognition memory tasks. What is important here is that the picture naming and word

pronunciation task in Part 1 of this experiment was identical to the Part 1 task of Experiment 1. The only difference between Experiments 1 and 3 was the question posed to the subjects in the second part of the experiments. In Part 2 of Experiment 3, subjects indicated whether or not they had seen a word earlier in the experiment, either as a picture or as a word. The results indicate that picture naming in Part 1 produces a contextual or episodic memory (Tulving, 1972) that can be accessed readily via a visual presentation of the picture name, but memory for having pronounced a word was poor. On the other hand, requiring subjects in Part 2 to indicate whether or not a stimulus was a word, as in Experiment 1, showed clear evidence of the effects of pronouncing a word in Part 1 but no evidence of any effect of having used the word to name a picture in Part 1. These results extend those reported by D. Scarborough et al. (1977). They varied the interval between repetitions of a word and found that the accuracy of old-new recognition memory decreased rapidly as the interval between presentations increased, although the same change in the interval had little effect on lexical decision latencies to repeated words. Thus, it seems that the typical recognition test of asking whether a stimulus is old or new within the context of the experiment does not always reveal memorial consequences of earlier experience that can be clearly revealed under different task circumstances (e.g., the lexical decision task).

Another point of interest in Experiment 3 is that the usual picture memory superiority was obtained although the circumstances of the experiment appear to favor recognition of the repeated words. That is, for "old" words, the same stimulus was presented both for pronunciation and for the recognition test. In contrast, the probe of picture memory was a stimulus word that the subject had not seen before. From some points of view, using a word as a probe for both picture and word memory should have reduced, or perhaps reversed, the usual superiority of picture memory. That is, although presentation of an old word was indeed a recognition test, presentation of a picture name for recognition was not really a recognition test but more like a cued recall test. The superiority of picture memory under these conditions is interesting, particularly in the context of the results of Experiments 1 and 2. It should be noted that apart from the problems just raised, the superior picture memory performance cannot be hastily written off in terms of a dual code advantage for pictures (Paivio, 1971), as the pronounced words in Part 1 represented referents equally as imageable as the pictures. Also, as the words and pictures were interspersed in Part 1, this should have encouraged subjects to think of the imageable referents of the words.

Finally, Experiment 3 reproduced the frequently observed effect that infrequent words are better

recognized than are frequent words (Glanzer & Bowles, 1976; Shepard, 1967). The effect seems curious in this context because low-frequency "old" probes were better recognized regardless of whether they represented probes of picture memory or of word memory. However, if low-frequency words generally have fewer representations or meanings in memory than do high-frequency words (Reder, Anderson, & Bjork, 1974), this result might reflect less uncertainty as to the starting point for search in memory with the low-frequency probes.

GENERAL DISCUSSION

Taken together, these experiments show that simply pronouncing familiar words can produce persistent changes in perception and/or memory as evidenced by changes in the speed with which the words are recognized. However, subjects cannot readily use these changes to report whether or not they saw a word before, as is shown by the relatively poor word recognition performance in Experiment 3. In contrast, picture naming produced different effects: good recognition of "old" picture names in Experiment 3, but no facilitation of word recognition latency in Experiments 1 and 2. This failure of transfer is perhaps surprising in light of results reported by Bartram (1973). He examined repetition effects in naming repeatedly presented line drawings. In addition, he examined transfer of practice in naming nonsense objects to naming pictures. That is, for part of the experiment, subjects learned to associate names of concrete objects with nonsense shapes, and then they practiced naming the shapes using the associated names. Later, they saw and named line drawings of the real objects whose names corresponded to the names used for the nonsense objects. Bartram found almost complete transfer of training. That is, six trials of responding with a name to the presentation of a nonsense shape speeded naming a drawing of the actual object on the seventh trial almost as much as if the first six trials had involved naming the line drawing itself. Such a result is quite consistent with Morton's (1969, 1970) logogen model and suggests that using the name in response to a nonsense object lowered the logogen threshold as much as presentation of the object itself. However, several other interpretations are possible. First, both of Bartram's tasks, the picture naming and the nonsense object naming, involved articulation of a common response, and it is possible that the repetition effects he observed occurred primarily in response production. If so, repetition effects might have occurred in the present experiments had Part 2 required pronunciation of the printed words. A second possibility is that transfer is a threshold phenomenon. Bartram's subjects produced each of the names six times in response to the nonsense shapes before transfer was tested, and this additional practice

