Specific Visual Transfer in Word Identification

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Prior presentation of a word can serve to enhance its later perceptual identification. A series of three experiments was designed to determine if this effect of prior experience depends on preserving the visual details of a word between its prior presentation and test. A first experiment revealed evidence of specific visual transfer only for words that were tested in lowercase. Words tested in lowercase that had been previously presented in lowercase were more readily identified than were those that had been previously presented in uppercase. Later experiments used more extreme manipulations of the visual details of a word in an attempt to maximize specific visual transfer. Results of the experiments are discussed in terms of the role of memory for visual details in word identification along with the possibility that perception can rely on memory for prior episodes.

A prior presentation of a word can have a large and longlasting influence on its later identification in perceptually difficult situations (e.g., Jacoby, 1983a; Jacoby & Dallas, 1981). Does this effect of experience depend on preserving the visual details of a word, such as typeface, between its prior presentation and later test? By a popular view of perception, variation in visual details should be unimportant. Word identification is treated as depending on the identification of abstract letter units with information about the visual details of a word being lost very early in the reading process (e.g., Adams, 1979; Papp, Newsome, & Noel, 1984). Visual details that are remembered from any particular encounter with a word are said to be irrelevant to its later identification. In contrast, we (e.g., Jacoby, 1983a; Jacoby & Brooks, 1984) have suggested that perception can rely on memory for prior episodes. That is, we have argued that identification of a word does not totally rely on the use of some abstract representation. Rather, memory for a prior encounter with a word can be retrieved and can serve to aid its later identification. Similar to the view proposed by Kolers (e.g., Kolers & Roediger, 1984), it is the processing or operations used to identify a word that is seen as being preserved by memory. By this view, changing the visual details of a word between its presentation and test can reduce transfer by decreasing the similarity of the operations used to identify the word on the two occasions. In light of these claims, it is important to demonstrate that effects of prior experience in later word identification can reflect memory for supposedly superficial details of that prior experience.

It might seem that the role of memory for visual details in word identification has already been thoroughly investigated. A great deal of research has been aimed at assessing the importance of the shape of a word for its identification. Also, Kolers (e.g., Kolers, 1979) has carried out many experiments to demonstrate the existence of specific visual transfer in reading transformed text. However, experiments that have shown effects of memory for visual details have typically used tasks and materials for which people lack expertise. It could be argued that people rely on memory for prior episodes only during the early stages of skill acquisition. When first learning to read transformed text, for example, visual details may be important only because the abstract representations that would free one from reliance on those visual details have not yet been acquired. To counter this argument, it is necessary to find evidence of specific visual transfer in skilled performance. What is needed is evidence that memory for visual details plays a role in identification of words presented in a common typeface and in a normal orientation.

Finding specific visual transfer for words presented in a normal orientation and a common typeface is also important for the controversy about the role of word shape in reading. A common strategy used to investigate the claim that word shape is used in reading has been to disrupt word shape by presenting a word to be read in alternating upper- and lowercase letters (e.g., WoRd), and to then compare the speed of its identification to that of a word that retains its shape information by being presented in uniform lowercase (e.g., Rudnicky & Kolers, 1984). Proofreading is another on-line task that has been used to investigate the importance of word shape. In proofreading experiments, the probability of detecting misspellings that change word shape has been compared to that of detecting misspellings that maintain word shape (e.g., Haber & Schindler, 1981; Monk & Hulme, 1983). As a means of assessing effects of word shape, transfer experiments hold advantages over the use of these online procedures. McClelland (1977) argued that word shape results obtained using on-line procedures can be explained as being due to an influence on letter analysis without assuming that word shape is stored explicitly in memory. The global shape of a word could be used to determine which letters could be present at each letter position, and then more detailed information extracted from the letter could be used to choose among the possible letters. In contrast, an advantage in transfer produced by maintaining the typography in which a word is presented between its study and test provides conclusive evidence that

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stored information about word shape or other visual details was used. Transfer experiments may also reveal effects that are more specific than those that can be revealed by modifying a text for use of on-line procedures. To expect an influence of stored word shape on identification when a word is first encountered in the laboratory, one has to assume that the representation of word shape is abstract enough to allow its use across at least superficial visual details such as minor variations in the size and spacing of print. Results from transfer experiments, in contrast, might reveal effects that are more specific to the visual details of a prior presentation of a word. Identification of repetitions of a word may rely on stored information about the word as a visual pattern that is specific to its prior presentation, memory for prior episodes.

