Running head: Word and pseudoword priming

Different perceptual codes support priming for words and pseudowords: Was Morton right all along?

Jeffrey S. Bowers

Rice University

Abstract

A perceptual identification task was used to assess priming for words and pseudowords that in their upper- and lower-case formats either share few (high-shift items) or many (low-shift items) visual features. Equivalent priming was obtained for high-shift words repeated in the same- and different-case, and this priming was greatly reduced when there was a study/test modality shift. Accordingly, the cross-case priming was mediated, in large part, by modality specific perceptual codes. By contrast, priming for high-shift pseudowords was greatly reduced following the case manipulation, as was the case with high-shift words when they were randomly intermixed with pseudowords. Low-shift items were not affected by the case manipulation. Based on the overall pattern of results, I argue that different mechanisms mediate priming for words and pseudowords, and that J. Morton (1979) was essentially correct in his characterization of word priming.

Different perceptual codes support priming for words
and pseudowords: Was Morton right all along?

Recently, a great deal of interest has focused on repetition priming phenomena. Repetition priming occurs when exposure to words or other items facilitates later performance on those items in a task that does not make direct reference to the past study episode, such as the word-stem completion (e.g., Graf, Mandler, & Haden, 1982) and word perceptual identification tasks (Jacoby & Dallas, 1981), among others. For example, participants are better able to identify words flashed quickly on a computer screen in the perceptual identification task when the same words were studied a few minutes earlier. Priming is often expressed when participants are unaware of the relation between the priming task and the prior study episode, and consequently, it has been considered an implicit as opposed to an explicit form of memory (Graf & Schacter, 1985).

Although many theoretical accounts of priming have been advanced, they can nevertheless be divided into two general camps. According to the first, priming reflects the activation and/or modification of pre-existing memory representations. A number of students of human memory have adopted this position (e.g., Diamond & Rozin, 1984; Dorfman, 1994; Graf & Mandler, 1984), but the chief advocates of this approach are found within the discipline of psycholingistics (e.g., Feldman & Moskovljevic, 1987; Monsell, 1985, 1987; Morton, 1969, 1979; Napps, 1989). One of the classic versions of this approach was proposed by Morton (1979), who argued that priming for visually displayed words reflects the modification of so-called logogen units -- orthographic representations of words that serve as access codes to semantic and phonological knowledge. On this theory, a by-product of reading a word is that its orthographic representation is strengthened, and this in turn facilitates its subsequent identification; thus priming is obtained. For purposes of exposition, the view that priming is mediated by pre-existing orthographic codes is labeled the modification approach[1].

In support of this approach, priming for words is often constrained by the lexical status of the study/test items. For example, robust priming is obtained between morphological relatives (e.g., cars/car; e.g., Napps, 1989;), and critically, these effects cannot be attributed to the perceptual, phonological, or semantic similarity of these items, because little or no priming is obtained between perceptually related words (e.g., card/car; Napps, 1989), between phonologically related items (e.g., ate/eight; Neisser, 1954; Murrell & Morton, 1974) or between semantically related items, such as synonyms (e.g., sofa/couch; Roediger & Challis, 1992), translation equivalents (e.g., chein/dog in a French/English bilingual; Kirsner & Dunn, 1985), or pictures and their corresponding names (e.g., Roediger & Weldon, 1987)[2]. In addition, robust priming is obtained between cognates (e.g., crema/cream; Cristoffanini, Kirsner, & Milech, 1986), and once again, the effects cannot be attributed to the visual or phonological or semantic overlap of these study/test items. These results provide support for modification theories because it is often argued that morphological and cognate relationships are represented within the orthographic system (e.g., Caramazza, Laudanna, & Romani, 1988; Chomsky & Halle, 1968).

Furthermore, there is a variety of evidence that both word priming and word reading are mediated by modality specific representations that are perceptually abstract -- i.e., modality specific codes that treat all tokens of a given word as functionally equivalent -- suggesting that common representations support both phenomena. Perhaps the most striking demonstration that priming is mediated by abstract codes was reported by Brown, Sharma and Kirsner (1984), who assessed priming for words displayed in Hindi/Urdu scripts: The spoken forms of these scripts are identical under normal circumstances, but their written forms are unrelated. Employing the lexical decision task, they observed similar, nonsignificantly different, amounts of priming when items were studied and tested in the same (113 ms) and different (93 ms) script conditions. Similar cross-script priming has been reported between the Cyrillic/Roman scripts of Serbo-Croatian (Feldman & Moskovljevic, 1987) and the Hiragana/Katakana scripts of Japanese, although a significant decrement in priming was obtained when study/test items were presented in the Hiragana/Katakana scripts, respectively, but not vice versa (Komatsu & Naito, 1992). More generally, numerous studies have found priming to be insensitive to various manipulations in the visual format of words in English (e.g., Carr, Brown, & Charalambous, 1989; Clarke & Morton, 1983; Feustel et al., 1983; Scarborough, Cortese, & Scarborough, 1977), although the perceptual changes in these latter studies were not as great as those mentioned above[3]. At the same time, changes in the modality of study-test items greatly reduce priming effects (e.g., Bowers, 1994; Jacoby & Dallas, 1981; but see Komatsu & Naito, 1992), suggesting that cross script priming is the product of modality specific perceptual codes rather than semantic or phonological representations. Consistent with these priming results, there is a variety of evidence that reading involves access to orthographic representations that are coded in a modality specific but perceptually abstract format (e.g. Besner, Coltheart, & Davelaar, 1984; Bowers, Arguin, & Bub, in press; Bowers, Bub, & Arguin, in press; Coltheart, 1981; Evett & Humphreys, 1981; McClelland, 1976; Rayner, McConkie, & Zola, 1980). Thus, once again, it is tempting to conclude that orthographically abstract representations mediate word priming.

However, according to the second theoretical position, priming is the product of new memory representations acquired during a single study episode (e.g., Jacoby, 1983; Schacter, 1990; Tulving & Schacter, 1990); henceforth, this approach is labeled the acquisition account. These theories generally adopt the principle of transfer-appropriate-processing according to which priming -- and memory in general -- is a function of the similarity between the encoding and retrieval operations at study and test (Morris, Bransford, & Franks, 1977; Tulving Thomson, 1973). For example, Schacter (1990) argues that priming is mediated by transfer-appropriate-processes embedded within perceptual systems that represent the structure of words and objects, but do not represent the semantic or phonetic information about them -- the so-called word form and the structural description systems, respectively. On this view, a new memory trace is created within one of these perceptual systems following a study episode, and this new trace facilitates performance on priming tasks to the extent that the critical perceptual properties of study/test items overlap. To date, many different acquisition theories have been proposed (Jacoby, 1983, Masson & Freedman, 1990; Roediger & Blaxton, 1987, 1992; Schacter, 1990, 1992; Squire, 1987; Tulving & Schacter, 1990), but they all share the fundamental assumption that new memory representations mediate priming.

At least two forms of evidence can be marshaled in support of this latter approach. First, priming extends to novel materials, including unfamiliar objects (e.g., Schacter, Cooper, & Delaney, 1990), novel line patterns (e.g., Musen & Triesman, 1990), pseudowords (e.g., Bowers, 1994; Feustel Shiffrin & Salasoo, 1983; Haist, Musen & Squire, 1991), and perhaps random letter strings (Bowers, 1994). These items are not represented in memory as a unit prior to an experimental encounter with them, and accordingly, priming for these materials is often thought to reflect new representations acquired during the study episode. Second, whenever words are displayed in unusual viewing conditions at study and/or test, priming tends to be greatest when the identical perceptual features are repeated, and reduced otherwise (e.g., Graf & Ryan, 1990; Kolers, 1975; Masson, 1986). For example, Masson (1986) presented words at study and test in mixed case letters (e.g., KeTtLe) and mirror reversed. Priming was greatest when study and test words were presented in the identical perceptual condition compared to a condition in which the case of the letters were switched (e.g., KeTtLe/kEtTlE). These latter results suggest that priming is mediated by new memory codes that represent the idiosyncratic perceptual details of the study words (for review of the modification/acquisition debate, see Tenpenny, 1995).

Clearly, these latter results support the conclusion that priming for some types of materials is mediated by newly acquired representations. However, these results are often used as evidence that priming for all materials -- including normally displayed words -- is the product of new representations. Indeed, the motivation for assessing priming for novel materials is often stated by the authors themselves as an attempt to evaluate the soundness of modification theories, and when priming is obtained for these items, the approach is rejected outright (e.g., Cermak, Blackford, O'Connor, & Bleich, 1988; Feustel et al., 1983; Haist et al., 1991; Musen & Squire, 1991; Schacter et al., 1990). It is important to note, however, that this strong version of the acquisition approach rests upon an assumption that is rarely examined; namely, that the same types of representations underlie priming for all types of materials. If this assumption is proven false, then modification and acquisition theories are not mutually incompatible. In this latter case, it is possible that priming for novel materials (this includes familiar words displayed in novel formats, such as mirror reversed words) is mediated by newly-acquired memory representations (e.g., Schacter, 1990), and priming for normally displayed words is mediated by pre-existing orthographic codes (e.g., Morton, 1979).

Not only does the strong version of the acquisition approach rely on an untested assumption, but furthermore, it is difficult to maintain this position given the previous evidence cited in support of modification theories. For example, according to one version of the acquisition approach, priming for words is obtained to the extent that the perceptual features of study/test items overlap (e.g., Roediger & Blaxton, 1987; Schacter, 1990; Tulving & Schacter, 1990). The problem with this account, however, is that robust priming is obtained between study/test words that are displayed in radically different visual formats (e.g., Brown et al., 1984). And theories that attribute abstract word priming to newly acquired representations within conceptual (e.g., Masson & Freedman, 1990; Komatsu & Naito, 1992) or phonological systems (e.g., Kirsner, Dunn, & Standen, 1989) have difficulty accommodating the modality specific nature of priming (Jacoby & Dallas, 1981; Jackson & Morton, 1982). The morphological and cognate priming results pose similar problems for these acquisition theories.

Given the various forms of evidence cited in support of both modification as well as acquisition theories, it is not unreasonable to argue that priming reflects the modification of pre-existing information under some circumstances, and the acquisition of new information under other circumstances. More specifically, when words are displayed in a normal format, and thus gain normal access to the orthographic system, then priming may be mediated by pre-existing orthographic codes, consistent with the view of Morton (1979). But when materials cannot gain normal access to the orthographic system -- for example, pseudowords and words displayed in unfamiliar formats -- then priming may reflect newly acquired representations, consistent with the acquisition approach (e.g., Roediger & Blaxton, 1987; Schacter, 1990).

If indeed different mechanisms mediate priming for normally displayed words on the one hand, and various novel materials on the other, then it should be possible to dissociate the priming effects obtained with these two sets of materials. In an attempt to obtain such a dissociation, the experiments reported below assessed priming for words and pseudowords when the perceptual features of the items were either identical or dissimilar at study and test. To the extent that abstract orthographic codes mediate priming for words, then the priming for words in the following experiments should be equivalent regardless of the perceptual overlap of the study/test items. By contrast, to the extent that newly-acquired perceptual representations mediate priming for novel materials, then the priming for pseudowords should be reduced when the items are perceptually dissimilar at study and test.

Experiment 1

Past experiments that have assessed priming between visually dissimilar words have employed non-English scripts -- i.e., Hindu/Urdu, Roman/Cyrillic, and Katakana/Hiragana scripts. However, it is important to note that a small set of words in English can also be written in two dissimilar formats. This follows from the fact that a number of letters in the alphabet are visually distinct in their upper- and lower-case forms; for example, the letters, a/A, d/D, e/E, g/G, n/N, q/Q, r/R (Boles & Clifford, 1989). It is just a historical accident that these specific visual forms are matched together, and the pairings could have been different; for instance, there is no obvious reason why d/D are matched together instead of q/D. The arbitrary mapping of visual features onto common letters is critical to the present experiments, because it makes it possible to construct English words that are visually dissimilar, i.e. read/READ.