may have been critical. A third difference between Bartram's task and the present experiments is that the interval between Bartram's nonsense shape naming task and the transfer task was relatively short compared to the rather long lag between the naming task and the lexical decision task in the present experiments. A fourth possibility is that transfer is mediated by the subject's knowledge and expectations about the situation. It is not clear whether Bartram's subjects knew that they were in a transfer task. However, the fact that there were repetitions was probably quite evident. Furthermore, the total number of stimuli was quite small, and only nine names were involved in the transfer. As subjects had ample time to learn the nine names before the transfer task, it is conceivable that the observed transfer could have been mediated by an active translation or control process. A final possibility is that transfer is simply asymmetric; that is, practice on words might transfer to picture naming, as in Bartram's task, but no transfer would be observed in the opposite direction, as in the present experiments.

The present data do not discriminate among these hypotheses. However, in other experiments that involved several of these factors (repetition of the same response, multiple repetitions, different lags, and different subject expectations), we have found some evidence of transfer from picture naming to the lexical decision task. However, the transfer has generally been weak and always much less than the transfer produced by repetition of the word itself.

With regard to questions raised in the introduction, the present results indicate that repetition effects occur automatically. That is, Part 1 pronunciation reliably facilitated responses to Part 2 repeated words, even though subjects were not aware during Part 1 that items would be repeated, and even though their ability to discriminate repeated from nonrepeated words was not especially good. Second, the repetition effect observed here does not depend upon maintaining the same explicit task demands (e.g., decision processes) or the same response. Third, the data clearly indicate that the observed repetition effects are not mediated by a central threshold change in a word detector that is modality independent, such as that posited by the logogen model. The results, then, support the idea that there are automatic repetition effects that are associated with the processing of a stimulus, for example, in its encoding and/or in the long-term memory retrieval processes that are unique to the stimulus representation. Exactly what the processes are is far from clear. Clearly, the repetition effects here cannot occur at the first levels of perceptual analysis. For example, the facilitation produced by repetition cannot be at the level of simple feature or letter detectors because repetition effects persist even when the stimulus is changed between presentations in terms of letter orientation (Kolers & Perkins, 1975), or in terms of upper- vs. lowercase

letters (D. Scarborough et al., 1977). A more likely hypothesis is that the level of coding affected by repetition involves more complex representations of the stimulus, perhaps in terms of letter clusters, or possibly the whole word. In this respect, it is interesting to note that the repetition effects are linked to the lexical status of the stimulus. That is, while low-frequency words generally show strong repetition effects, nonwords, which are, in a sense, extremely low-frequency words, show only relatively weak repetition effects that dissipate quickly (D. Scarborough et al., 1977). Additionally, the level at which repetition is facilitative is not so general as to be independent of stimulus format or modality, as shown in the present experiments. Taken together, then, the current data suggest that the repetition effects produced by pronunciation of a visually presented word may occur only if the word is later presented in a similar or systematically related form (e.g., upper- vs. lowercase letters).