Evidence of memory for visual detail is obtained when people lack expertise with the type of material or the task that is used. In his investigations of reading inverted text, an unusual task, Kolers observed specific visual practice effects. He found that transfer is maximal when the orientation of the text and its type case is held constant between practice and test (e.g., Kolers, 1979; Kolers, Palef, & Stelmach, 1980). Masson (1986) provided further evidence of the specificity of these effects by showing that transfer in identifying typographically transformed words occurred only when training and test instances shared common letters printed in the same case. McClelland (1977) found effects of specific visual practice with nonwords in a categorization task. Subjects learned meanings for nonwords and practiced categorizing each nonword on the basis of its meaning. Speed of categorization was slowed when the typeface of the nonwords was changed from script to uppercase printing, or vice versa, between practice and the transfer test. Training transferred better from uppercase to script than from script to uppercase, presumably because of the greater reliance on configural information when reading nonwords in script during training. Also, Brooks (1977) found evidence of specific visual transfer when subjects were required to search through words printed in a mix of upper- and lowercase letters. Search was slowed if the pattern of upper- and lowercase letters used to print a word for the transfer test did not match that used during the training phase. The results of these experiments provide evidence that visual details are likely to be remembered and influence transfer when those details produce distinctive configurations and are encountered in areas in which people have little expertise, circumstances that encourage extensive processing of visual details.

Finding specific visual practice effects with words presented in a common typeface and a normal orientation would provide support for the claim that skilled performance can also rely on memory for prior episodes, and would provide evidence that configural information, word shape, is used at least sometimes in word identification (McClelland, 1977). Only relatively small effects are to be expected since bases for reading that do not rely on word shape are also available to a reader (e.g., Rudnicky & Kolers, 1984). However, prior investigations of word identification have failed to find any significant effect of changing the visual details of a word between its prior presentation and test. Morton (1979) reports that reading words in a typed format does not confer significantly more benefit to later tachistoscopic identification of those words presented in a typed format than does having previously read the words in a handwritten format. Morton takes this lack of specific visual transfer as evidence that word identification relies on abstract representations, logogens, that do not preserve visual information that is unique to individual encounters with a word. Feustel, Shiffrin and Salasoo (1983) found that changes in case between repetitions of a word did not have a significant influence on tachistoscopic identification performance. Scarborough, Cortese and Scarborough (1977) reported a lack of a significant effect of changing the case of a word between its repetitions in a lexical-decision task.

Although significant effects have not been found, the direction of the difference between conditions in each of the experiments described above has been consistent with a claim of specific visual practice effects. Also, the experiments manipulating case between repetitions of a word have not analyzed effects in identification separately for words printed in lowercase and those printed in uppercase letters. The ascenders and descenders used in lowercase print produce word shapes that are more distinctive than those produced when words are typed in uppercase letters. Consequently, effects of specific visual practice are more likely to be observed in the identification of words printed in lowercase letters. In our first experiment, we presented words for study in either uppercase or lowercase, and then tested the tachistoscopic identification of those words in either the same case or the opposite case from that in which they had been studied. Results were analyzed separately for words tested in lowercase and those tested in uppercase. Two additional experiments were done as attempts to magnify effects of specific visual practice found in Experiment 1.

General Method

As one basic paradigm is used throughout the three experiments, the method is described in detail at this point. Variations in the general method will be indicated as each experiment is described.

The subjects were volunteers from an introductory psychology course at McMaster University who served in the experiment for course credit. Subjects were tested individually.

Each experiment included a study phase and a test phase. During the test phase, words that had been studied and "new" words were intermixed and presented for a perceptual identification test. All stimuli were five-letter words and were presented as 7×8 dot matrix characters by means of an Apple II Plus computer on a 14-in. black-and-white television set. The character size was approximately 5.7×6.6 mm. The subjects viewed the characters from a distance of approximately 70-75 cm.

The study phase was introduced to subjects as a test of reading. Subjects were informed that their reading latency for each word was being recorded and were instructed to read each word aloud as rapidly as possible. These instructions served to provide a cover task; reading latencies were not recorded. Subjects were not told of the impending test of perceptual identification.

Prior to the test of perceptual identification, subjects were informed that words would be flashed on the screen and that they were to report each word immediately after its presentation. Subjects were encouraged to respond to each test item, guessing if necessary. The sequence of events in the test of perceptual identification was as follows: The message *Press return when ready* appeared on the bottom of the screen and remained there until the subject pressed the *return* key. One second after the message left the screen, there was a 750-ms fixation and warning display. This consisted of two bar markers in the middle of the screen, located two characters to the left and two characters to the right of the following target word. The target word was then presented, centered between the markers, for a duration of either 30 or 35 ms. The target display was terminated by a mask composed of five ampersands (&) in the same position as the target. The mask was presented for 1 s. This sequence was repeated until the entire list had been tested. Before the main test list was presented, each subject was given a practice list of 10 words. None of these words appeared elsewhere in the experiment. The first of the practice words was presented for a test duration of x + 100 ms, where x represents the test duration used for the main list. The duration of each subsequent practice word was reduced by 10 ms so that the duration of the final practice word was x + 10 ms, a duration close to that used during the testing of critical items.