The above letters contrast with another set of letters that share a strong resemblance in their upper- and lower-case forms; for example, the letters c/C, i/I, o/O, p/P, s/S, u/U, and w/W (Boles & Clifford, 1989). Of course, words composed from this latter set of letters are similar when presented in their upper- and lower-case forms, i.e., soup/SOUP. Words that differ greatly in upper- and lower-case formats will be labeled high-shift words, and words that do not change substantially in their upper- and lower-case formats will be labeled low-shift words.

Given the existence of high- and low-shift words, it is possible to assess priming for words that share a few or many perceptual features in upper- and lower-case formats. A reasonable expectation is that robust priming will be obtained for the low-shift words following a change in letter case, because this manipulation does not substantially change the visual features of the items. The critical question is whether robust priming will be obtained for the high-shift words following a change of letter case. If cross-case priming is obtained for the latter set of words, this would replicate the results obtained between Hindi/Urdu, Roman/Cyrillic, and Katakana/Hiragana scripts, supporting the modification position.

Method

Participants. Forty-eight University of Arizona undergraduates participated in the experiment for course credit.

Design and Materials. The experiment included two within-subject factors: Stimulus Type (high-shift vs. low-shift words), and Study/Test Condition (studied/tested in same-case vs. studied/tested in different-case vs. nonstudied/tested). Consequently, the experiment was a 2x3 within-subjects design.

The materials consisted of 30 high-shift words (median frequency = 20, range = 1-59 occurrences per million) and 30 low-shift words (median frequency = 16, range = 2-72 occurrences per million) selected from the Kucera and Francis (1967) norms. All words were four letters in length, and in order to be included in the high- and low-shift conditions, words were required to contain at least three letters from the appropriate set. That is, high-shift words contained at least three letters from the set: a, d, e, g, n, q, and r, and low-shift words contained at least three letters from the set: c, i, o, p, s, u, w. See Appendix A for list of high- and low-shift words.

During the study phase, participants studied 20 high-shift words and 20 low-shift words; half of the items in each condition were presented in upper-case letters, and half were presented in lower-case letters. The remaining 10 high-shift words and 10 low-shift words were not studied; they were included on the perceptual identification task in order to determine baseline levels of performance. Consequently, the perceptual identification task consisted of 60 critical items: 40 studied items (20 high-shift and 20 low-shift) and 20 nonstudied items (10 high-shift and 10 low-shift). Three test forms were created so that each high- and low-shift word could be studied in upper-case letters, lower-case letters, or nonstudied equally often, yielding a fully counterbalanced design. High- and low-shift words were displayed in a different random order for each participant during the study task, whereas items were presented in the same order to all participants in the perceptual identification task, with high- and low-shift words randomly intermixed. The fixed presentation order in the identification task was included so that the experimenter could assess the accuracy of participants' responses. All words were presented in lower-case format at test.

Procedure. The experiment was conducted under conditions of incidental encoding: Participants were told that they were participating in an experiment concerned with word perception, and they were not informed that study items were repeated in the perceptual identification task. Items were presented on a Princeton Ultrasync color monitor controlled by a 386 IBM PC, using the DMASTER display software developed at Monash University and at the University of Arizona, which synchronizes the timing of the display with the video raster.

Standard IBM text font was used. Participants were tested individually.

In order to insure that floor and ceiling effects did not obscure repetition effects, I attempted to determine an exposure duration for each participant that resulted in an identification rate of approximately 50% for nonstudied words. To this end, participants were presented with an initial identification task that assessed their ability to identify a set of practice words, all of which were all different from the critical set of words. On each trial, the target item was immediately preceded and followed for one second by a mask ( ) created by a series of four ALT-206 ASCII characters. Participants were encouraged to name the first four letters that came to mind after the letters flashed on the computer screen, and to respond as quickly as possible. The emphasis on responding quickly and naming the first letters that came to mind was intended to minimize explicit memory strategies that participants might otherwise adopt during the completion of this task (for a discussion of this issue, see Bowers & Schacter, 1990; Schacter, Bowers, & Booker, 1989). Based on their performance on this initial task, participants were assigned to the slow, medium or fast version of the experiment. Exposure times for words were 35, 30, and 27 ms in the slow, medium, and fast conditions, respectively.

In the study phase, words were displayed for 5 seconds each, and participants were asked to pronounce the words aloud, and then count the number of vowels and enclosed spaces in the item (an enclosed space was defined as an area within a letter that can be colored in, for example, the letter "B" has two enclosed spaces). Following the encoding task, participants completed the perceptual identification task. The identification task contained ten practice items followed by 60 target items, although participants could not distinguish between practice and target items. Both practice and target items were presented for an exposure duration determined in the first part of the experiment, and once again, the items were immediately preceded and followed for one second by the pattern mask ( ). As in the initial identification task, subjects were asked to quickly name the first four letters that came to mind.

Results

The results of Experiment 1 are presented in Table 1. As expected, similar priming was obtained for low-shift words studied and tested in the same (.20) and different (.17) format conditions, respectively. The critical result is that a similar amount of priming was also obtained for high-shift words studied and tested in the same (.18) and different (.16) letter case conditions. Two Analyses of Variance (ANOVA) were carried out on the priming data (difference scores for studied and nonstudied items), one treating subjects as a random factor, and the other treating items as the random factor. A 2x2 ANOVA that included Stimulus Type and Study/Test Condition as factors failed to reveal any significant effects on the subject analysis [all $F1(1,45)$ values < 1.8, MSe values > 611.08, p values $> .18$], or on the item analysis [all $F2(1,58)$ values <1], indicating that similar priming was obtained in all conditions. In order to determine whether the priming results were significantly above baseline in the various experimental conditions, a series of simple contrasts were carried out. Priming was significant in all cases [all $t1(47)$ values > 5.77; all $t2(29)$ values > 3.16, p values $< .01$].

Discussion

The key result of Experiment 1 is that word priming was insensitive to the case manipulation, even for high-shift words that share few visual features in common in upper- and lower-case, e.g. READ/read. These results, in combination with the cross-script priming obtained with Hindi/Urdu, Roman/Cyrillic, and Hiragana/Katakana scripts, provide strong evidence that word priming is abstract within the visual modality as long as words are displayed in a normal type font[4].

Given that robust priming is obtained between study/test words that share few visual features in common, the view that word priming reflects the perceptual overlap between study/test items can be rejected (Schacter, 1990; Roediger & Blaxton, 1987). It is worth noting that most reports of cross-case priming do not permit such a strong conclusion. In the typical experiment, abstract priming was assessed by changing the case of words at study and test, and no consideration was given to the perceptual similarity of the component letters in upper- and lower-case (e.g., Brown & Carr, 1993; Feustel et a., 1983, Scarborough et al., 1977). Because most letters in the alphabet are perceptually similar in upper- and lower-case, the perceptual overlap between these words was probably quite high. Accordingly, it could be argued that the cross-case priming obtained in these experiments was due to invariant perceptual features of the study/test words. This sort of argument has been used to explain the abstract priming obtained between study/test objects that differ in size (Biederman & Cooper, 1992; Schacter, Cooper, Delaney, Peterson, & Tharan, 1991), in position (Biederman & Cooper, 1991), and in orientation (Biederman & Gerhardstein, 1993; but see Srinivas, 1993). But given the present results -- as well as the Hindi/Urdu, Roman/Cyrillic, and Hiragana/Katakana results -- this argument is difficult to maintain for words. Instead, the results support the conclusion that priming for words is mediated by orthographically abstract representations.

Experiment 2

If the same mechanisms mediate priming for words and pseudowords, then priming for pseudowords should also be unaffected by perceptual manipulations within the orthographic domain. Consistent with this view, Feustel et al. (1983) reported equivalent priming for words and pseudowords in a perceptual identification task when study/test items were repeated in the same- and different-case. Similarly, Carr et al. (1989) assessed priming for pseudowords in a reading task in which pseudowords were organized into paragraphs -- so-called "Jabberwocky" paragraphs. Paragraphs were read twice, and priming was measured as the reduction in time needed to read repeated paragraphs. The authors obtained priming for the Jabberwocky paragraphs, and critically, the priming was insensitive to variations in the visual format of the study/test pseudowords: Equal priming was obtained between typed/typed paragraphs, and handwritten/typed paragraphs. More recently, Brown and Carr (1993) reported priming for a list of individually displayed words and pseudowords in a naming task, and they found priming to be insensitive to the perceptual overlap of the study/test items when test items were presented in a familiar type font. Finally, Dorfman (1994) reported priming for pseudowords to be insensitive to a case manipulation when priming was assessed with a word judgment task in which participants rated pseudowords in terms of their "word-likeness".

Although pseudoword priming in the above studies was insensitive to perceptual manipulations, it is important to note the these results are not equivalent to the abstract priming observed between perceptually unrelated study/test words (e.g., Brown et al., 1984). In the pseudoword studies, the visual structure of the items was varied by presenting pseudowords in upper/lower-case formats or in script/typed formats (or vice versa). But since most typewritten letters are similar in upper- and lower-case formats, and this is also true for letters presented in script and type, it is likely that many of the pseudowords shared invariant perceptual features at study and test. In order to provide a stronger test of whether priming for pseudowords is insensitive to case manipulations, it is necessary to assess priming for pseudowords that share few perceptual features at study and test, i.e., high-shift pseudowords (e.g., NEGA/nega). If in fact cross-case priming for high-shift pseudowords is equivalent to within-case priming, then clearly, priming for words and pseudowords is equally abstract. Experiment 2 assessed this possibility.

Method

Participants. Forty-eight University of Arizona undergraduates participated in the experiment for course credit.

Design and Materials. The experiment included two within-subject factors: Stimulus Type (high-shift vs. low-shift pseudowords) and Study/Test Condition (studied/tested in same-case vs. studied/tested in different-case vs. nonstudied/tested). Consequently, the experiment was a 2x3 within-subjects design.

The materials consisted of 30 high-shift and 30 low-shift pronounceable pseudowords. All items were four letters in length, and in order to be included in the high- and low-shift conditions, pseudowords were required to contain at least three of the four critical letters, as in Experiment 1. See Appendix B for a list of high- and low-shift pseudowords. The counterbalancing scheme was the same as in Experiment 1.

Procedure The experiment employed the same basic procedure as Experiment 1. Participants first completed an identification task for pseudowords in which they named the first four letters that came to mind. Based on their performance, participants were placed into the slow, medium or fast version of the experiment. Exposure durations were 50, 45, and 40 ms in the slow, medium, and fast conditions, respectively. In the study phase of the experiment, pseudowords were displayed for 5 seconds each, and participants were asked to pronounce the pseudowords aloud and count the number of vowels and enclosed spaces in each item. Finally, participants completed the perceptual identification task by naming the first four letters that came to mind. There was no overlap in the set of pseudowords used in the initial and main identification tasks.

Results

The results of Experiment 2 are presented in Table 2. As was the case with words, a similar amount of priming was obtained for low-shift pseudowords studied and tested in the same- (.10) and different- (.09) case. The critical result is that more priming was obtained for high-shift pseudowords studied and tested in the same- (.21) compared to different- (.13) case, which contrasts with the cross-case priming results obtained with high-shift words. Consistent with this characterization of the data, a 2x2 ANOVA carried out on the priming data revealed a marginally significant interaction between the Study/Test Condition x Stimulus Type in the subject analysis, [$F1(1, 45) = 3.82$, $MSe = 166.84$, $p < .06$], although this interaction did not achieve significance in the item analysis, [$F2(1,58) = 1.8$, $MSe = 225.54$, $p = .19$]. Note, the failure to obtain a significant interaction on the item analysis may be attributable to the small number of items per condition for each subject (n=10). Critically, a simple contrast comparing within- vs. cross-case priming for high-shift pseudowords was significant on the subject analysis, [t1(47) = 3.01, p <.01], and approached significance on the item analysis, [t2(29) = 1.89, p < .07], again indicating that priming for these items was reduced following the case manipulation. In order to determine whether priming was significantly above baseline in the various experimental conditions, a series of t-tests were carried out. Priming was significant in all cases, [all t1(47) values > 3.52, p values < .01; all t2(29) values > 2.44, p values < .05].