The Part 1 data from the current experiments provide additional data that are of general interest. These data replicate the phenomenon that reading words is faster than naming drawings of the corresponding objects (Fraisse, 1969; Potter & Faulconer, 1975). The data also reproduce the result that word-frequency effects for word pronunciation tend to be smaller than frequency effects in the lexical decision task (e.g., as in Experiment 2). However, what is most noteworthy is the substantial difference in the size of the frequency effects observed with pronunciation and with picture naming. The frequency effects for picture naming in these and other data (Bartram, 1973, 1974; Lachman, 1973; Oldfield, 1966) are substantially larger than those typically observed in pronunciation and lexical decision tasks (Frederiksen & Kroll, 1976; Rubenstein et al., 1970; D. Scarborough et al., 1977; D. Scarborough & Springer, Note 1). The basis for this relationship is unclear. However, repetition of pictures in a naming task substantially reduces the frequency effects in such a task (Bartram, 1973, 1974), but picture presentation did not alter the frequency effects for the corresponding names in the lexical decision task in the present experiments. This suggests that we may be dealing with two different frequency mechanisms. That picture naming latencies are predicted by word-frequency counts may simply reflect a high correlation between the frequency of encounters with such concrete objects and with their linguistic tokens. However, it is surprising to note that in Experiment 2, word-frequency data apparently predicted picture naming latencies in Part 1 better than lexical decision latency in Part 2.

CONCLUSION

The present results demonstrate an automatic facilitation in the processing of single repeated words that apparently occurs in encoding and in memory access.

This effect is not specific to a particular task, and, in fact, shows transfer across tasks if the stimulus modality is preserved. The present experiments show this effect when an interval of 100 or more trials intervenes between presentations. Other results (D. Scarborough et al., 1977) show that these repetition effects can last for days. The apparent robustness, size, and generality of these effects makes it likely that they occur in many tasks, such as categorization (Hopf-Weichel, 1977) and the word superiority effect (Baron & Thurston, 1973), as well as in other tasks such as reading (Kolers, 1975, 1976). This repetition effect is particularly surprising in that it shows a high degree of plasticity in a highly practiced skill, namely, word recognition by college students. The phenomenon of such an immediate persistent change in the way a person processes specific information in his environment poses a challenge to theories of perception, memory, and neurophysiology.

REFERENCE NOTE

1. Scarborough, D., & Springer, L. *Noun-verb differences in word recognition*. Paper presented at the Fourteenth Annual Meeting of the Psychonomic Society, St. Louis, Missouri, November 1973.