The presentation durations used for the test of perceptual identification and other intervals were only approximate because the screen was not directly controlled by the computer, so the refresh cycle of the screen was a source of error. This source of error resulted in the true duration of some events being a maximum of ± 17 ms from the intended duration. Using this system of entering a small change in the presentation duration (e.g., from 30 to 35 ms) influenced the distribution of durations as well as its mean. Manipulations of presentation duration, then, were not exact but could still be used to influence the overall level of performance. The variability of presentation duration was random and does not compromise interpretation of the results.

Significance level for all tests was set at p < .05.

Experiment 1

Method

Subjects. A total of 24 volunteers served in a 1-hr session; 12 subjects were randomly assigned to each of two between-subjects conditions.

Design and materials. A list of 120 words was presented for study, and a list of 180 words was presented for the test of perceptual identification. Half the studied words were presented in lowercase letters, whereas the other half were presented in uppercase letters. A similar division was used during the perceptual identification test, with the constraint that half of the repeated words were tested in the same case and half were tested in the opposite case as used in study. This resulted in four test conditions, with 30 words representing each of the combinations of case at study and case at test. Also, of the 60 new words, 30 were tested in lowercase and 30 in uppercase, so there was a total of six within-subjects test conditions. Frequency in the language was another within-subjects manipulation. Half of the 30 words representing each of the six combinations of study and test condition were high-frequency words, whereas the other half were low-frequency words. A betweensubjects manipulation was a 5-ms difference in the duration of test exposure and was intended as a precaution against floor or ceiling levels of performance. The target word was shown for 35 ms for one group and for 30 ms for the other group.

All words were five-letter nouns. A pool of 180 words was selected from Thorndike and Lorge's (1944) word book; 90 of the selected words were low frequency (1 to 5 per million) and 90 were high frequency (A and AA) as scaled by Thorndike and Lorge. Words from this pool were used to construct six 30-word sublists to be used in constructing study and test lists. Each sublist contained 15 low- and 15 high-frequency words. Six formats were constructed by rotating these sublists through the six combinations of study and test conditions such that, across formats, the words in each sublist represented each combination of conditions. For presentation, two random orders of the words in each study list were used. A single random order of words in the test list was used for all subjects.

Procedure. Words were presented at a 2-s rate during study. Subjects

Table 1

Probability of Perceptual Identification in	Two	Study
Conditions: Experiment 1		

Test case	High-frequency words			Low-frequency words		
	Upper	Lower	New	Upper	Lower	New
Upper	.91	.90	.79	.78	.80	.59
Lower	.73	.80	.66	.62	.65	.44

were instructed to read each word aloud as quickly as possible. Instructions for the test of perceptual identification were as described in the General Method. Except for the time devoted to instructions and the 10-word practice list, the perceptual identification test immediately followed study.

Results and Discussion

An initial analysis of the results included case at test (uppercase vs. lowercase), test rate (30 vs. 35 ms), frequency in the language (high vs. low) and study condition (uppercase, lowercase, or no study) as factors. Results of that analysis showed that words tested in uppercase were identified more readily than were words tested in lowercase, F(1, 22) = 106.95, $MS_e = .014$. High-frequency words were more likely to be identified than were low-frequency words, F(1, 22) = 96.64, $MS_e = .017$, and the probability of identifying words presented for 35 ms at test was higher than that of identifying words presented for 30 ms, F(1, 22) = 5.24, $MS_e = .20$. The interaction of case at test with test rate, F(1, 22) = 7.48, $MS_e = .014$, was also significant. The advantage in identification of words tested in uppercase over those tested in lowercase was larger when a 30-ms (.73 vs. .57) rather than a 35-ms (.84 vs. .75) presentation rate was used for the test. The advantage of words presented in uppercase letters presumably reflects the larger size and, perhaps, less confusability of the uppercase as compared with lowercase letters.