Finally, the overall analysis revealed a main effect of Stimulus Type in the subject analysis [$F(1,45) = 53.2$, $MSe = 166.84$, $p < .05$] and it approached significance in the item analysis [$F(1, 58) = 2.09$, $MSe = 830.48$, $p = .15$], reflecting the greater overall priming for the high-shift compared to low-shift pseudowords. The reason for this latter result is unclear, and presumably reflects uncontrolled differences between high- and low-shift items. One finding consistent with this conclusion is that students had more difficulty identifying high- (.38) compared to low- (.44) shift pseudowords in the baseline condition. The elevated baseline for low-shift items may have contributed to the reduced priming for these items. Whatever the reason for the reduced priming, it must be admitted that this result weakens the claim that high- and low-shift pseudoword are differentially sensitive to the case manipulation. It is possible, for example, that case specific priming would have emerged if more priming had been obtained for low-shift pseudowords in the same-case condition. That is, specificity effects may have been eliminated by a functional ceiling that reduced cross- as well as within-case priming. Note, if future research shows that case-specific priming extends to low-shift pseudowords, this would strengthen, rather than diminish, the distinction between word and pseudoword priming.

Discussion

In contrast with the abstract priming obtained with high-shift words in Experiment 1, priming for high-shift pseudowords was reduced when items were studied and tested in a different-case. As noted above, it is often assumed that similar mechanisms mediate priming for words and pseudowords, but given this dissociation, there is reason to argue that different representations support priming for the different items.

The failure to obtain equivalent within- and cross-case priming for high-shift pseudowords contrasts with the abstract results reported by Brown and Carr (1993), Carr et al. (1989), Dorfman (1994), and Feustel et al. (1983). It is important to emphasize, however, that the high-shift pseudowords in the present study share few perceptual features in upper/lower-case, whereas the pseudowords in the earlier studies were presumably more similar in the different formats. Accordingly, these contrasting results may indicate that priming for pseudowords is only case insensitive under a limited set of conditions; namely, when the study/test items share invariant perceptual properties. Consistent with this interpretation, equivalent within- and cross-case priming was obtained in the present experiment for low-shift pseudowords.

Of course, it is always possible that some factor other than lexical status was responsible for the contrasting results obtained in Experiment 1 and 2. In an attempt to assess the role of two possible factors, I compared high-shift words and high-shift pseudowords in terms of their bigram frequency and syllable structure. The mean bigram frequency of words summed across positions was similar for words (143) and pseudowords (115; Mayzner & Tresselt, 1965), but there was a discrepancy in the number of multi-syllable words (3/30) compared to pseudowords with an obvious multi-syllable reading (12/30). As is discussed below, however, priming for high-shift words was also insensitive to a case manipulation in Experiment 4 that included 12/48 multiple syllable high shift words. Thus, there is no indication that the syllable or bigram properties of words and pseudowords can account for the contrasting results, consistent with the claim that their lexical status was responsible.

In order to account for the present results, I would like to argue that word and pseudoword priming is largely mediated by abstract orthographic codes (e.g., Morton, 1979), and newly acquired perceptual representations (e.g., Schacter, 1990), respectively. Note, the cross-case priming obtained with low-shift pseudowords (and the pseudowords in the above mentioned studies) does not compromise this claim, because these items share invariant perceptual features in their two formats. Thus, the cross-case priming between JUSS/juss, for example, need not reflect repeated access to an abstract orthographic code, but rather, may reflect repeated access to a specific perceptual code that treats the two items equivalently.

Although I want to argue that perceptually specific representations played an important role in the above pseudoword priming results, I should emphasize that the results do not support the strong conclusion that pseudoword priming is exclusively mediated by these codes. Indeed, given the significant cross-case priming obtained for high-shift pseudowords, it is necessary to conclude that a system other than the perceptually specific system played a role in the priming. It is possible, for example, that phonological codes (Kirsner et al., 1989) or episodic memory (cf. Bowers & Schacter, 1990) contributed to the pseudoword priming. It is also possible that this priming was mediated by abstract sub-lexical (as opposed to lexical) orthographic codes that pseudowords contact (cf. Peterson , Fox, Posner, Mintun, Raichle, 1989; Rugg & Nagy, 1987). For example, the pseudoword NEGA may access and strengthen the sub-lexical code NEG that is common to NEGATIVE, NEGLECT, NEGOTIATION, etc., and this sub-lexical code supported the cross-case priming for NEGA (cf. Bowers, 1994). In fact, Dorfman (1994) has argued that all pseudoword priming reflects the modification of sub-lexical representations that are case-independent. I would suggest that this latter conclusion is unwarranted, given that priming for high-shift pseudowords was sensitive to a case manipulation, and given recent evidence that priming extends to illegal nonwords that do not have sub-lexical representations (Bowers, 1994). Nevertheless, it is possible that sub-lexical codes supported the cross-case priming for high-shift pseudowords, and that perceptually specific representations supported the case-specific component of priming.

Whatever the proper explanation for the intact cross-case priming for high-shift pseudowords, I want to emphasize that priming for these items was significantly reduced following the case manipulation, whereas under identical test conditions, priming for high-shift word was not. This contrast suggests that different underlying representations play different roles in supporting word and pseudoword priming. Given that the contrasting results were obtained across studies, however, additional evidence is required before any strong conclusions are warranted.

Experiment 3

The numerous reports of abstract word priming, including the results of Experiment 1 and its replication, are consistent with the claim that word priming is mediated, in large part, by abstract perceptual codes. However, the conclusion that perceptually specific representations play a key role in pseudoword priming is based solely on the results of Experiment 2. In order to assess the reliability of these findings, Experiment 3 assessed priming for high-shift words and high-shift pseudowords within the same experiment.

Method

Participants. A group of 48 University of Arizona undergraduate students participated in the experiment for course credit.

Design, materials and procedure The experiment included two within-subject factors: Stimulus Type (words vs. pseudowords) and Study/Test Condition (studied/tested in same-case vs. studied/tested in different-case vs. nonstudied/tested). Therefore, the experiment was a 2x3 within-subjects design.

The experiment included the same set of high-shift words and pseudowords from Experiments 1-2, while the low-shift items were dropped. Participants studied 20 high-shift words and 20 high-shift pseudowords, with half of the items presented in upper-case, and half in lower-case. The remaining items were not studied; they were included on the identification task in order to determine baseline levels of performance for high- and low-shift items. In order to present each item in the various experimental conditions, three experimental files were created, yielding a fully counterbalanced design. As above, items were presented in a different random order for each participant during the study task, and in the same random order during the perceptual identification task, with items presented in lower-case format.

The procedure in Experiment 3 was similar to the previous experiments. Participants first completed an identification task that included words and pseudowords, and based on their performance, they were placed into the slow, medium or fast version of the experiment. Exposure times for words and legal pseudowords were 35 vs. 52.5, 30 vs. 45, and 27 vs. 40 ms in the slow, medium, and fast conditions, respectively. Then, just as above, participants studied items and completed the perceptual identification task.

Results

The results of Experiment 3 are presented in Table 3. As was the case in Experiment 2, more priming was obtained for high-shift pseudowords when items were studied and tested in the same- (.17) compared to the different- (.06) case. Accordingly, the conclusion that pseudoword priming is perceptually specific is supported by the present data. In contrast with abstract priming results in Experiment 1, however, words studied and tested in the same-case (.11) were better identified than in the different-case (.05). A 2x2 ANOVA carried out on the priming data revealed a main effect of the Study/Test Condition on the subject analysis, [$F1(1,45) = 14.35$, $MSe = 232.29$, $p < .001$] and item analysis [$F2(1,58) = 6.23$, $MSe = 334$, $p < .05$], indicting priming was reduced in the cross-case condition. Although there is some indication that the pseudoword priming was more affected by case manipulation than word priming, the interaction between Study/Test Condition x Stimulus Type for the priming effects did not achieve significance on the subject analysis [$F1(1, 45) = 2.31$, $MSe = 1152.29$, $p = .14$], nor on the item analysis, [$F2(1, 58) < 1$]. Consistent with this analysis, simple contrasts comparing within- vs. cross-case priming for pseudowords revealed a significant difference on both the subject and item analyses [$t1(47) = 4.76$, $p < .01$; $t2(58) = 2.4$, $p < .05$], whereas the difference for words only achieved significance on the subject analysis [$t1(47) = 2.43$, $p < .05$; $t2(58) = 1.19$, $p > .2$].

In order to determine whether priming was significantly above baseline in the various experimental conditions, a series of t-tests were carried out. Same-case priming was significant for words and pseudowords on both the subject and item analyses [$t1(47)$ values > 4.76, $t2(29)$ values > 2.3, p values < .05], whereas cross-case priming for words and pseudowords was significant on the subject analysis [$t1(47)$ values > 2.34, p values < .05] but not the item analysis [$t2(29)$ values < 1.4, p values > .1]. Finally, same-case pseudoword priming was larger than the same-case word priming on the subject analysis [$t1(47) = 2.48$, $p < .05$] and this difference approached significance on the item analysis [$t2(58) = 1.3$, $p = .18$]. This finding is consistent with a recent series of studies by Bowers (1994), where a small advantage of pseudoword compared to word priming was consistently obtained.

Discussion

Two findings are noteworthy in Experiment 3. First, priming was greater for high-shift pseudowords studied and tested in the same- compared to different-case. This result is consistent with Experiment 2, and strengthens the conclusion that priming for pseudowords is sensitive to the perceptual format of the study/test items[5]. Second, there is some indication that priming for words was also greater for words studied and tested in the same- (.11) compared to different-case (.05). This result was unexpected given that priming for high-shift words was insensitive to the case manipulation in Experiment 1, and given that abstract priming was reported with Hindi/Urdu, Roman/Cyrillic, and Katakana/Hiragana scripts.

Based on the case specific priming obtained with words and pseudowords, it is tempting to conclude that priming is sensitive to the perceptual features of study/test items in general. That is, the present set of results seem to support the argument that priming for all types of materials -- even words typed in a normal format -- is mediated by new and highly specific perceptual representations, in accordance with the strong acquisition account (e.g., Roediger & Blaxton, 1987; Schacter, 1990). The problem with this conclusion, however, is that it leaves unexplained the contrast between the present result and relatively abstract priming that is generally obtained using English, Hindi/Urdu, Roman/Cyrillic, and Katakana/Hiragana scripts. Although most studies report a small tendency for specific priming, it is rare to obtain a case specific effect as large as the present one.

Rather than adopting the strong acquisition position, I would like to suggest that the large case specific word priming in Experiment 3 (large in relation to past reports of case specific priming) reflects an idiosyncratic characteristic of the present experiment that led participants to treat the words as if they were pseudowords -- a condition in which specificity effects might be expected. In fact, a reasonable argument can be made that the inclusion of pseudowords in a perceptual identification task would prevent (or discourage) participants from encoding words as complete orthographic word patterns. That is, if all items in a perceptual identification task are treated as potential words, the identification of pseudowords might suffer given that pseudowords are not represented as lexical entries within the orthographic system. By contrast, treating all of the to-be-identified items as sub-lexical orthographic patterns is a reasonable strategy given that both words and pseudowords are represented as sub-lexical patterns.

