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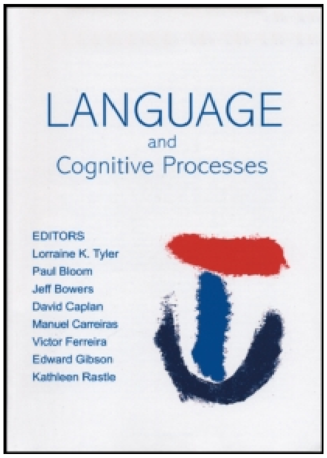

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Transposed-letter effects: Consonants, vowels and letter frequency

Stephen J. Lupker [a]; Manuel Perea [b]; Colin J. Davis [c]
[a] University of Western Ontario, London, ON, Canada
[b] Universitat de València, València, Spain
[c] Royal Holloway University of London, Egham, UK

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Transposed-letter effects: Consonants, vowels and letter frequency

Stephen J. Lupker
University of Western Ontario, London, ON, Canada

Manuel Perea
Universitat de València, València, Spain

Colin J. Davis
Royal Holloway University of London, Egham, UK

There is now considerable evidence (e.g., Perea & Lupker, 2003a, 2003b) that transposed-letter nonword primes (e.g., *jugde* for *JUDGE*) are more effective primes than replacement-letter nonword primes (e.g., *jupte* for *JUDGE*). Recently, Perea and Lupker (2004) demonstrated that, in Spanish, this transposed-letter prime advantage exists only when the transposed letters are consonants (C-C transpositions) and not when they are vowels (V-V transpositions). This vowel-consonant difference causes problems even for models that can successfully explain transposed-letter effects (e.g., SOLAR, Davis, 1999). In Experiment 1 in the present paper, we demonstrated a parallel result in a language with a different syllabic structure (English) in both a masked priming experiment and an unprimed lexical decision task in which the transposed letter strings (e.g., *ADACEMY*, *ACEDAMY*) were used as the nonwords. Results in Experiment 2 suggest that at least part of the reason for

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Correspondence concerning this article should be addressed to: Steve Lupker, Department of Psychology, University of Western Ontario, London, Ontario N6A 5C2, Canada (e-mail: lupker@uwo.ca) or Manuel Perea, Departament de Metodologia, Facultat de Psicologia, Av. Blasco Ibáñez, 21, 46010-València, Spain (e-mail: mperea@uv.es) or Colin Davis, Department of Psychology, Royal Holloway University of London, Egham, Surrey TW20 0EX, UK (e-mail: C.Davis@rhul.ac.uk).

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the vowel-consonant difference is because of the higher letter frequencies of the vowels. Possible alternative interpretations of the vowel-consonant difference are discussed.

Most readers have little difficulty reading an isolated word in their native language. As the past 30 years of research on word recognition has indicated, however, the ease with which readers accomplish this task is quite deceptive, as the process of reading even an isolated word has turned out to be a highly complex one. In the present paper, we consider one aspect of that process: how the reading system encodes letter positions when a word is being read.

The question of how letter positions are coded is a key one for all models of reading. Readers have little trouble distinguishing between words like *READ* and *DEAR* (and *DARE*) in spite of the fact that these words are composed of the same set of four letters. Clearly, there must be a component of the reading process responsible for assigning letters to positions. Most early models of the process (e.g., the multiple read-out model, Grainger & Jacobs, 1996; the interactive-activation model, McClelland & Rumelhart, 1981; the activation-verification model, Paap, Newsome, McDonald, & Schvaneveldt, 1982) simply assumed that that the spatial location of each letter was, essentially, perfectly coded. That is, featural information was assumed to be tagged to its letter position accurately and immediately, or at least well before the letter's features would have been processed to the point that the letter's identity could be established. The processing required in order to establish a letter's identity would then continue independently of the letters at other positions. Models making this type of assumption about coding letter position are said to have a 'channel specific' coding scheme.