Of greater interest was the effect of study condition (uppercase vs. lowercase vs. new) and its interactions with other factors. Means from the interaction of study condition, case at test, and frequency in the language are displayed in Table 1. The effect of study condition was significant, F(2, 44) = 88.36, $MS_e = .008$, as was the interaction of study condition with frequency in the language, F(2, 44) = 5.60, $MS_e = .011$. The probability of identifying new words (.62) was lower than that of identifying old words, words that had been presented for study in either uppercase (.76) or lowercase (.79) letters. Replicating the results of prior experiments (e.g., Jacoby & Dallas, 1981), this influence of prior presentation of a word on its later identification was larger for low-frequency than for high-frequency words. Neither the interaction of study condition with case at test nor any higher order interaction involving those two factors approached significance, Fs < 1.

To more closely examine effects of specific visual practice, data from new words were excluded from later analyses, and effects were examined separately for words tested in uppercase and those tested in lowercase. When words were tested in lowercase, words studied in lowercase were more likely to be identified (.73) than were words that had been studied in uppercase (.68), F(1, 22) = 4.79, $MS_e = .013$. Analyses of the results from words tested in lowercase also revealed effects of test duration, F(1, 22) = 7.03, $MS_e = .090$, and word frequency, F(1, 22) = 31.77, $MS_e = .012$. No interactions were significant. When words were tested in uppercase, only the effect of word frequency was significant, F(1, 22) = 45.13, $MS_e = .007$. Words studied in uppercase (.85) did not hold any advantage in probability of later identification over those studied in lowercase (.85).

An effect of specific visual practice was found only for words tested in lowercase. The finding of an overall disadvantage in identification for words tested in lowercase letters is surprising because others (e.g., Coltheart & Freeman, 1974) have reported the opposite, finding an advantage for words tested in lowercase as compared with those tested in uppercase letters. The lowercase letters used in our experiment were smaller in size and, perhaps, more confusable than were the uppercase letters. However, the set of letters used to present words in lowercase was not selected to produce any unusual difficulty in reading. Indeed, the set of lowercase letters is a standard one that is used when the computer is used as a word processor and was chosen to be as easily read as possible. More important than overall differences in difficulty of identification, perhaps, words printed in lowercase produce word shapes that are more distinctive than those produced when words are printed in uppercase. It is memory for configural information, word shape, that is most likely to serve as a basis for specific visual practice effects (e.g., McClelland, 1977).

Experiment 2

The first experiment revealed effects of specific visual practice only when words were tested in lowercase letters, and even then the effect was a small one. The second experiment was designed as an attempt to increase the effect observed in the first experiment by using a more extreme change in the visual details of a word between its study and test. The manipulation of case used in the first experiment sometimes amounted to only a manipulation of size. The lowercase version of some letters was very similar to but smaller than the uppercase version. Rather than using uppercase letters in the second experiment, we used a typography that differed radically from lowercase letters. The letters in this new typography were poorly formed and much larger. Letters had a three dimensional appearance, resembling letters shaped from a ribbon, viewed in relief. An example of one word printed in this new typography is shown in Figure 1 along with the same word printed in lowercase standard type. In the second experiment, all words were presented in standard lowercase letters for the test of perceptual identification. That is, a test of perceptual identification using the unusual typography for presentation of test words was not included in the experiment. A finding of specific visual transfer in the reading of that typography would almost certainly be obtained but would add little to conclusions that can be drawn from the transfer effects observed in investigations using transformed text (e.g., Kolers, 1979).

The second experiment was also designed to examine the possibility that differences in recognition memory performance



-- nurse --Figure I. Example of typographies used in Experiment 2.

play some role in producing specific visual transfer. Presenting text in an unusual orientation generally produces higher recognition memory performance and greater amounts of specific visual transfer than does presenting text to be read in a normal orientation (e.g., Kolers, 1973). Given that pattern of results, it is possible that recognition memory performance plays some role in producing specific visual transfer. For example, subjects may do less to verify their reading of words that they recognize as being old. Against this possibility, however, there is evidence that transfer effects in perceptual identification can be dissociated from effects in recognition memory performance. Jacoby (1983b) found that generating a word as an antonym of a cue word produced better recognition memory performance but poorer later perceptual identification performance than did reading the word. It was concluded that recognition memory performance can rely on prior conceptually driven processing, whereas perceptual identification of a word reflects the similarity of its prior data-driven processing to that required at the time of test. In line with this argument, a dissociation between effects in recognition memory performance and those in perceptual identification was expected in the present experiment. Words studied in the unusual typography were expected to hold an advantage in recognition memory performance but to be disadvantaged in later perceptual identification as compared to words that were studied, as well as tested, in standard lowercase letters.

Method

Subjects. A total of 18 volunteers served in a 1-hr session.