Evidence compatible with this claim can be found in a series of experiments that show that words are read via sub-lexical rather then lexical orthographic codes when words are intermixed with pseudowords (e.g., Baluch & Besner, 1991; Besner & Smith, 1992; Tabossi & Laghi, 1992). Perhaps the most relevant finding has been reported within the word superiority paradigm, in which participants attempt to identify briefly displayed words and pseudowords that are surrounded by pre-and post-masks -- as in the present procedure[6]. When words are compared to pseudowords, the standard result is that words are better identified that pseudowords even though the items are displayed under identical conditions -- the so- called word superiority effect. The key result for present concerns, however, is that the word superiority effect is most pronounced when words and pseudowords are presented in separate blocks. When words and pseudowords are randomly intermixed, the effect is weakened or lost (e.g., Carr, Davidson, & Hawkins, 1978; Manelis, 1973; cf. McClelland & Rumelhart, 1981). For example, Carr et al. (1978) failed to obtain a word superiority effect when words were randomly mixed with pseudowords, regardless of whether 25% or 75% of the items were pseudowords (Experiment 1-2). Similarly, no word superiority effect was obtained when participants only expected to see pseudowords, and a few (unexpected) word trials were included (Experiment 4). However, a robust word superiority effect was obtained when participants only expected to see words and a few (unexpected) pseudowords were included (Experiment 3). Accordingly, it appears that participants treated words and pseudowords equivalently in the perceptual identification task when items were intermixed, or when they expected to encounter pseudowords[7]. Further evidence in support of this general argument can be found in a number of related studies that report that the word superiority effect is lost under conditions that discourage participants from encoding words as complete orthographic patterns (Hayman & Jacoby, 1989; Johnston & McClelland, 1974; Thompson & Massaro, 1973).

If mixing words and pseudowords led to the perceptually specific priming for words in Experiment 3, then the abstract results should reemerge when words are tested separately from pseudowords. By contrast, if the results of Experiment 3 are taken to be quite general, and the results of Experiment 1 are considered anomalous, then perceptually specific priming should be obtained regardless of the context. In order to evaluate these two accounts, a direct replication of Experiment 1 was carried out with 27 participants from McGill University who were paid 5$ for participating. The experiment used the same design, equipment, materials, and procedures as in Experiment 1. The important finding was that abstract priming was again obtained. Similar priming was obtained for low-shift words studied and tested in the same- (.17) and different- (.15) case conditions, as for high-shift words studied and tested in the same- (.14) and different- (.13) case conditions. A 2x2 ANOVA carried out on the priming data failed to obtain any significant results on either the subject or item analysis, indicating similar priming was obtained in all conditions, [all F1(1, 24) values < 1.13, MSe values < 419.44, all p values > .30; all F2(1,58) values <1]. A series of t-tests showed that priming was significantly above baseline in the various experimental conditions [all t1(26) values > 4.01, p values < .01; all t2(29) values > 2.5, p values < .05].

Based on this replication of Experiment 1, it appears as if priming for words is abstract in the perceptual identification task as long as all the critical materials are words. When words and pseudowords are randomly intermixed -- a situation that may encourage participants to treat all items as pseudowords -- then priming for words shows some tendency to be perceptually specific. But clearly, future studies will have to be carried out in order to characterize the specific circumstances in which word priming is case specific. It is still possible, for example, that the contrasting results of Experiment 1 and 3 are attributable to the inclusion vs. exclusion of low-shift words rather than the inclusion vs. exclusion of pseudowords. Even if it is assumed that the inclusion of pseudowords was responsible for the difference, it is not clear whether the critical factor is the inclusion of pseudowords at study, test, or both (cf. Whittlesea & Brooks, 1988). Indeed, given the relatively small effect of the case manipulation on word priming in Experiment 3, the reliability of this finding needs to be assessed.

Whatever the explanation for the small specificity effect for words in Experiment 3 is, I want to emphasize the contrasting results that were obtained with high-shift words and pseudowords. To highlight this contrast, an overall analysis was carried out on the case specific priming (that is, the difference between within- and cross-case priming), collapsing across all of the above experiments and materials. The difference scores were entered into a between subject ANOVA, and the results are presented in Table 4. As can be seen in the table, there is little difference in same- compared to different-case priming for low-shift words (.03), low-shift pseudowords (.01), or for high-shift words, even when the results of Experiment 3 are included (.03). However, there is a clear difference for high-shift pseudowords (.10). An overall ANOVA revealed a main effect of word type, [$F1(3, 338) = 3.62$, $MSe = 332.64$, $p < .05$], indicating that the case manipulation had a greater effect on high-shift pseudowords compared to the other materials. Critically, the case manipulation had a greater effect on high-shift pseudowords (.10) compared to high-shift words (.03), [$F1(1,338) = 6.65$, $MSe = 332.64$, $p = .01$]. In addition, the case manipulation did not significantly affect priming for high-shift words, although the .03 same-case advantage approached significance [$F1(1,122) = 3.36$, $MSe = 183.87$, $p = .07$]. Note, the failure to observe a significant case effect for high-shift words, as well as for low-shift words and low-shift pseudowords is not due to a lack of power, given that the above analyses had the power to detect a .10 reduction in priming following the case manipulation for each of these kinds of items [all power levels greater than .98 for an alpha level of .05 with a one-tailed test]. Thus, when the results of Experiments 1-3 are pooled together, they provide strong support for the conclusion that priming for high-shift pseudowords is more sensitive to the case manipulation than priming for high-shift words.

Experiment 4

The finding that word priming is largely insensitive to a case manipulation is consistent with a view according to which word priming is largely mediated by pre-existing orthographic representations (Morton, 1979). It is important to note, however, that this conclusion is predicated on the assumption that the priming in the above studies was mediated by modality specific representations, which has not been demonstrated thus far. In most studies that have compared priming within and between modalities, priming is reduced 50%, and sometimes more (e.g., Jacoby & Dallas, 1981); accordingly, it seems likely that priming in the above studies would also have been reduced following a modality shift manipulation. However, robust priming is sometimes observed across modalities, and in some cases, cross-modal and within-modal priming effects do not significantly differ (e.g., Komatsu & Naito, 1992). Thus, it is possible that the abstract word priming obtained above was mediated by non-perceptual representations -- such as conceptual or phonological representations -- contrary to the orthographic account of priming. Indeed, the cross script priming reported between Hindi/Urdu, Roman/Cyrillic, and Hiragana/Katakana scripts have been attributed to non-perceptual representations (Komatsu & Naito, 1992; Kirsner et al., 1989; Masson & Freedman, 1990).

In order to determine whether the cross-case priming for high-shift words was mediated by modality specific (orthographic) or nonspecific (non-orthographic) codes, Experiment 4 compared cross-case priming to cross-modal priming for the same set of items. To the extent that cross-case priming for high-shift words is the product of non-perceptual representations, priming should be unaffected by a study/test modality shift. By contrast, to the extent that priming is mediated by orthographic representations, priming should be reduced following this manipulation. In addition, Experiment 4 assessed memory with a yes/no recognition task. Numerous studies have reported a dissociation between priming and recognition memory following a study/test modality shift, with priming but not recognition memory being reduced following the modality shift. If this result is obtained in the present study, it would indicate that performance on the priming task was not contaminated by explicit memory strategies (but see Jacoby , 1991).

Method

Participants Seventy-two Rice University undergraduate students participated in the experiment for course credit.

Design and Materials The experiment included one within subject factor (Study/Test Condition: studied/tested in same-case vs. studied/tested in different-case vs. studied/test in different modality, vs. nonstudied/tested) and one between subject factor (Memory Test: perceptual identification vs. recognition). Consequently, the experiment was a 4 x 2 mixed design.

The materials included a new set of 48 low frequency high-shift words (median frequency 6, range = 1-19 occurrences per million). The criterion for selecting words was that they were largely composed of letters that are visually dissimilar in their upper/lower-case formats; specifically, the letters A/a, B/b, D/d, E/e, G/g, L/l, Q/q (Boles & Clifford, 1989). Words were 4 and 5 letters in length, and at most one letter in a word was outside this set. The set of high-shift letters was slightly different from above, which facilitated my selection of a larger set of words, with relatively little overlap in the set of words used in this and prior studies. See Appendix C for the list of words.

During the study phase, participants studied 36 high-shift words: 12 items were presented in upper-case letters, 12 items in lower-case letters, and 12 items were presented auditorily. The 36 study items were presented in a random order using a program developed by Steven Neumann from Rice University. The remaining 12 high-shift words were not studied; they were included on the identification task in order to determine baseline levels of performance, and on the recognition memory task as distracter items. Consequently, the perceptual identification and recognition tasks consisted of 48 critical items: 36 studied items and 12 nonstudied items. In order to present each word in the various conditions, four experimental files were created for each test, yielding a fully counterbalanced design. At test, half of the participants were randomly assigned to the recognition test condition, and half to the perceptual identification test condition. Items in the perceptual identification and recognition tasks were presented in the same random order to all participants.

Procedure. Participants who were assigned to the perceptual identification condition first completed an identification task that assessed their ability to identify briefly flashed words. Based on their performance, they were assigned to the slow, medium or fast conditions. Exposure durations were the same as in Experiment 1. In the study phase, the words were presented one at a time every five seconds, and participants were asked to read aloud items that were presented visually, and repeat aloud items presented auditorily. Finally, participants completed either the perceptual identification task or the recognition test, with all items in both tests displayed in lower-case letters. In the identification task, participants named the first word that came to mind, and in the recognition task, participants pressed the right shift key for studied words, and the left shift key for nonstudied words. Words in the recognition task were displayed until participants responded.

Results

The identification results from Experiment 4 are presented in Table 5A. Consistent with Experiment 1 and its replication, similar priming was obtained for high-shift words studied and tested in the same- (.17) and different- (.16) case. The critical new finding was that priming was greatly reduced following the study/test modality shift (.05). An ANOVA carried out on the priming data revealed a main effect of the study condition on the subject analysis [$F(2, 70) = 10.35$, $MSe = 153.63$, $p < .001$] as well as on the item analysis [$F(2, 94) = 4.32$, $MSe = 492.55$, $p < .05$], reflecting the greater priming within modality compared to between modality. Furthermore, a simple contrast comparing same- and different-case priming did not approach significance, [$F1(1, 70) < 1$; $F2(1,94) < 1$], indicating that priming in these two conditions was equivalent. In order to determine whether priming was significantly above baseline in the various experimental conditions, a series of t-tests were carried out. For both the subject and item analyses, priming failed to reach significance in the modality shift condition [$t1(35) = 1.79$, $p = .08$; $t2(47)= 1.141$ $p= .27$], but was significant in the other conditions [$t1(35)$ values > 5.63, p values $< .01$; $t2(47)$ values > 3.50, p values $< .01$].

As can be seen in Table 5B, recognition memory for the high-shift words was similar in the same-case condition (.47), different-case condition (.43), and the cross-modal condition (.45). An ANOVA carried out on the hit-false alarm data failed to reveal a significant effect, indicating that memory performance was similar in the various conditions, [$F1(2, 70) < 1$; $F2(2, 94) < 1$].

Finally, in order to directly compare priming and recognition memory, a 2x3 ANOVA that treated Memory Condition as a between subject variable and Study/Test Condition as a within subject variable was carried out. Critically, the interaction between these variables was significant on the subject analysis [$F1(2,140) = 4.47$, $MSe = 195.25$, $p < .05$], and approached significance on the item analysis [$F2(2, 188) = 2.74$, $MSe = 424.22$, $p < .07$.], reflecting the fact that priming was reduced following the study/test modality shift, whereas recognition memory was not. This dissociation between priming and recognition memory provides direct evidence that participants were not using explicit retrieval strategies during their completion of the perceptual identification task.