The fact that this channel specific assumption is incorrect is now well-documented. Specifically, the channel specific assumption leads to the prediction that readers would find the letter strings *JUPTE* and *JUGDE* equally similar to the word *JUDGE* because both nonwords have exactly three letters in the same 'channels' as the word *JUDGE* does. Evidence, particularly evidence from the masked priming paradigm (Forster, Davis, Schoknecht, & Carter, 1987; Perea & Lupker, 2003a, 2003b, 2004; Schoonbaert & Grainger, 2004; see also Johnson, Perea, & Rayner, 2007, for evidence based on a manipulation of parafoveal previews during reading), demonstrates that this prediction is simply wrong.

In the masked priming paradigm, a letter string, the prime, is presented briefly and masked. Participants typically are not only unaware of the prime's identity, they are usually unaware of its existence. A target letter string is then presented, generally requiring a lexical decision response. Response latencies to *JUDGE* following primes like *jugde* (transposed-letter, TL, primes) are faster than latencies following primes like *jupte* (replacement-letter, RL, primes) indicating that the former activates the lexical representation of the word *JUDGE* to a larger extent than the latter. (In the present paper, we refer to this type of phenomenon as a transposed-letter prime advantage.) Similar conclusions can be drawn from studies using transposed- versus replacement-letter nonwords as foils in unprimed lexical decision tasks (Chambers, 1979; O'Connor & Forster, 1981; Perea & Lupker, 2004; Perea, Rosa, & Gómez, 2005).

Although these transposed-letter effects cannot be explained by channel-specific models of letter position coding, they can be explained by some of the more recent models of letter coding, for example, the SOLAR model (Davis, 1999), the overlap model (Gómez, Ratcliff, & Perea, 2007), or open-bigram coding models (Grainger & van Heuven, 2003; Whitney, 2001). The SOLAR model uses a coding scheme called *spatial coding* in which letters are assigned a temporary position code, with larger values assigned to earlier letters (e.g., in *JUDGE*, the *J* would be assigned a larger value than the *U*, which would have a larger value than the *D*, etc.). Exactly the same set of (position-independent) letter units would be used to code *JUDGE* and *JUGDE*, but the spatial codes would be slightly different (the position code values assigned to the *D* and *G* letter units would differ). Consequently, the perceptual match between *JUDGE* and its transposition neighbour *JUGDE* would be much greater than the match between *JUGDE* and its (double) replacement neighbour *JUPTE*.

In the overlap model (Gómez et al., 2007), for any string of letters, each letter is assumed, at least initially, to be associated with more than one position. That is, each letter has a different spread of association (i.e., a standard deviation) across letter positions (this value is treated as a free parameter in the model). For instance, if the string of letters is the word *JUDGE*, the letter *D* will be associated with position 3, but also, to a lesser degree, with positions 2 and 4, and, to an even lesser degree, with positions 1 and 5. This model therefore also predicts that *JUDGE* and *JUGDE* are relatively perceptually similar.

Open-bigram coding schemes (Grainger & van Heuven, 2003; Whitney, 2001) code letter strings by activating a series of bigram nodes that reflect the order of the letters (e.g., for the word *JUDGE*, the nodes for *JU*, *JD*, *JG*, *UD*, *UG*, etc. would all be activated, but not the node for *DJ* because the *J* comes before the *D*). According to this model, *JUDGE* and *JUGDE* share exactly the same set of open-bigram codes, except for the one that codes the pair of letters *D* and *G*. In summary, each of these models can do a good job of explaining transposed-letter effects because, according to these models, *JUGDE* and *JUDGE* are more similar than *JUPTE* and *JUDGE*.

The results reported by Perea and Lupker (2004) represent the jumping off point for the present investigation. In a lexical decision task using Spanish words, Perea and Lupker demonstrated that transposed-letter nonwords (e.g., *caniso* for the target *CASINO*) do not have to involve adjacent letters in order to produce more priming than replacement-letter nonwords (e.g., *caviro* for the target *CASINO*). More importantly for present purposes, Perea and Lupker demonstrated that this transposed-letter prime advantage existed only when two consonants were transposed (e.g., *caniso*) and not when two vowels were transposed (e.g., *cisano*). In a final experiment, Perea and Lupker demonstrated that although the vowel-transposed nonwords (e.g., *CISANO*) were more difficult to reject in an unprimed lexical decision task (i.e., they seemed more like words) than vowel replacement nonwords (e.g., *CESUNO*), the difference was substantially smaller than that between consonant transposition and consonant replacement nonwords.