REFERENCES

- BANKS, W. P. Signal detection theory and human memory. *Psychological Bulletin*, 1970, **74**, 81-99.
- BARON, J., & THURSTON, I. An analysis of the word superiority effect. *Cognitive Psychology*, 1973, **4**, 207-228.
- BARTRAM, D. J. The effects of familiarity and practice on naming pictures of objects. *Memory & Cognition*, 1973, **1**, 101-105.
- BARTRAM, D. J. The role of visual and semantic codes in object naming. *Cognitive Psychology*, 1974, **6**, 325-356.
- BROOKS, L. Visual pattern in fluent word identification. In A. Reber & D. Scarborough (Eds.), *Toward a psychology of reading: Proceedings of the CUNY conferences*. Hillsdale, N.J.: Erlbaum, 1977.
- CARROLL, J., DAVIES, P., & RICHMAN, B. *The American heritage word frequency book*. New York: American Heritage, 1971.
- CLARK, H. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior*, 1973, **12**, 335-359.
- FRAISSE, P. Why is naming longer than reading. *Acta Psychologica*, 1969, **30**, 96-103.
- FREDERIKSEN, J., & KROLL, J. Spelling and sound: Approaches to the internal lexicon. *Journal of Experimental Psychology: Human Perception and Performance*, 1976, **2**, 361-379.
- GLANZER, M., & BOWLES, N. Analysis of the word-frequency effect in recognition memory. *Journal of Experimental Psychology: Human Learning and Memory*, 1976, **2**, 21-31.
- HOPF-WEICHEL, R. Reorganization in semantic memory: An interpretation of the facilitation effect. *Journal of Verbal Learning and Verbal Behavior*, 1977, **16**, 261-275.
- KOLERS, P. Specificity of operations in sentence recognition. *Cognitive Psychology*, 1975, **7**, 289-306.
- KOLERS, P. Reading a year later. *Journal of Experimental Psychology: Human Learning and Memory*, 1976, **2**, 554-565.
- KOLERS, P., & PERKINS, D. Spatial and ordinal components of form perception and literacy. *Cognitive Psychology*, 1975, **7**, 228-267.
- KUČERA, H., & FRANCIS, W. *Computational analysis of present-day American English*. Providence, R.I.: Brown University Press, 1967.
- LACHMAN, R. Uncertainty effects on time to access the internal lexicon. *Journal of Experimental Psychology*, 1973, **99**, 199-208.
- MORTON, J. Interaction of information in word recognition. *Psychological Review*, 1969, **76**, 165-178.
- MORTON, J. A functional model for memory. In D. Norman (Ed.), *Models of human memory*. New York: Academic Press, 1970.
- OLDFIELD, R. Things, words and the brain. *Quarterly Journal of Experimental Psychology*, 1966, **18**, 340-353.
- PAIVIO, A. *Imagery and verbal processes*. New York: Holt, Rinehart, & Winston, 1971.
- POTTER, M., & FAULCONER, B. Time to understand pictures and words. *Nature*, 1975, **253**, 437-438.
- REDER, L., ANDERSON, J., & BJORK, R. A semantic interpretation of encoding specificity. *Journal of Experimental Psychology*, 1974, **102**, 648-656.
- RUBENSTEIN, H., GARFIELD, L., & MILLIKAN, J. Homographic entries in the internal lexicon. *Journal of Verbal Learning and Verbal Behavior*, 1970, **9**, 487-494.
- RUBENSTEIN, H., RICHTER, M., & KAY, E. Pronounceability and the visual recognition of nonsense words. *Journal of Verbal Learning and Verbal Behavior*, 1975, **14**, 651-657.
- SAVIN, H. Word frequency effects and errors in the perception of speech. *Journal of the Acoustical Society of America*, 1963, **35**, 200-206.
- SCARBOROUGH, D., CORTESE, C., & SCARBOROUGH, H. Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance*, 1977, **3**, 1-17.
- SCARBOROUGH, H. Development of visual, name, and conceptual memory codes for pictures. *Journal of Experimental Child Psychology*, 1977, **24**, 260-278.
- SHEPARD, R. Recognition memory for words, sentences and pictures. *Journal of Verbal Learning and Verbal Behavior*, 1967, **6**, 156-163.
- SOLOMON, R., & HOWES, D. Word frequency, personal values, and visual duration thresholds. *Psychological Review*, 1951, **58**, 256-270.
- SPOEHR, K., & SMITH, E. The role of orthographic and phonotactic rules in perceiving letter patterns. *Journal of Experimental Psychology: Human Perception and Performance*, 1975, **1**, 21-34.
- THORNDIKE, E., & LORGE, I. *The teacher's word book of 30,000 words*. New York: Columbia University, Teacher's College Press, 1944.
- TULVING, E. Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory*. New York: Academic Press, 1972.

Appendix

Test Stimuli Used in Experiment 2

High-Frequency Words			
apple	clock	horse	star
baby	door	house	table
ball	fish	keys	train
bear	foot	king	tree
bird	hand	moon	truck
book	heart	shoes	watch
Medium-Frequency Words			
apron	chair	flag	piano
barn	clown	fork	pipe
bell	coat	iron	queen
belt	desk	lamb	ring
boots	doll	lamp	shirt
broom	duck	lion	snake
Low-Frequency Words			
angel	crown	leaf	snail
cake	dice	mask	spoon
camel	drum	pants	tent
cane	frog	seal	tooth
cigar	hose	skull	vase
comb	kite	sled	witch

(Revision accepted for publication November 28, 1978.)