Discussion

The key result of Experiment 4 is that priming for high-shift words was unaffected by the case manipulation, and at the same time, priming was dramatically reduced following the study/test modality shift. This combination of results is directly predicted by the view that priming is mediated by orthographic word codes (Morton, 1979), and provides a direct challenge to theories that attribute abstract priming to non-perceptual representations. According to Masson and Freedman (1990) and Komatsu & Naito (1992), for example, the abstract priming obtained between the Roman/Cyrillic and Hiragana/Katakana scripts reflects the repeated access to the same conceptual representations at study and test. Kirsner et al. (1989) also conclude that non-perceptual representations mediate abstract priming phenomena, but they argue that the cross-script priming between Hindi/Urdu is mediated by phonological codes used in speech production. Note, the underlying assumption of these authors is that priming cannot be mediated by perceptual representations when study/test items are perceptually dissimilar. However, the present combination of modality specific and perceptually abstract priming challenges this assumption, and supports the view that abstract orthographic codes support word priming.

In addition, the finding that priming dissociated from recognition memory suggests that participants did not adopt explicit retrieval strategies during their performance on the perceptual identification task in Experiment 4. Given that the same test procedures were used in Experiments 1-3, and given that priming for words and pseudowords was recently dissociated from explicit memory when the identical test procedures were employed (Bowers, 1994), it also seems unlikely that explicit memory contaminated the priming results in the prior studies.

General Discussion

Two classes of theories have been advanced in order to explain priming phenomena: (a) modification theories that maintain that priming is the result of strengthening preexisting representations and (b) acquisition theories that maintain that priming is the product of new representations. Within the memory literature, there has been a tendency to assume that the same mechanisms mediate priming for all types of materials; that is, all priming is thought to reflect either the modification of preexisting codes or the acquisition of new information. This assumption is revealed most clearly in a series of studies that have assessed priming for pseudowords: The observation that priming extends to pseudowords is taken as evidence that priming for both pseudoword and words is the product of new memory representations. Indeed, the pseudoword priming results are often considered incompatible with modification theories of word priming (e.g., Cermak et al., 1988; Feustel et al., 1983; Haist et al., 1991; Schacter, 1990; but see Bowers, 1994; Dorfman, 1994; see Tenpenny, 1995, for general discussion of this issue).

In contrast with this common assumption, the present experiments have yielded evidence that different types of representations play different roles in word and in pseudoword priming. The key result of Experiments 1 (and its replication) and 4 is that equivalent priming was obtained for high-shift words repeated in the same- and different-case. Given that high-shift words share few perceptual features in upper- and lower-case formats, this result strongly supports the conclusion that word priming is mediated by representations that treat all tokens of a given word as equivalent (as long as words are displayed in a normal format). The key result of Experiments 2 and 3, however, was that priming for high-shift pseudowords was perceptually specific. In fact, the cross-case priming for these items was reduced approximately by half compared to within-case priming, which lends support to the view that specific perceptual information plays a role in pseudowords priming.

Although priming for high-shift words and pseudowords dissociated from one another in the present experiments, it is important to note that priming for these materials is similar in many respects. The most commonly reported parallel is that robust priming extends to both words and pseudowords in amnesic patients (e.g., Haist et al., 1991; for review, see Bowers & Schacter, 1993). But the correspondence is much more striking, given that priming for both sets of items is insensitive to levels-of-processing manipulations, and given that priming for both sets of materials is severely reduced following a study/test modality shift (Bowers, 1994). Importantly, these priming results dissociated from recognition memory in both cases (Bowers, 1994; see Duchek & Neely, 1989; Mitterer & Begg, 1979, for additional evidence that levels-of-processing manipulations affect explicit memory for pseudowords, contrary to the priming results). Furthermore, priming for both words and pseudowords was found to decay at the same rate, with a 50% decline following a 45 minute study/test delay (Bowers, 1994).

These parallel priming results, in combination with the present dissociation, provide some basic insights into the representations that mediate priming for words and pseudowords. For present concerns, the key similarity that needs to be emphasized is that priming for both sets of items is greatly reduced following a study/test modality shift, and accordingly, priming for both words and pseudowords is mediated, in large part, by modality specific perceptual mechanisms. Given this result, and given that robust priming is obtained between words that are displayed in visually unrelated formats, a strong case can be made that abstract perceptual representations mediate priming for words. Such a conclusion is consistent with modification theories of priming, because as noted above, orthographic codes are also represented in an abstract, modality specific format. By contrast, the combination of modality specific and case specific priming obtained with pseudowords strongly supports the acquisition approach in which newly acquired perceptual representations support priming, as a number of authors have argued (e.g., Roediger & Blaxton, 1987; Schacter, 1990). Thus, two different types of perceptual codes -- one abstract and one specific -- are implicated in priming phenomena.

Two additional sets of experiments lend further support to this conclusion. First, Marsolek, Kosslyn, & Squire (1992) assessed priming for words using the stem completion task when stems were flashed to the left and right visual fields of normal participants (note, words were not selected to be either high- or low-shift). The interesting result was that a different pattern of priming was obtained in these two conditions. When stems were flashed in the left visual field (and thus first processed by the right hemisphere), priming was greater for words studied and tested in the same-case compared to different-case. By contrast, when stems were flashed to the right visual field (and thus first processed within the left hemisphere), equivalent priming was obtained for items studied and tested in the same- and different-case. Furthermore, regardless of the hemisphere in which items were first processed, the within- and cross-case priming was greater than the priming obtained following a study/test modality shift. Based on these findings, the authors argued that two separate perceptual systems mediate priming, one located in the right hemisphere that supports perceptually specific priming, and one located in the left hemisphere that supports abstract priming (see Reuter-Lorenz & Baynes, 1991 for similar conclusion based on priming data obtained with a split brain patient).

Second, Schacter and Church (1992) carried out a series of experiments within the auditory domain that assessed priming for words spoken in either the same or different voice at study and test. In three experiments, they reported that a voice change did not affect priming (that is, priming was perceptually abstract) when test items were masked by white noise, whereas priming was sensitive to this voice manipulation in two experiments when targets were spoken clearly at test. In order to explain these discrepant results, Schacter and Church speculated that the auditory processing abilities of the right hemisphere is especially impaired by white noise (cf. Zaidel, 1978), and thus, the abstract priming observed in combination with white noise was thought to reflect abstract phonological representations within the left hemisphere. By contrast, the right hemisphere was assumed to contribute to priming when white noise was removed, and thus the voice effects that emerged were thought to reflect highly specific voice representations within the right hemisphere. Additional support for this conclusion was reported by Schacter, Aminoff, & Church (cited in Schacter, 1994) in a priming task that employed the dichotic listening technique. Priming was abstract when target words were presented to the right ear (left hemisphere), and specific when targets were presented to left ear (right hemisphere). Importantly, normal auditory priming was reported in a patient with severe auditory comprehension problems (Schacter, McGlynn, Milberg, & Church, 1993), and in amnesic participants (Schacter, Church, & Treadwell, 1994) indicating that auditory priming reflects perceptual rather than semantic or episodic mechanisms. Accordingly, Schacter (1994) concluded that both an abstract as well as a specific perceptual system mediates priming within the auditory domain (but see Goldinger, in press).

Taken together, the above experiments and the present data provide strong evidence that two different perceptual systems mediate priming -- one operating with abstract representations, the other with specific codes. It is worth emphasizing, however, that the conclusions of these different studies are complementary rather than redundant. Based on the reviewed studies, it was suggested that two different perceptual systems support priming for words; namely, an abstract system within the left hemisphere, and a specific system within the right hemisphere. And based on the present set of experiments, I have argued that two different systems tend to mediate priming for words and pseudowords; namely, an abstract orthographic system for words, and a perceptually specific system for pseudowords. Given these two sets of results, a seemingly straightforward way to integrate the findings is to argue that the orthographic codes that mediate word priming (and perhaps a limited degree of pseudoword priming) are located within the left hemisphere, and the representations that support pseudoword priming (and perhaps a limited degree of word priming, particularly when items are presented to the left visual field) are located in the right hemisphere. It is interesting to note that a variety of cognitive neuropsychological data are consistent with conclusion that the abstract orthographic representations of words are located within the left hemisphere, and that the perceptual details of verbal and non-verbal materials are represented within the right hemisphere (e.g., Reuter-Lorenz Baynes, 1991; McCandliss, Curran, Posner, 1994; cf. Corballis, 1989). Thus, a coherent story emerges when the present data are considered in the context a diverse set of research.

It is also worth emphasizing that the present account is different from other theoretical approaches that assume that different underlying mechanisms support word and pseudoword priming. In these accounts, it is generally argued that priming for words is mediated by pre-existing orthographic codes, whereas priming for pseudowords reflects episodic memory (e.g., Monsell, 1985; Whitlow & Cebollero, 1989, Whitlow, 1990; but see Salasoo et al., 1985). Consistent with this proposal, Whitlow (1990) reported that pseudoword priming and recognition memory are both facilitated by multiple study trials, suggesting a common basis for both phenomena, whereas priming for words was insensitive to this manipulation, suggesting a non-episodic basis for this latter effect. However, it is difficult to reconcile this episodic account of pseudoword priming with reports of intact pseudoword priming in amnesic patients (cf. Bowers & Schacter, 1993), and the recent reports of implicit/explicit dissociations observed for pseudowords (Bowers, 1994). Given these latter findings, and given the evidence that specific and abstract perceptual systems exist in the left and right hemispheres (Marsolek et al., 1992; Schacter & Church, 1992), there are good reasons to argue that new memory representations within a perceptual system, rather than an episodic system, support long-term pseudoword priming (see Tenpenny, 1995, for discussion of hybrid models of priming).

It should be noted that Rueckl and colleagues have also reported a dissociation between word and pseudoword priming, and they have described a connectionist framework that can account for their results (Rueckl, 1990; Rueckl & Olds, 1993; Rueckl & Dror, 1994). More specifically, the authors reported that words and pseudowords are primed by orthographically similar items (see Footnote 2), and that word identity priming increases with multiple prime presentations whereas neither pseudoword identity priming nor word or pseudoword similarity priming increases with repetitions. In order to explain these results, they argued that connections between orthographic and semantic codes contribute to repetition priming for words, but that these connections cannot contribute to priming for the latter items given that the connections do not exist for pseudowords (which do not have meaning), nor for orthographically similar words (which have different meanings). As a consequence, the dissociation is obtained. The success of this approach in accommodating the word/pseudoword dissociation in their experiments suggests that it is worth exploring this connectionist account in relation to the present set of data. Although it is not clear to the present author how the presence/absence of orthographic-semantic connections can account for the cross-case and modality-specific word priming and the case-specific pseudoword priming, this and related accounts may prove to be viable alternatives to the present proposal.

One criticism that might still be levied against the present account is that many studies have found a small reduction of priming when the visual structure of normally displayed words are changed (i.e., TABLE/table), although the decrement is rarely significant at the level of the individual experiment (but see Jacoby & Hayman, 1987; Roediger & Blaxton, 1987). Indeed, in Experiment 1 and 4 (as well as the replication of Experiment 1), there was a small advantage (non significant) in identifying high- and low-shift words repeated in the same- compared to different-case. Based on the consistency of this finding across studies, it has sometimes been concluded that priming for words cannot be the product of abstract orthographic representations, as advocated here (cf. Richardson- Klavehn & Bjork, 1988). In defense of the present account, however, it can be pointed out that the perceptually specific system does in fact mediate priming for words when they are presented to the left visual field, and thus encoded within the right hemisphere (Marsolek et al., 1992). There is no reason to assume that this system is inoperative when words are displayed to the center of the visual field, given that information encoded in this way is processed by both hemispheres. So extending this argument, it is reasonable to presume that both systems support priming whenever words are studied/tested in the same-case, and only one system (the abstract system) when high-shift items are displayed in different-cases. Therefore, a small but consistent specificity effect should be expected on the present theory as long as the perceptually specific system contributes a small unique contribution to priming above and beyond that produced by the abstract system.