Perea and Lupker's (2004) results suggest that there is something different about the processing of vowels versus consonants. This result, of course, is not something that can be explained by SERIOL, SOLAR or the overlap model since none of these models distinguish between vowels and consonants. However, the existence of a vowel-consonant difference is in line with proposals by Berent and colleagues (Berent & Perfetti, 1995; Berent, Bouissa, & Tuller, 2001) and Caramazza and colleagues (Caramazza, Chialant, Capasso, & Miceli, 2000; Caramazza & Miceli, 1990; Tainturier & Caramazza, 1996), among others. In general, what these authors have suggested is that the consonant-vowel structure of a word is determined very early in processing (e.g., for *CASINO*, it would be CVCVCV) and that structure then guides subsequent processing. In addition, Berent and colleagues have argued that the assignment of consonants to their positions occurs earlier in processing than the assignment of vowels.

If vowels are, indeed, processed more slowly than consonants, one could propose that there is not sufficient time to establish any vowel identities when presented with either the *cisano* prime or the *cesuno* prime. Thus, these primes establish only consonant information making them equally similar to the target *CASINO* and, hence, causing them to have equal impacts on target processing, as Perea and Lupker (2004) observed. On the other hand, one could explain Perea and Lupker's results by making the exact opposite argument, that is, that vowels are processed more rapidly than consonants and are, in fact, rapidly slotted into their correct letter positions. Thus, vowel information from both *cisano* and *cesuno* would indicate that there are vowel mismatches with the target *CASINO* at both letter position two and letter position four. As a result, the two primes would have equal impacts on target processing, again, as Perea and Lupker (2004) observed.

Before speculating any further on the mechanism producing this vowel-consonant difference, however, an important point to note is that this particular phenomenon has only been reported in Spanish. Spanish is different from many languages, for example, English or French, in a couple of potentially important ways. One notable difference is that it has a very regular syllable structure. Specifically, words are (usually) made up of a set of common short syllables. *CASINO* is a good example. It is a three-syllable word in which all syllables are two letters in length. Due to the nature of Spanish, all letter transpositions in the stimuli in Perea and Lupker's (2004) experiments were, of necessity, between-syllable transpositions.

At a general level, one implication of this aspect of Spanish is that the syllable may play a larger role for Spanish readers than for English readers (e.g., see Perea & Carreiras, 1998, for evidence of syllabic effects in Spanish). Thus, one could conceptualise the transposed-letter primes that Perea and Lupker (2004) used as actually being syllable-replacement primes (e.g., *caniso* is derived from *CASINO* by replacing the middle syllable of *CASINO* with the syllable *NI* and the final syllable with the syllable *SO*). Similarly, the replacement-letter primes (e.g., *caviro*) could also be conceptualised as syllable-replacement primes. Because no effort was made to equate the relevant syllables in the two prime types on any dimensions (e.g., syllable frequency), the possibility exists that the result that Perea and Lupker (2004) observed could be a syllable-based phenomenon rather than a letter-based phenomenon. Hence, this phenomenon may be beyond the scope of letter coding models like the SOLAR, overlap, or open-bigram models.[1]

A second way in which Spanish differs from English (and French) is that there is essentially a one-to-one correspondence between letters and phonemes in Spanish which is not true in English (or French). Thus, when two letters are transposed in Spanish, the resultant letter string (e.g., *CANISO*) has an unambiguous pronunciation involving the same phonemes, in a different order, as the base word. A transposition of vowel letters, therefore, is also a transposition of vowel phonemes and the same is true for consonants. In contrast, in English, a letter transposition, involving either vowels or consonants, can often produce a letter string containing a different set of phonemes (e.g., *INSURE* contains different phonemes than *INRUSE*). To the extent that phonology might be important in the processing of TL nonwords, it is certainly possible that the principles underlying TL effects, and, hence, the vowel-consonant contrast observed in Spanish, might be somewhat different in English. If so, once again, it may be the case that the explanation of any vowel-consonant differences may be beyond the scope of letter coding models.[2]