Design and materials. Stimuli studied in uppercase in Experiment 1 were viewed in a distorted typography in Experiment 2. All words tested for perceptual identification were presented in lowercase, the same type-face as half the study words. Each test condition was represented by 30 frequent and 30 rare words. Item counterbalancing and the randomization of words for study and tests lists followed Experiment 1, and required 6 subjects for a full counterbalancing.

The new typography used for half the study words used 52×76 dot matrix letters. A five-letter word as viewed by the subject subtended a visual angle of about 5° horizontally and 1–1.5° vertically. Each letter was created by taking simple, one-dot wide line drawings of a letter and redrawing the letter 10 times, with each repetition displaced to the right by one dot and down by two dots. The resulting letter as viewed on the computer screen resembled a three-dimensional letter. Of the 120 study words, 60 were studied in standard lowercase and 60 were studied in the large and degraded typeface.

Procedure. During study, a word was presented on the video screen

.80

.48

Conditions: Expe	Perceptu riment 2	ai Iaeniin	cation in	Inree Su	ay
	Lowercase		Degraded		
Word frequency	P	% ^a	Р	% ^a	New

Table 2

^a Percentage correctly identified conditionalized for correct naming during study.

86

73

.86 .72 .85

.65

85

66

every 2 s and remained on the screen until replaced by the next word. The two types of study typeface were randomly intermixed. Subjects were instructed to read the study words aloud. If they misread a word the experimenter corrected them and made a note of the error for subsequent conditionalization of the perceptual identification performance on correct identification during study. The test of perceptual identification used a 35-ms duration for the target words. Otherwise, the study and test procedure in Experiment 2 was identical to that in Experiment 1. Immediately following the test of perceptual identification, each subject was given a surprise test of recognition memory. The recognition test comprised one sheet of paper with six columns and thirty rows of words for a total of 180 words. These words were a random arrangement of all the words tested in the previous test of perceptual identifications. The subjects were instructed to circle only those words that they saw during the study phase of the experiment.

Results and Discussion

Perceptual identification. The probability of perceptual identification for the three test conditions is displayed in Table 2 for high- and low-frequency words. Probabilities of identification conditionalized on correct naming during study are displayed in brackets to the right of the unconditionalized scores. A $3 \times$ 2 analysis of variance (ANOVA) (two levels of study plus new, and two levels of word frequency) was performed on the unconditionalized perceptual identification scores. Results of the analysis of conditionalized scores paralleled those of the analysis of unconditionalized scores, so only the latter will be reported.

In the analysis of the unconditionalized accuracy there was a main effect of word frequency, F(1, 17) = 99.29, $MS_e = .013$, a main effect of study conditions, F(2, 34) = 28.67, $MS_e = .0076$, and an interaction between study condition and word frequency, F(2, 34) = 19.52, $MS_r = .004$. In a preplanned comparison using a t test for the differences between several means, it was found that low-frequency words studied in standard lowercase were identified more accurately than were low-frequency words studied in the degraded typography, t(34) = 3.62, which in turn were identified more accurately than new low-frequency words, t(34) = 7.94. For the high-frequency words, words studied in the lowercase were more accurately identified than were new words, t(34) = 2.82, p < .01, and words studied in the degraded typography were also more accurately identified than were new words, t(34) = 2.38, p < .05. High-frequency words studied in the standard lowercase did not hold a significant advantage in identification over those studied in the degraded typography.

Recognition memory. The probability of a false alarm was .25. Because the design used made it unnecessary to correct for differences among conditions in the probability of a false alarm, the proportion of studied items that were correctly recognized as having been previously presented was used as the measure of recognition memory performance. Replicating the results of prior experiments, (e.g., Gregg, 1976), recognition accuracy was greater for low-frequency (66%) than for high-frequency words (50%), F(1, 17) = 26.68, $MS_e = 163$. Of greater interest, words studied in the degraded typography were more likely to be recognized (62%) than were words studied in the standard lowercase (55%), F(1, 17) = 4.59, $MS_e = 166$, an ordering of conditions that is opposite to that observed in perceptual identification performance. This dissociation of identification and recognition memory performance parallels results reported by Jacoby (1983b). The advantage in recognition memory performance for words that were read in the degraded typography parallels the earlier finding of a recognition memory advantage for words that were generated rather than read, and is also similar to the superior recognition memory for words read in a transformed rather than a normal typography. The dissociation of effects in perceptual identification and recognition memory performance is incompatible with any account that is couched in terms of one set of conditions producing "better" memory than does another set of conditions, and is, perhaps, best interpreted as reflecting the importance of the compatability of study processing with that required by the test of memory (e.g., Jacoby, 1983b; Kolers, 1979; Tulving & Thomson, 1973).