Note, this same argument can be advanced in order to account for the cross-case pseudoword priming in Experiments 2-3. Since pseudowords can be characterized as both sub-lexical patterns as well as novel visual patterns, it is quite likely that pseudowords are also processed within both the abstract and specific systems (at least when the items are presented to the center of fixation). Accordingly, the abstract component of pseudoword priming may be mediated by sub-lexical codes (cf. Dorfman, 1994), whereas the specific priming is mediated by the specific system. The different degree of cross-case priming for words and pseudowords would then reflect the fact that words gain access to both sub-lexical and lexical orthographic codes whereas pseudowords only access the former codes, and as a consequence, the perceptually specific system may play a larger role in priming for pseudowords compared to words. In order to account for the finding that priming for low-shift words is insensitive to the case manipulation (also see Brown & Carr, 1993; Carr et al., 1989; Dorfman, 1994; Feustel et al., 1983), it only needs to be assumed that the study/test items were sufficiently similar in their visual properties that the perceptually specific system treats them equivalently.

Before concluding, a brief comment should be made regarding the preliminary evidence that case-specific priming is obtained for high-shift words when words and pseudowords are randomly intermixed (Experiment 3). The interpretation I offered above was that participants encoded words sub-lexically (as if they were pseudowords) in the mixed condition, and as a result, the abstract system contributed less and the specific system more to the overall priming effect. In support of this claim, I noted that the word superiority effect is reduced or lost when words and pseudowords are intermixed (e.g., Manelis, 1973). Now, it is worth adding that priming for words is in fact perceptually specific under conditions in which words are functionally equivalent to pseudowords; namely, when words are first processed within the right hemisphere that does not contain an orthographic system with abstract letter and word codes (cf. Reuter-Lorenz & Baynes, 1991). Thus, there are good reasons to assume that the specific system plays an important role in word priming in a number of different conditions, including when words are first processed by the right hemisphere, when words are randomly intermixed with pseudowords, as well as when they are displayed in unusual formats. Furthermore, there is some indication that participants can control the degree to which the specific system contributes to word priming, given that Graf and Ryan (1990) found priming to be specific when participants were instructed to encode perceptual attributes of words (a condition in which the specific perceptual system might be engaged), and priming was found to be abstract when participants were instructed to encode words in a meaningful fashion (a condition in which lexical orthographic codes are most likely to be accessed). Nevertheless, given the robust priming that is consistently obtained between visually dissimilar words, and given the very small, generally nonsignificant reduction in priming following extensive manipulations in the visual features of normally displayed words, it appears that word priming is largely mediated by orthographically abstract codes, as Morton (1979) argued all along.

General Conclusions

Given the present set of results, it appears that priming for words is typically mediated by pre-existing orthographic representations, whereas a substantial part of pseudoword priming is mediated by newly-acquired perceptual representations. Accordingly, the present account adopts the frameworks of both modification and acquisition theories, and assumes that these views are complementary rather than incompatible. In fact, it is likely that both systems contribute to word and pseudoword priming, and the relative importance of the two systems can be altered by a variety of manipulations, as noted above.

An important virtue of this approach is that it can accommodate the data cited in support of both modification and acquisition theories of priming. The reports of cognate and morphological priming, as well as the abstract priming for words, are consistent with the present account, because word priming it is assumed to be mediated by abstract orthographic codes that serve lexical functions (Morton, 1979). Similarly, the finding that priming extends to various sorts of novel materials is consistent with this view, because it is assumed that priming for these items is meditated by newly acquired representations within a perceptual system (e.g., Schacter, 1990, 1992). By contrast, theories that attempt to accommodate all priming data within a single framework have difficulty accounting for the results cited in support of the alternative framework.

If one adopts the present line of argument, then it is necessary to conclude that there may be as many as four (perhaps more) different perceptual systems underlying priming for different types of materials: One specific and one abstract system for a) visually displayed verbal materials, b) auditorily presented verbal materials, and perhaps c) visually displayed objects, given that abstract and specific priming effects have also been reported for these items (e.g., Biederman & Cooper, 1991, 1992 for abstract results; Srinivas, 1993 for specific results). Although such a proliferation of "memory systems" has often been criticized in the literature as a post-hoc account of the priming data (e.g., Roediger, Rajaram, & Srinivas, 1990), it must be emphasized that these different systems have not only been put forward in response to the priming data, but have also been formulated on the basis of independent research in neuropsychological, cognitive, and computational domains (e.g., Farah, 1990; Kosslyn, Chabris, Marsolek, & Koenig, 1992; Peterson et al., 1989). Given this convergence of evidence, the above criticism of the "multiple systems" approach is considerably weakened.

Nevertheless, I would hesitate to conclude that multiple memory systems support implicit memory phenomena. The claim that multiple memory systems support priming suggests that the primary function of these systems is a memory function per se. On the present account, it seems more appropriate to conclude that multiple perceptual systems support word and pseudoword priming. Priming, then, would reflect learning processes internal to the different perceptual systems.

References

Baluch, B & Besner, D. (1991). Visual word recognition: Evidence for strategic control of lexical and nonlexical routines in oral reading. Journal of Experimental Psychology: Learning, Memory, and Cognition, 17, 644-652.

Besner, D., Coltheart, M. & Davelaar, E. (1984). Basic Processes in reading: Computation of abstract letter identities. Canadian Journal of Psychology, 38, 126-134.

Besner, D. & Smith, M.C. (1992). Basic processes in reading: Is the orthographic depth hypothesis sinking? In R. Frost & L. Katz (Eds.) Orthography, Phonology, Morphology, and Meaning. Amsterdam, Elsevier.

Biederman, I. & Cooper, E.E. (1991). Evidence for complete translation and reflectional invariance in visual object priming. Perception, 20, 585-593.

Biederman, I. & Cooper, E.E. (1992). Size invariance in visual object priming. Journal of Experimental Psychology: Human Perception and Performance, 18, 121-133.

Biederman, I. & Gerhardstein, P.C. (1993). Recognizing depth-rotated objects: Evidence for 3-D viewpoint invariance. Journal of Experimental Psychology: Learning, Memory, and Cognition, 19, 1162-1182.

Blaxton, T.A. (1989). Investigating dissociations among memory measures: Support for a transfer appropriate processing framework. Journal of Experimental Psychology: Learning, Memory, and Cognition, 15, 657-668.

Boles, D.B., & Clifford, J.E. (1989). An upper- and lower-case alphabetic similarity matrix, with derived generation similarity values. Behavior Research Methods, Instruments, & Computers, 12, 597-586.

Bowers, J.S. (1994). Does implicit memory extend to legal and illegal nonwords? Journal of Experimental Psychology: Learning, Memory, and Cognition, 20, 534-549.

Bowers, J.S., Arguin, M. & Bub, D. (in press). Fast and specific access to orthographic knowledge in a case of letter-by-letter surface alexia. Cognitive Neuropsychology.

Bowers, J.S., Bub, D. & Arguin, M. (in press). A characterization of the word superiority effect in a case of letter-by-letter surface alexia. Cognitive Neuropsychology.

Bowers, J. S., & Schacter, D. L. (1990). Implicit memory and test awareness. Journal of Experimental Psychology: Learning, Memory and Cognition, 16, 404-416.

Bowers, J. S., & Schacter, D. L. (1993). Priming of novel information in amnesic patients: Issues and data. In P. Graf, M. Masson (Eds.) Implicit memory: New directions in cognition development, and neuropsychology.(pp. 303-326). Hillsdale, NJ: Erlbaum.

Brown, S. B. & Carr, T.H. (1993). Limits on perceptual abstraction in reading: Asymmetric transfer between surface forms differing in typicality. Journal of Experimental Psychology: Learning, Memory, & Cognition, 19, 1277-1296.

Brown, H. L., Sharma, N. K., & Kirsner, K. (1984). The role of script and phonology in lexical representation. Quarterly Journal of Experimental Psychology, 36A, 491-505.

Caramazza, A., Laudanna, A., & Romani, C. (1988). Lexical access and inflectional morphology. Cognition, 28, 297-332.

Carr, T.H., Brown, J.S., & Charalambous, A. (1989). Repetition and reading: Perceptual encoding mechanisms are very abstract but not very interactive. Journal of Experimental Psychology Learning, Memory and Cognition, 15, 763-779.

Cermak, L. S., Blackford, S. P., O'Connor, M., & Bleich, R. P. (1988). The implicit memory ability of a patient with amnesia due to encephalitis. Brain and Cognition, 7, 312-323.

Chomsky, N. & Halle, M. (1968). The sound pattern of English. New York: Harper and Row.

Clarke, R.G.B. & Morton, J. (1983). Cross modality facilitation in tachistoscopic word recognition. Quarterly Journal of Experimental Psychology, 35A, 79-96.

Coltheart, M. (1981). Disorders of reading and their implications for models of normal reading. Visible Language, 3, 245-286.

Corballis, M.C. (1989). Laterality and human evolution. Psychological Review, 96, 492-505.

Cristoffanini, P., Kirsner, K., & Milech, D. (1986). Bilingual lexical representation: The status of Spanish-English cognates. Quarterly Journal Experimental Psychology, 38A, 367-393.

Diamond, R., & Rozin, P. (1984). Activation of existing memories in the amnesic syndromes. Journal of Abnormal Psychology, 93, 98-105.

Dorfman, J. (1994). Sublexical components in implicit memory for novel words. Journal of Experimental Psychology: Learning, Memory, and Cognition, 20, 1108-1125.

Drews, E. & Zwitserlood, P. (1995) Morphological and orthographic similarity in visual word recognition. Journal of Experimental Psychology: Human Perception and Performance, 21, 1098-1116.

Duchek, J.M., & Neely, J.H. (1989). A dissociative word-frequency and levels-of-processing interaction in episodic recognition and lexical decision tasks. Memory & Cognition, 89, 148-162.

Evett, L.J. & Humphreys, G.W. (1981). The use of abstract graphemic information in lexical access. Quarterly Journal of Experimental Psychology, 33A, 325-350. 81

Farah, M.J. (1990). Visual Agnosia: Disorders of Object Recognition and What They Tell Us About Normal Vision. Cambridge, MA: MIT Press.

Feldman, L. B., & Moskovljevic, J. (1987). Repetition priming is not purely episodic in origin. Journal of Experimental Psychology: Learning, Memory and Cognition, 13, 573-581.

Feustel, T. C., Shiffrin, R. M., & Salasoo, M. A. (1983). Episodic and lexical contributions to the repetition effect in word identification. Journal of Experimental Psychology: General, 112, 309-346.

Goldinger, S. (in press) Words and voices: Episodic effects in spoken word identification and recognition memory. Journal of Experimental Psychology: Learning Memory and Cognition.

Graf, P., & Mandler, G. (1984). Activation makes words more accessible, but not necessarily more retrievable. Journal of Verbal Learning and Verbal Behavior, 23, 553-568.

Graf, P., Mandler, G., & Haden, P. (1982). Simulating amnesic symptoms in normal participants. Science, 218, 1243-1244.

Graf, P., & Ryan, L. (1990). Transfer appropriate processing for implicit and explicit memory. Journal of Experimental Psychology: Learning, Memory and Cognition, 16, 978-992.

Graf, P., & Schacter, D.L. (1985). Implicit and explicit memory for new associations in normal and amnesic patients. Journal of Experimental Psychology: Learning, Memory, and Cognition, 11, 501-518.

Haist, F., Musen, G., & Squire, L.R. (1991). Intact priming of words and nonwords in amnesia. Psychobiology, 19, 275-285.