The argument that Perea and Lupker's (2004) vowel-consonant differences are due to the letter coding process, rather than a syllable-based or a phonologically based process, would receive much stronger support if a similar pattern were produced in English. At present, what little evidence on

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[1] It should be noted, however, that in a recent study in Spanish, Perea and Carreiras (2006b) failed to observe an effect of syllable transpositions over and above an effect of bigram transpositions in a single-presentation lexical decision task.

[2] The authors would like to thank Clive Frankish for bringing these ideas to our attention.

this issue actually exists in English does suggest that English behaves like Spanish. Specifically, in a post-hoc analysis of their English stimuli, Perea and Lupker (2003a) found evidence of a larger transposed-letter prime advantage when those primes involved two consonants (C-C) than when they involved two vowels (V-V). Unfortunately, the numbers of each type of prime were small, especially the V-V transposed/replacement primes, because the majority of the primes involved a transposition/replacement of one vowel and one consonant.

An additional issue concerning Perea and Lupker's (2003a) stimuli is that whereas the Spanish primes in Perea and Lupker (2004) involved the transposition of nonadjacent letters (e.g., *caniso*-*CANISO*) the English primes in Perea and Lupker (2003a) involved the transposition of adjacent letters (e.g., *bugdet*-*BUDGET*). In the case of the V-V transpositions, what this typically meant was that the letters in a grapheme were being transposed (e.g., *braeht*-*BREATH*). Such was true much less often for consonant transpositions (e.g., *bugdet*-*BUDGET*). To the extent that graphemes represent important visual units, this fact might have artefactually reduced the similarity between the V-V primes and their targets.

EXPERIMENT 1

The goal of Experiment 1 was to investigate the question of the existence of this vowel-consonant difference in English more systematically. A set of target words was selected which allowed for both nonadjacent C-C and V-V transpositions (e.g., *ANIMAL, aminal, anamil*). (In Perea and Lupker's (2004) experiments, different base words were used to generate the stimuli for the C-C versus V-V conditions. Thus, the present manipulation, involving the same base word (i.e., target) for both conditions, provides a cleaner manipulation of the C-C versus V-V contrast.) In Experiment 1a, these words were primed by either a C-C transposition prime, a V-V transposition prime (the TL primes) or control primes involving replacement of either the two consonants or the two vowels in question (RL primes), as in Experiment 3 in Perea and Lupker (2004). In Experiment 1b, these nonword primes were used as nonword targets in an unprimed lexical decision task, as in Experiment 4 in Perea and Lupker (2004). If the processes are the same in Spanish and English, the expectation is that the TL-RL contrast will be larger for the C-C manipulation than for the V-V manipulation. Specifically, the TL-RL difference in terms of priming effects will be larger for C-C primes than for V-V primes in Experiment 1a and the TL-RL difference, in terms of overall latencies to respond 'nonword', will be larger for the C-C targets than for the V-V targets in Experiment 1b.

Method

Participants. Fifty-two undergraduates from the University of Bristol received course credit for participating in Experiment 1a and 20 undergraduate students from the University of Western Ontario received course credit for participating in Experiment 1b. All of them either had normal or corrected-to-normal vision and were native speakers of English.

Materials. The word targets in Experiment 1a were 80 English words. Their mean length is 7.3 letters (range 6–9) and their mean word frequency (per million) in the CELEX count is 34.0 (range: 0.6–167.9) (in the Kucera and Francis (1967) count, their mean frequency is 48.3 with a range of 9–222).

Four nonwords were created based on each word target to serve as primes in Experiment 1a and as nonword foils in Experiment 1b. These nonwords were created by: (1) transposing two nonadjacent vowels (*anamil*-*ANIMAL*, the V-V TL condition), (2) replacing those vowels with other vowels (*anemol*-*ANIMAL*, the V-V RL condition), (3) transposing two nonadjacent consonants (*aminal*-*ANIMAL*, the C-C TL condition) and (4) replacing those two consonants with other consonants (*asiral*-*ANIMAL*, the C-C RL condition). Average position of the first transposed/replaced letter was the same for V-V transpositions and for C-C transpositions (mean = 3.1 in both cases). These stimuli are all listed in the Appendix.