Experiment 3

The degraded words used in the second experiment resulted in less transfer than did the lowercase words. Because the degraded words were too large to be read as a whole, they must in some sense have been read with greater attention given to their constituent letters than is normal in reading. The purpose of the third experiment was to explore the extent to which transfer in perceptual identification depends upon subjects viewing a word as opposed to successively viewing its letters. In one condition, letters from a word were presented one at a time from left to right, with the constraint that no two letters were to be seen simultaneously. Subjects did not actually see a word, at least, in any conventional sense. Instead, they had to infer the word on the basis of its spelling pattern. This procedure was meant to maximally disrupt normal word processing during study and to provide less transfer in a subsequent perceptual identification test than would any word presentation that involved the simultaneous presentation of its letters.

Method

Subjects. A total of 18 volunteers served in a 1-hr session.

Design and materials. The words viewed in the degraded typography in the study session in Experiment 2 were viewed letter by letter in the standard lowercase in Experiment 3. As an example, the sequential presentation of a word, such as nurse, would begin with a 400-ms presentation of the letter n. At the end of the specified interval the letter n would

High

Low

Table 3	
Probability (P) of Perceptual Identification in	Three Study
Conditions: Experiment 3	

Word frequency	Intact		Letter by letter		
	Р	% a	Р	% ^в	New
High Low	.91 .81	91 82	.87 .73	88 75	.84 .58

^a Percentage correctly identified conditionalized for correct naming during study.

be erased and the letter u would be presented one letter position to the right of the position previously occupied by the letter n. The remaining letters were presented in a similar fashion such that the final letter in the word (e) was presented four letter positions to the right of the initial letter. The total time required to view the five-letter words was 5×400 ms, or 2000 ms. Phenomenologically, this display procedure yielded the desired sequential effect. No two letters appeared to exist simultaneously, and each presented letter appeared shifted to the right. As in Experiment 2, the other half of the study words were seen in standard lowercase, with all the letters of a word presented simultaneously.

Procedure. During study, a word was presented on the video screen every 2 s and remained on the screen until replaced by the next word. The two types of word presentation were randomly intermixed. As in the previous experiments, subjects were asked to read the study words as quickly as possible. If the subjects made a mistake in reading a study word, they were told the correct word and the experimenter noted the error for a subsequent conditionalization of the perceptual identification accuracy on reading accuracy in the study session. Words were presented in the standard lowercase at a rate of 35 ms for the test of perceptual identification.

Results and Discussion

The probability of perceptual identification for the three study conditions is displayed separately for high- and low-frequency words in Table 3. Where appropriate, the conditionalized accuracy scores are displayed, in brackets, to the right of the unconditionalized scores. A 3×2 ANOVA (two levels of study plus new, and two levels of word frequency) was performed on the unconditionalized perceptual identification scores. The results of the analysis of the conditionalized data paralleled those of the unconditionalized data, so only the latter will be reported.

In the analysis of the unconditionalized accuracy, there was an interaction between study condition and word frequency, F(2, 34) = 19.55, $MS_e = .003$, a main effect of word frequency, F(1, 17) = 93.29, $MS_e = .008$, and a main effect of study condition, F(2, 34) = 57.79, $MS_e = .004$. The interaction of study condition and word-frequency parallels that found in the first two experiments. Low-frequency words gained more from a prior presentation than did high-frequency words. In a preplanned comparison using a *t* test for the differences between several means it was found that low-frequency words studied intact were identified more accurately than were low-frequency words studied by sequential letter presentation, t(34) = 4.37, which, in turn, were identified more accurately than new lowfrequency words, t(34) = 7.95. For the high-frequency words, words studied intact were more accurately identified than were words studied sequentially, t(34) = 2.41, and new words, t(34) = 3.88. The difference in accuracy between the high-frequency words studied sequentially and new high-frequency words approached but did not attain significance.

General Discussion

Each of the three experiments yielded evidence of specific visual transfer. Words tested in the standard lowercase were more likely to be identified if they had been previously presented in the lowercase rather than in some other visual form. Changes in the appearance of a word between its study and test reduced transfer to approximately two thirds of the amount that was otherwise observed. Reading a word letter by letter (Experiment 3) produced approximately the same amount of transfer to its later identification in lowercase as did reading a degraded version (Experiment 2) or a standard uppercase version (Experiment 1) of the word. This equality in transfer can be taken as evidence that each of the changes was sufficient to totally disrupt configural information that served as a basis for transfer when words were presented and tested in standard lowercase. That is, there was no evidence that the manipulations produced graded transfer, reflecting differences in visual similarity between the study and test versions of a word.