Hayman, C.A.G. & Jacoby, J.L. (1989). Specific word transfer as a measure of processing in the word-superiority paradigm. Memory & Cognition, 17, 125-133.

Jacoby, L. L. (1983). Perceptual enhancement: Persistent effects of an experience. Journal of Experimental Psychology: Learning, Memory and Cognition, 9, 21-38.

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. Journal of Experimental Psychology: General, 110, 306-340.

Jacoby, L.L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. Journal of Memory and Language, 30, 513-541.

Jacoby, L. L., & Hayman, C. A. G. (1987). Specificity of visual transfer in word identification. Journal of Experimental Psychology: Learning, Memory and Cognition, 13, 456-463.

Johnston, J.C. & McClelland, J.L. (1974). Perception of letters in words: Seek not and ye shall find. Science, 184, 1192-1194.

Komatsu, S. & Naito, M. (1992). Repetition priming with Japanese Kana scripts in word-fragment completion. Memory and Cognition, 20, 160-170.

Kosslyn, S.M., Chabris, C.F., Marsolek, C.M., & Koenig, O. (1992). Categorical versus coordinate spatial relations: Computational analyses and computer simulations. Journal of Experimental Psychology: Human Perception and Performance, 18, 562-577.

Kirsner, K. (1973). An analysis of the visual component in recognition memory for verbal stimuli. Memory & Cognition, 1, 449-453.

Kirsner, K., & Dunn, J. (1985). 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., Dunn, J.C., & Standen, P. (1989). Domain-specific resources in word recognition. In S. Lewandowsky, J.C. Dunn, & K. Kirsner, (Eds.), Implicit memory: Theoretical issues (pp. 99-122). Hillsdale, NJ: Erlbaum.

Kolers, P. A. (1975). Specificity of operation in sentence recognition. Cognitive Psychology, 7, 289-306.

Marsolek, , C.J., Kosslyn, S.M. & Squire, L.R. (1992). Form-specific visual priming in the right cerebral hemisphere. Journal of Experimental Psychology: Learning, Memory, and Cognition, 18, 492-508.

Manelis, L. (1974). The effect of meaningfulness in tachistoscopic word perception. Perception & Psychophysics, 16, 182-192,

Masson, M. E. J. (1986). Identification of typographically transformed words: Instance-based skill acquisition. Journal of Experimental Psychology: Learning, Memory and Cognition, 12, 479-488.

Masson, M.E.J., & Freedman, L. (1990). Fluent identification of repeated words. Journal of

Experimental Psychology: Learning Memory and Cognition, 16, 355-373.

Mayzner, M.S., & Tresselt, M.E. (1965). Tables of single-letter and digram frequency counts for various word-length and letter-position combinations. Psychonomic Monograph Supplements, 1, 13-32.

McCandliss, B.D., Curran, T. & Posner, M.I. (1994). Exploring the time course of word recognition for identical and cross-case repetitions. Poster presented at 35'th Annual Meeting: The Psychonomic Society.

McClelland, J.L. (1976). Preliminary letter identification in the perception of words and nonwords. Journal of Experimental psychology: Human Perception and Performance, 3, 80-91.

McClelland, J.L. & Johnston, J.C. The role of familiar units in perception of words and nonwords. Perception & Psychophysics, 22, 249-261.

McClelland, J.L., & Rumelhart, D.E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. Psychological Review, 88, 375-407.

Mitterer, J.O. & Begg, I. (1979). Can meaning be extracted from meaningless stimuli? Canadian Journal of Psychology, 33, 193-197.

Monsell, S. (1985). Repetition and the Lexicon. In A. W. Ellis, (Eds.), Progress in the Psychology of Language: Vol 2. New Jersey: Hillsdale.

Monsell, S. (1987) Non-visual orthographic processing and the orthographic lexicon. In M. Coltheart (Ed.), Attention and Performance XII. London: Lawrence Erlbaum.

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Level of processing versus transfer appropriate processing. Journal of Verbal Learning and Verbal Behavior, 16, 519-533.

Morton, J. (1969). The interaction of information in word recognition. Psychological Review, 16, 165-178.

Morton, J. (1979). Facilitation in word recognition: Experiments causing change in the logogen model. In P. A. Kolers, M. E. Wrolstad, & H. Bouma, Processing models of visible language. New York: Plenum.

Murrell, G., & Morton, J. (1984). Word recognition and morphemic structure. Journal of Experimental Psychology, 102, 963-968.

Musen, G., & Triesman, A. (1990). Implicit and explicit memory for visual patterns. Journal of Experimental Psychology: Learning, Memory and Cognition, 16, 127-137.

Musen, G., & Squire, L. R. (1991). Normal acquisition of novel verbal information in amnesia. Journal of Experimental Psychology: Learning, Memory and Cognition, 17, 1095-1104.

Napps, S. (1989). Morphemic relationships in the lexicon: Are they distinct from semantic and formal relationships?. Memory & Cognition, 17, 729-739.

Neisser, U. (1954). An experimental distinction between perceptual process and verbal response. Journal of Experimental Psychology, 47, 399-402.

Peterson , S.E., Fox, P.T., Posner, M.I., Mintun, M.A., Raichle, M.E. (1989). Positron emission tomographic studies of the processing of single words. Journal of Cognitive Neuroscience, 2, 320-343.

Rayner, K., McConkie, G.W., & Zola, D. (1980). Integrating information across eye movements. Cognitive Psychology, 12, 206-226.

Reicher, G.M. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. Journal of Experimental Psychology, 81, 274-280.

Reuter-Lorenz, P .A. & Baynes, K. (1991). Models of lexical access in the callosotomized brain. Journal of Cognitive Neuroscience, 4, 155-163.

Richardson-Klavehn, A., & Bjork, R. A. (1988). Measures of memory. Annual Review of

Psychology, 36, 475-543.

Roediger, H. L. III (1990). Implicit memory: Retention without remembering. American Psychologist, 45, 1043-1056.

Roediger, H. L. III, & Blaxton, T. A. (1987). Retrieval modes produce dissociations in memory for surface information. In D. S. Gorfein, & R. R. Hoffman (Eds.), Memory and cognitive processes: The Ebbinghause centennial conference. Hillsdale, NJ: Erlbaum.

Roediger, H. L. III, & Challis, B. H. (1992). Effects of exact repetition and conceptual repetition on free recall and primed word fragment completion. Journal of Experimental Psychology, 18, 3-14.

Roediger, H. L. III, Rajaram, S., & Srinivas, K.,. Specifying criteria for postulating memory systems. In Diamond, A. (Ed.), The Development and Neural Basis of Higher Cognitive Functions. New York: The New York Academy of Sciences.

Roediger, H.L. III, & Weldon, M.S. (1987). Reversing the picture superiority effect. In M.A. McDaniel, M. Pressley (Eds.). Imagery and Related Mnemonic Processes: Theories, Individual Differences, and Applications. New York: Springer-Verlag.

Rueckl, J. G. (1990). Simmilarity effects in word and pseudoword repetition priming. Journal of Experimental Psychology: Learning, Memory, and Cognition, 16, 374-391.

Rueckl, J.G., & Dror, I. I. (1994). The effect of orthographic-sematnic systematicity on the acquisiion of new words. In C. Umilta & M. Moscovitch (Eds.), Attention and performance XV: Conscious and nonconscious information processing (pp. 571-588). Cambridge, MA: MIT Press.

Rueckl, J. G. & Olds, E.M. (1993). When pseudowords acquire meaning: Effect of semantic associations on pseudoword repetition priming. Journal of Experimental Psychology: Learning, Memory, and Cognition, 19, 515-527.

Rugg, M.D. & Nagy, M.E. (1987). Lexical contribution to non-word repetition effects: Evidence from event-related potentials. Memory & Cognition, 15, 473-481.

Salasoo, A. & Shiffrin, R.M. (1985). Building permanent memory codes: Codification and repetition effects in word identification. Journal of Experimental Psychology: General, 114, 50-77.

Scarborough, D. L., Cortese, C., & Scarborough, H. S. (1977). Frequency and repetition effects in lexical memory. Journal of Experimental Psychology: Human Perception and Performance, 3, 1-17.

Schacter, D. L. (1987). Implicit memory: History and current status. Journal of Experimental Psychology: Learning, Memory and Cognition, 13, 501-518.

Schacter, D. L. (1990). Perceptual representation system and implicit memory: Toward a resolution of the multiple memory debate. In A. Diamond (Ed.), Development and Neural Basis of Higher Cognitive Function. Annals of the New York Academy of Science.

Schacter, D. L. (1992). Understanding implicit memory: A cognitive neuroscience approach. American Psychologist, 47, 559-569.

Schacter, D.L (1994). Priming and multiple memory systems: Perceptual mechanisms of implicit memory. In D.L. Schacter & E. Tulving (Eds.). Memory Systems 1994. Cambridge, MA: MIT Press.

Schacter, D.L., Bowers, J. & Booker, J. (1989). Intention, awarness and implict memory: The retrieval intentionality criterion. In S. Lewandowsky, J.C. Dunn, & K. Kirsner (Eds.), Implicit memory: Theoretical issues (pp 47-65). Hillsdale, NJ: Erlbaum.

Schacter, D.L., & Church, B.A. (1992). Auditory priming: Implicit and explicit memory for words and voices. Journal of Experimental Psychology: Learning, Memory and Cognition, 18, 915-930.

Schacter, D.L., Church, B.A., & Treadwell, J. (in press). Implicit memory in amnesic patients: Evidence for spared auditory priming. Psychological Science.

Schacter, D. L., Cooper, L. A., & Delaney, S. M. (1990). Implicit memory for unfamiliar objects depends on access to structural descriptions. Journal of Experimental Psychology: General, 119, 5-24

Schacter, D.L., McGlynn, S.M., Milberg, W.P., & Church, B.A. (1993). Spared priming despite impaired comprehension: Implicit memory in a case of word meaning deafness. Neuropsychology, 7, 107- 118.

Srinivas, K., & Roediger, H.L. (1990). Testing the nature of two implicit tests: Dissociations between conceptually-driven and data-driven processes. Journal of Memory and Language, 28, 398-412.

Srinivas, K. (1993). Perceptual specificity in nonverbal priming. Journal of Experimental Psychology: Learning, Memory and Cognition, 19, 582-602.

Squire, L. R. (1987). Memory and Brian. New York: Oxford University Press.

Tabossi, P. & Laghi, L. (1992). Semantic priming in the pronunciation of words in two writing systems: Italian and English. Memory & Cognition, 20, 315-328.

Thompson, M.C. & Massaro, D.W. (1973). Visual information and redundancy in reading Journal of Experimental Psychology, 98, 49-54.

Tulving, E. & Schacter, D.L. (1990). Priming and human memory systems. Science, 247, 301-305.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. Psychological Review, 73, 540-549.

Weldon, M.S. (1991). Mechanisms underlying priming on perceptual tasks. Journal of Experimental Psychology: Learning, Memory and Cognition, 17, 526-541.

Whitlow, J.W. Jr. (1990). Differential sensitivity of perceptual identification for words and pseudowords to test expectations: Implications for the locus of word frequency effects. Journal of Experimental Psychology: Learning, Memory, and Cognition, 16, 837-851.

Whitlow, J.W. Jr. & Cebollero, A. (1989). The nature of word frequency effects on perceptual identification. Journal of Experimental Psychology: Learning, Memory, and Cognition, 15, 643-656.

Whittlesea, B.W.A. & Brooks, L.R. (1988). Critical influence of particular experiences in the perception of letters, words, and phrases. Memory & Cognition, 16, 387-399.

Zaidel, E. (1978). Lexical organization in the right hemisphere. In P. Buser, & A. Rougeul-Buser (Eds.). Cerebral Correlates of Conscious Experience (pp. 177-197). Amsterdam: Elsvier.