For the nonword trials in Experiment 1a, 80 nonwords (mean length of 7.3 (range 6–9)) were selected. In addition, V-V TL, V-V RL, C-C TL, and C-C RL primes were created for each of the nonword targets in a manner similar to how they were created for the word targets. All of these primes were also nonwords. For the word trials in Experiment 1b, 80 words were selected (mean length of 7.3 (range 6–8), mean CELEX frequency of 4.6 (range 0–27.2) and mean Kucera-Francis (1967) frequency of 4.0 (range 0–5)).

In Experiment 1a, the targets (both words and nonwords) were presented in upper-case and were preceded by primes in lower-case that came from one of the four nonword prime conditions. To accomplish the appropriate counterbalancing, the targets were divided into four sets of size 20 and each set was primed by primes from one of the four prime conditions. Four groups of subjects were required in order to complete the counterbalancing.

In Experiment 1b, a similar counterbalancing was required. For each set of 20 base words, one of the four types of nonwords was selected. Thus, each subject saw only one nonword derived from each base word. The type of nonword selected for each base word was rotated across four groups of subjects. The same 80 word targets were used for all subjects.

Apparatus. In Experiment 1a, the stimuli were presented using PCs running the DMDX software for Windows (Forster & Forster, 2003) on a

15-inch CRT monitor (AOC, Model 7V1r) with a 16 ms refresh rate. Responses were made by pressing the left and right shift keys on a standard keyboard. In Experiment 1b, the stimuli were presented using an IBM-clone computer system (Trillium Computer Resources Model No. 316S-80MS). The monitor was a TTX Multiscan Monitor (Model No. 3435P) and a button box was used to record responses.

Procedure. Subjects were tested either individually or (for some subjects in Experiment 1a) in groups of two. Reaction times were measured from target onset until the subject's response. In Experiment 1a, on each trial, a forward mask consisting of a row of six hash marks (######) was presented for 500 ms in the centre of the screen. Next, a centred lower-case prime was presented for 47 ms. Primes were immediately replaced by an upper-case target item, which remained on the screen until the response. In Experiment 1b, a fixation point was initially presented in the centre of the screen for 500 ms followed by an upper-case target which remained on the screen until the response.

In both experiments, subjects were told that they would see strings of letters, and that they were to press the button marked 'WORD' (with their right index finger) if they thought the letter string spelled a real English word, and they were to press the button marked 'NONWORD' (with their left index finger) if they thought the letter string did not spell a real English word. Subjects were instructed to make this decision as quickly and as accurately as possible. Subjects were not informed of the presence of lower-case items in Experiment 1a. Each subject received a different, randomised order of trials. There were 10 practice trials in Experiment 1a and 8 practice trials in Experiment 1b. Each experiment lasted no more than 15 minutes.

RESULTS

Experiment 1a. Incorrect responses (3.4% of the trials) and response times greater than 1500 ms (0.9% of the trials) were excluded from the latency analysis. The mean response times and error percentages from the subject analysis for the word data are presented in Table 1. (The data from nonwords will not be considered further.) ANOVAs based on the subject and item mean correct response times and error rates were conducted based on a 2 (Prime type: transposition, replacement) × 2 (Letter type: consonants, vowels) × 4 (List: list 1, list 2, list 3, list 4) design. List (which can be conceptualised as Group in the subject analysis) was included as a dummy variable in the ANOVAs to extract the variance due to the error associated

TABLE 1
Mean lexical decision times (in ms) and percentage of errors (in parentheses) for word targets in Experiment 1a

	Type of Prime		
	TL	*RL*	*TL priming*
Consonant-Consonant	639 (3.3)	663 (3.1)	24 (−0.2)
Vowel-Vowel	650 (4.3)	653 (2.9)	3 (−1.4)