Effects with high-frequency words were inconsistent across experiments. High-frequency words showed nonsignificantly more specific transfer than did low-frequency words in Experiment 1. However, effects for high-frequency words were smaller than those for low-frequency words in the last two experiments and were not significant in the second experiment. This inconsistency of results across experiments is probably due to differences in overall level of performance. In the last two experiments, perceptual identification of new high-frequency words was near ceiling, so only small effects could be obtained. The equipment used to present items for the perceptual identification test did not allow precise enough control of durations to permit us to equate overall performance on high- and low-frequency words. However, the results are sufficient to discourage our original reason for including the manipulation of frequency in the language. We expected much more specific transfer for low-frequency than for high-frequency words. The reasoning was that a more detailed visual analysis of low-frequency words would be required to allow them to be read, and that this further analysis would result in more specific transfer. However, the effect of changing typography was small even for low-frequency words. Significant interactions involving frequency in the language are likely to be difficult to obtain.

Although the results of our experiments are consistent with the claim that perception can rely on memory for prior episodes, those results can also be interpreted as consistent with a claim that reading relies only on a more abstract representation of word shape. Recently, Kirsner, Milech and Standen (1983) proposed two levels of lexical representation: one that is modality specific and one that is modality independent. The proposal of two lexical representations was deemed necessary to account for the reduction but not complete elimination of transfer that is produced by changing the modality of presentation between study and test. Words that differ in modality are said to map onto common modality-independent units but separate modality-specific units, leading to transfer from only the common level of lexical representation. In a later article Kirsner and Dunn (1986) considered revising this analysis by adding a third level of lexical representation that is specific to a particular typography, such as lowercase. By this revised analysis, the advantage of maintaining typography between study and test could be described as due to the study presentation of a word serving to temporarily prime an abstract representation of the word in the particular typeface.

Rather than proposing a new level of abstract lexical representation to account for each manipulation that produces a reduction in transfer, we prefer to emphasize the importance of processing by claiming that perception can rely on memory for prior processing episodes. That is, the observed transfer is seen as reflecting rapid context-specific learning rather than the priming of some preexisting abstract representation. One reason for preferring this view is that the effects of a prior presentation are so persistent as to cause problems for any model that attributes those effects to the temporary priming of some abstract representation (e.g., Jacoby, 1983a). Also, if transfer in word identification does rely on an abstract representation, a representation of that form can apparently be gained very rapidly, perhaps after a single presentation of a word in a particular typeface. As described in the introduction, evidence of specific visual transfer is easily gained when words are presented in an unusual rather than a common orientation or orthography (e.g., Kolers et al., 1980). It seems unlikely that a person begins an experiment designed to investigate the reading of inverted text with an abstract representation of an inverted word in a particular typeface that is available to be primed by an encounter with the word. Some new learning that is specific to the visual details of presented words obviously occurred during the course of those experiments. Emphasis seems better placed on new learning, the modification of memory representations by recent experience, rather than on static abstract representations.

An emphasis on processing encourages investigation of the possibility that the magnitude of specific visual practice effects depends on task demands at study. Although significant, the effects of word shape observed in our experiments were relatively small. It may be possible to increase the magnitude of those effects by making typeface relevant for the task that subjects engage in during study. In an investigation of recognition memory, Hock, Throckmorton, Webb, and Rosenthal (1981) manipulated the task that subjects engaged in during study such that the typeface of a presented item was made relevant to the task under one set of conditions but irrelevant under another set of conditions. A change in typeface between study and test produced a larger reduction in later recognition memory performance when typeface had been relevant for the prior task. Jacoby and Brooks (1984) found similar results in an investigation of picture identification. In their experiment, a picture presented for a test of perceptual identification was either identical to a picture that had been previously presented (identical) or shared the name of a previously presented picture but was not

identical to that picture (same name). As an example of the same name condition, a picture of a dog was presented for study and then a picture of a different dog was presented for the test of perceptual identification. The advantage in perceptual identification of identical pictures over same name pictures was greater after a study task that required subjects to deal extensively with the visual details of presented pictures rather than simply to name those pictures. Many of the theoretical issues surrounding the role of memory for visual details in picture identification are the same as those surrounding the use of word shape in word identification (Jacoby & Brooks, 1984).