Author Notes

I would like to express my appreciation to Patricia Bowers, Jennifer Dorfman, Michael Masson, Henry H. Roediger III, Jay Rueckl, Gabriella Vigliocco, Mary Susan Weldon, and J.W. Whitlow for helpful discussion. Correspondence concerning this article should be addressed to Jeffrey S. Bowers, Department of Psychology, Rice University, Houston, Texas, 77251-1892.

Footnotes

1. The term modification rather than activation is adopted in the text because the former term suggests that priming is the product of a structural change to pre-existing word codes that acts to strengthen the representations, whereas the latter term implies that priming is due to a "active" state of word codes that persists following the encoding of words. Given that priming persists over minutes, hours, or perhaps longer, it seems more reasonable to presume that priming reflects a structural change rather than persistent activity. This distinction was in fact recognized by Morton, who argued that long-term priming reflects the lowering of thresholds of logogen units (a structural change in the representation), rather than the temporary activation of the logogen units. Similarly, this distinction is found in connectionist models of learning, where events can be represented for brief durations in the activation patterns within a network, or over long intervals by modifying connection weights. It is interesting to note that masked and semantic priming only last one or two seconds (e.g., Forster & Davis, 1984; Napps, 1989), suggesting that the temporary activation of pre-existing codes underlies these effects.

2. It should be noted that there are reports of priming between orthographically and phonologically related study/test words, but the conditions in which these effects are obtained are quite different from the conditions that support morphological priming. In the case of morphological priming, a single encounter with a word at study leads to robust priming to a morphologically related word at test (e.g.,cars/car), and the size of the priming is generally the same magnitude as repetition priming (e.g., Napps & Fowler, 1987). By contrast, orthographic priming for words is only observed when there are multiple encounters with orthographically similar study/test items. For example, Rueckl (1990) asked participants to study a list of words composed of different permutations of a small set of letters, and he found that they performed better on a perceptual identification task for non-studied words composed of the same set of letters compared to non-studied words composed of different letters. And

even here, the priming is dramatically reduced compared to the repetition condition (also see Feustel, Shiffrin, & Salasoo, 1983). But when orthographically related study/test words are presented only once, the priming effects do not even approach significance (e.g., Drews & Zwitserlood, 1995; Feldman & Moskovljevic, 1987; Napps & Fowler, 1987; Weldon, 1991). Similarly, a small amount of phonological priming has been reported when participants are presented with multiple encounters with study items that are phonologically related to test items (Mandler, Graf & Kraft, 1986; Mandler, Hamson, & Dorfman, 1990). But when phonologically related study/test words are presented once, little or no priming is obtained in the tasks that support morphological priming. Accordingly, it is difficult to attribute the robust morphological priming to phonological or orthographic factors.

3. Critics of the modification account might argue that changing the perceptual format of study/test words displayed in normal viewing conditions (e.g., TABLE/table) tends to reduce priming, although the decrement is rarely significant at the level of the individual experiment (cf. Richardson-Klavehn & Bjork, 1988). But given the extraordinarily small size of these effects under most circumstances, and the considerable priming obtained between words displayed in visually dissimilar scripts, the results obtained with normally displayed words provide little basis for rejecting the modification approach. Nevertheless, the small specificity effects are discussed in more detail in the General Discussion.

4. An exception to this general pattern of results was reported by Jacoby, Levy, and Steinbach (1992), who obtained case specific priming in a series of three experiments when words were presented in a normal format. In the first phase of these studies, participants answered general knowledge questions typed in Elite font, and then at test, they answered old and new questions typed in the same and different font (IBM Script). The authors reported that a change in font at study and test reduced the amount of savings in re-answering questions by 50 ms in Experiment 1, and an average reduction of 52 ms in Experiments 2-3, in all cases a significant reduction. Although this result indicates that priming can be sensitive to case changes even

when words are displayed in normal format, it is not at all clear whether the priming reported by Jacoby et al. relate to the present discussion, given that their task required re-answering general knowledge questions (a conceptual task), whereas the present experiment, and the experiments cited above involve the processing of single words or words out of context (primarily a perceptual task). In this regards, it is worth noting that Jacoby et al. reported a repetition priming effects of 537 ms averaged across experiments, which is much larger than the priming effects obtained with single words when reaction times are measured. Interestingly, when Jacoby et al. asked participants to re-read rather than re-answer the same questions (a more perceptually based priming task), repetition priming was only 91 ms. It should also be noted that an average priming effect of 440 ms was obtained following a modality shift when participants re-answered questions, indicating that a substantial component of the priming was non-perceptual. Accordingly, their results indicate that case-specific priming may be obtained with conceptually driven tasks, but these results do not compromise the claim priming is largely insensitive to case manipulations when priming is assessed for single words.

5. One possible objection to this conclusion is that cross-case priming was only assessed when items were studied/tested in upper/lower-case, respectively. Accordingly, the specificity effects could reflect, at least in principle, a study-case effect in which items studied in upper-case produce less priming then items studied in lower-case letters, regardless of the case of items at test. However, this account cannot readily explain the finding that specificity effects were only obtained for high-shift pseudowords. On the study-case explanation, specificity effects should also have been found for high- and low-shift words as well as low-shift pseudowords. Given that this was not the finding, I would argue that the present results are most compatible with the conclusion that priming is case-specfic for pseudowords when the perceputal features of study/test items are dissimilar. Nevertheless, it is worth noting that assymetrical priming effects have been reported following upper-to-lower vs. lower-to-upper

case manipulations (Jacoby & Hayman, 1987; Roediger & Blaxton, 1987), and thus this issue merits further investigation.

6. In the classic study by Reicher (1969), the word superiority effect was revealed when participants were better able to identify letters presented in the context of words rather than by themselves. However, it is also common to assess the word superiority effect by comparing the identification rates of words to pseudowords (e.g., Manelis, 1974; McClelland, 1976).

7. It should be noted that this characterization of the Carr et al. (1977) results is somewhat at odds with the conclusion that the authors advance themselves. According to Carr et al. (1997), participants' accuracy of identifying words is unaffected by their expectation of whether a word or pseudoword (or random letter string) will be presented in the next trial. Instead, the authors argue that only pseudoword identification is affected by expectations. If this is the correct characterization of performance in the word superiority task, then it would challenge the present claim that participants treated words as pseudowords in the mixed condition. However, there are reasons to challenge their conclusion, given that participants identified 84.6% of words when they expected words and only 78.6% words when they expected pseudowords (Carr et al., 1977, p. 686). Unfortunately, the authors do not report if this difference is significant. The reader is referred to the original article for more details of the study.

Table 1

Proportion of High- and Low-Shift Words Identified as a Function of the Study Conditions

Study		Test (lower-case)	Priming
Low-shift	Upper-case	.56	.17
	Lower-case	.59	.20
	Nonstudied	.39	
High-shift	Upper-case	.60	.16
	Lower-case	.62	.18
	Nonstudied	.44	

Table 2

Proportion of High- and Low-Shift Pseudowords Identified as a Function of the Study Conditions

Study		Test (lower-case)	Priming
Low-shift	Upper-case	.53	.09
	Lower-case	.54	.10
	Nonstudied	.44	
High-shift	Upper-case	.51	.13
	Lower-case	.59	.21
	Nonstudied	.38	

Table 3

Proportion of High-Shift Words and High-Shift Pseudowords Identified as a Function of the Study Conditions

Study		Test (lower-case)	Priming
Words	Upper-case	.37	.05
	Lower-case	.43	.11
	Nonstudied	.32	
Pseudowords	Upper-case	.39	.06
	Lower-case	.50	.17
	Nonstudied	.33	

Table 4

Priming for High- and Low-Shift Words and Pseudowords as a function of the Case Condition Collapsed across Experiments 1-3 (including replication of Experiment 1)

Stimulus	Same-case	Different-case	Cross-Case Change
Low-shift words	.19	.16	.03
High-shift words	.14	.11	.03
Low-shift pseudowords	.10	.09	.01
High-shift pseudowords	.19	.09	.10

Table 5

A) Proportion of High-Shift Words Identified as a Function of the Study Conditions

Study	Test (lower-case)	Priming
Upper-case	.51	.16
Lower-case	.52	.17
Auditory	.40	.05
Nonstudied	.35	

B) Proportion of High-Shift Words Recognized as a Function of the Study Conditions

Study	Test (lower-case)	Hits-False Alarms
Upper-case	.71	.43
Lower-case	.75	.47
Auditory	.73	.45
Nonstudied (False Alarms)	.28	

Appendix A

High-shift Words	Low-shift Word
RAGE/rage	SOCK/sock
DEER/deer	SWIM/swim
GALE/gale	LIMP/limp
EDGE/edge	LOOP/loop
GARB/garb	SLIP/slip
JADE/jade	COIL/coil
LANE/lane	WHIP/whip
GRIN/grin	PULP/pulp
BAND/band	OPUS/opus
DAWN/dawn	CUSP/cusp
AJAR/ajar	PLOW/plow
EARN/earn	SOUP/soup
YARD/yard	WOOL/wool
DENT/dent	PUMP/pump
RARE/rare	CHIP/chip
BARD/bard	SICK/sick
RAKE/rake	MOCK/mock
GLAD/glad	HISS/hiss
GATE/gate	CHIC/chic
ARID/arid	FUZZ/fuzz
BRAN/bran	SOLO/solo
NEON/neon	SOIL/soil
FADE/fade	CHOW/chow
TEND/tend	HOOP/hoop

TREE/tree	SPIT/spit
FERN/fern	PICK/pick
GANG/gang	PLUS/plus
GORE/gore	PUSH/push
GALA/gala	WISP/wisp
HEED/heed	VOWS/vows

Appendix B

High-shift Pseudowords	Low-shift Pseudowords
ADET/adet	BISS/biss
AGEN/agen	CIOP/ciop
AKAR/akar	CULP/culp
ANED/aned	CUSKcusk
ANGE/ange	FISP/fisp
AQUE/aque	FUPP/fupp
DAGE/dage	HUSP/husp
DELD/deld	IPIS/ipis
DERD/derd	ISOT/isot
EDER/eder	JUSS/juss
EGET/eget	OSIP/osip
FEAG/feag	PISK/pisk
GREE/gree	POIPpoip
HAGE/hage	POSK/posk
JANG/jang	POSSposs
KERN/kern	PUSP/pusp
REDA/reda	SIBU/sibu
RENG/reng	SOIS/sois
SARN/sarn	SOIT/soit
TAND/tand	SOOB/sobb
BEAG/beag	UPOS/upos
DAND/dand	WHIS/whis
DARG/darg	WILP/wilp
ERAG/erag	WIOT/wiot

GADE/gade	WISO/wiso
GEAG/geag	WOLP/wolp
IREE/iree	WOST/wost
NARE/nare	WUPT/wupt
NEGA/nega	YOSP/yosp
QUAN/quan	ZIOS/zios

Appendix C

High-shift Words

AIDE/aide	REEF/reef
ARID/arid	WEED/weed
BALD/bald	ALARM/alarm
BANG/bang	ANGEL/angel
BLED /bled	ARENA/arena
BRAG/brag	BADGE/badge
BREW/brew	BLADE/blade
DAME/dame	BLAND/bland
DARN/darn	BLEND/blend
DEAF/deaf	BRAND/brand
DEBT/ebt	BRIBE/bribe
DEED /deed	DADDY/daddy
DIAL/dial	DREAD/dread
DRAB/drab	EAGLE/eagle
DRAG/drag	FABLE/fable
EDGY/edgy	GLIDE/glide
FLAG/flag	GRAPE/grape
GERM/germ	GREED/greed
GRAB/grab	GRILL/grill
HERB/herb	HEDGE/hedge
JADE/jade	LABEL/labe
LAME/lame	LAYER/layer
LEND/lend	RIDGE/ridge
RAGE/rage	WAGER/wager