Notes: TL = Transposed-Letter prime, RL = Replacement-Letter prime.The mean correct nonword latency was 738 ms (4.6% of the nonword trials were errors).

with the random assignment of items to lists. Both Prime type and Letter type were within-subject and within-item factors.[3]

In the latency data, the main effect of Prime type was significant, $F_1(1, 48) = 9.53$, $MSE = 938$, $p < .005$; $F_2(1, 76) = 5.22$, $MSE = 1789$, $p < .03$ while the main effect of Letter type was not significant (both Fs < 1). More importantly, there was a significant interaction between these two factors $F_1(1, 48) = 4.78$, $MSE = 1264$, $p < .05$; $F_2(1, 76) = 7.09$, $MSE = 1696$, $p < .01$. This interaction is due to the fact that the TL-RL difference was larger in the C-C condition (24 ms) than in the V-V condition (3 ms). The former difference is significant, $F_1(1, 48) = 13.18$, $MSE = 1126$, $p < .001$; $F_2(1, 76) = 13.07$, $MSE = 1627$, $p < .001$ whereas the latter is not, (both Fs < 1). None of the effects approached significance in the error data.

Experiment 1b. Only the nonword data were analysed. Incorrect responses (7.6% of the trials) and response times greater than 1500 ms (12.7% of the trials) were excluded from the latency analysis. The mean response times and error percentages from the subject analysis are presented in Table 2. ANOVAs based on the subject and item mean correct response times and error rates were conducted based on a 2 (Alteration type: transposition, replacement) × 2 (Letter type: consonants, vowels) × 4 (List: list 1, list 2, list 3, list 4) design. List (which can be conceptualised as Group in the subject analysis) was again included as a dummy variable in the ANOVAs to extract the variance due to the error associated with the random

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[3] For 8 of the 80 words, the V-V condition involved a transposition with two intermediate letters (e.g., *cirdanal-CARDINAL*). All the other transpositions involved only one intermediate letter (e.g., *anamil-ANIMAL*). Removing these eight words from the analyses in both Experiment 1a and 1b did not alter the pattern of results.

TABLE 2
Mean lexical decision times (in ms) and percentage of errors (in parentheses) for nonword targets in Experiment 1b

	Type of Nonword Target		
	TL	*RL*	*TL effect*
Consonant-Consonant	969 (17.5)	868 (1.5)	101 (16.0)
Vowel-Vowel	916 (7.0)	867 (3.0)	49 (4.0)

Notes: TL = Transposed-Letter nonword foil, RL = Replacement-Letter nonword foil. The mean correct word latency was 799 (7.7% of the word trials were errors).

assigment of items to lists. Both Alternation type and Letter type were within-subject and within-item factors.[4]

In the latency data, the Alteration type $F_1(1, 16) = 18.66$, $MSE = 6026$, $p < .001$; $F_2(1, 75) = 58.04$, $MSE = 12125$, $p < .001$ and the Letter type main effects $F_1(1, 16) = 5.95$, $MSE = 2454$, $p < .03$; $F_2(1, 75) = 6.25$, $MSE = 10216$, $p < .02$ were significant. More importantly, there was a significant interaction between these two factors $F_1(1, 16) = 7.84$, $MSE = 1647$, $p < .02$; $F_2(1, 75) = 9.26$, $MSE = 8985$, $p < .005$. This interaction is due to the fact that the TL-RL difference is larger in the C-C condition (101 ms) than in the V-V condition (49 ms).

In the error data, the Alteration type $F_1(1, 16) = 12.62$, $MSE = 6.34$, $p < .005$; $F_2(1, 75) = 46.11$, $MSE = .40$, $p < .001$ and the Letter type main effects $F_1(1, 16) = 17.28$, $MSE = .94$, $p < .001$; $F_2(1, 75) = 14.28$, $MSE = .23$, $p < .001$ were significant. More importantly, there was a significant interaction between these two factors $F_1(1, 16) = 11.76$, $MSE = 2.45$, $p < .005$; $F_2(1, 75) = 24.42$, $MSE = .25$, $p < .001$. This interaction is due to the fact that the TL-RL difference is larger in the C-C condition (16%) than in the V-V condition (4%).