Specifying sources of transfer in word identification and finding the combination of conditions that maximizes the storage and use of word shape in reading remains a challenge for future research. However, the results of the experiments reported here do provide evidence that stored visual details play a role in word identification. Although the effects were small, the implications of a fast learning mechanism that serves as a basis for effects of specific visual practice in word identification are too important to be ignored.

References

- Adams, M. J. (1979). Models of word recognition. Cognitive Psychology, 11, 133-176.
- Brooks, L. R. (1977). Visual pattern in fluent word identification. In A. S. Reber & D. L. Scarborough (Eds.), *Toward a psychology of read*ing (pp. 143–181). Hillsdale, NJ: Erlbaum.
- Coltheart, M., & Freeman, R. (1974). Case alternation impairs word identification. The Bulletin of the Psychonomic Society, 3, 102-104.
- Feustel, T. C., Shiffrin, R. M., & Salasoo, A. (1983). Episodic and lexical contributions to the repetition effect in word identification. *Journal* of Experimental Psychology: General, 112, 309–346.
- Gregg, V. (1976). Word frequency, recognition and recall. In J. Brown (Ed.), *Recall and recognition* (pp. 183–216). London: Wiley.
- Haber, R. N., & Schindler, R. M. (1981). Errors in proofreading: Evidence of syntactic control of letter processing? Journal of Experimental Psychology: Human Perception and Performance, 7, 573–579.
- Hock, H. S., Throckmorton, B., Webb, E., & Rosenthal, A. (1981). The effect of phonemic processing on the retention of graphemic representations for words and nonwords. *Memory & Cognition*, 9, 461– 471.
- Jacoby, L. L. (1983a). Perceptual enhancement: Persistent effects of an experience. Journal of Experimental Psychology: Learning, Memory, and Cognition, 9, 21–38.
- Jacoby, L. L. (1983b). Remembering the data: Analyzing interactive processes in reading. *Journal of Verbal Learning and Verbal Behavior*, 22, 485-508.
- Jacoby, L. L., & Brooks, L. R. (1984). Nonanalytic cognition: Memory, perception and concept learning. In G. Bower (Ed.), *The psychology* of learning and motivation (Vol. 18, pp. 1–47). New York: Academic Press.
- Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, 3, 306-340.
- Kirsner, K., & Dunn, J. (1986). The perceptual record: A common factor in repetition priming and attribute retention. In M. I. Posner & O. S. M. Marin (Eds.), Attention and performance XI (pp. 547-565). Hillsdale, NJ: Erlbaum.
- Kirsner, K., Milech, D., & Standen, P. (1983). Common and modalityspecific coding in the mental lexicon. *Memory & Cognition*, 11, 621– 630.

Kolers, P. A. (1973). Remembering operations. *Memory & Cognition*, 3, 347–355.

- Kolers, P. A. (1979). A pattern-analyzing basis for recognition memory. In L. S. Cermak & F. I. M. Craik (Eds.), *Levels of processing and human memory* (pp. 363-384). Hillsdale, NJ: Erlbaum.
- Kolers, P. A., Palef, S. R., & Stelmach, L. B. (1980). Graphemic analysis underlying literacy. *Memory & Cognition*, 8, 322–328.
- Kolers, P. A., & Roediger, H. L. (1984). Procedures of mind. Journal of Verbal Learning and Verbal Behavior, 23, 425–449.
- Masson, M. (1986). Identification of typographically transformed words: Instance-based skill acquisition. Journal of Experimental Psychology: Learning, Memory, and Cognition, 12, 479-488.
- McClelland, J. L. (1977). Letter and configural information in word identification. Journal of Verbal Learning and Verbal Behavior, 16, 137-150.
- Monk, A. F., & Hulme, C. (1983). Errors in proofreading: Evidence for the use of word shape in word recognition. *Memory & Cognition*, 11, 16-23.

Morton, J. (1979). Facilitation in word recognition: Experiments caus-

ing change in the logogen model. In P. A. Kolers, M. E. Wrolstal, & H. Bouma (Eds.), *Processing of visible language*. New York: Plenum,

- Papp, K. H., Newsome, S. L., & Noel, R. W. (1984). Word shape's in poor shape for the race to the lexicon. *Journal of Experimental Psy*chology: Human Perception and Performance, 10, 413–428.
- Rudnicky, A. I., & Kolers, P. A. (1984). Size and case of type as stimuli in reading. Journal of Experimental Psychology: Human Perception and Performance, 10, 231–249.
- Scarborough, D., Cortese, C., & Scarborough, H. (1977). Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance*, 3, 1-17.
- Thorndike, E. L., & Lorge, I. (1944). The teaching wordbook of 30,000 words. New York: Columbia University.
- Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, 80, 352– 373.

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