Discussion

The contrast between the C-C condition and the V-V condition is very similar to that found with Spanish. In Experiment 1a, in the C-C condition, there was a significant transposed-letter prime advantage (in comparison to the replacement-letter primes). In the V-V condition, there was no such advantage. This result closely replicates the results in Experiment 3 in Perea and Lupker (2004). In Experiment 1b, both C-C transpositions and V-V

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[4] The latency data from one nonword in the C-C TL condition Experiment 1b (*CEMERONY*) could not be analysed because none of the subjects seeing that nonword responded correctly.

transpositions produced longer latencies and higher error rates than nonwords created by replacing the letters in question. However, the transposed-letter disadvantage was much larger for the C-C nonwords than for the V-V nonwords. If anything, these data show an even stronger effect than the effect reported in Perea and Lupker's (2004) Experiment 4 using Spanish stimuli. In that experiment, the interaction was only significant in the error analysis.

The results of these experiments suggest that the parallel pattern in Spanish is not due to the unique syllable-based nature of the Spanish language nor its transparent relationships between letters and sounds. Rather, the pattern appears to be due to the fact that consonant transposition nonwords (e.g., *CANISO*, *AMINAL*) are more similar to their base words (e.g., *CASINO*, *ANIMAL*) than vowel transposition nonwords (e.g., *CISANO*, *ANAMIL*) are to their base words. Hence, the former provide more activation of the lexical structures of their base words than the latter. Note also that the existence of a TL disadvantage for V-V transpositions in Experiment 1b does indicate that V-V transposition nonwords (e.g., *ANAMIL*) are more similar to their base words than V-V replacement nonwords (e.g., *ANEMOL*). The similarity is simply weaker than that for C-C transpositions.

As noted earlier, the newer letter coding models – SOLAR (Davis, 1999; Davis & Bowers, 2006), the overlap model (Gómez et al., 2007), the SERIOL model (Whitney, 2001), and Grainger and van Heuven's (2003) open-bigram coding model – do have difficulty with these types of results, specifically, with the lack of a transposed-letter prime advantage for V-V targets. The reason is that these models do not distinguish between vowels and consonants and, thus, none of the models has a mechanism for explaining why this effect should vary as a function of whether the letters in question are vowels or consonants. Before amending any of these models in an attempt to make them consistent with the data from Experiment 1, however, we need to consider at least one potential explanation for the vowel-consonant differences in Experiment 1.

EXPERIMENT 2

It clearly is the case that vowels and consonants play qualitatively different roles in the structure of words. However, they also differ in a few other ways. In particular, they differ in terms of frequency. The five standard vowels (*a*, *e*, *i*, *o*, *u*) are among the most frequent letters in the English language. Letter frequencies for consonants tend to be somewhat lower. One could certainly propose, therefore, that what was observed in Experiment 1 (and in Perea & Lupker, 2004), was a letter frequency effect. More frequent letters may be more easily processed and more readily tied to their positions. Thus, vowel information from both *cisano* and *cesuno*, when presented as primes, would be available very quickly and, in both cases, indicate that there are vowel mismatches with the target *CASINO* at letter positions two and four. In contrast, consonant information from *caniso* and *caviro* may not be as quickly activated or, more importantly, not as quickly tied to a position. Thus, the existence of an *n* and an *s* in *caniso* may provide extra activation for *CASINO* beyond that provided by *caviro*.

Experiment 2 was an attempt to determine whether the size of the transposed-letter prime advantage is a function of letter frequency with lower frequency letters producing a larger advantage. Two sets of six- to ten-letter words were selected. One set had two low-frequency consonants in nonadjacent letter positions (e.g. SI*Z*A*B*LE), the other set had two high-frequency consonants in nonadjacent letter positions (e.g. P*R*E*T*EXT). Both sets were primed by transposed-letter primes and by replacement-letter primes (the two letters in the positions that were transposed in the transposed-letter prime condition were replaced by letters similar in form in the replacement-letter prime condition, for example, an *n* would be replaced by an *m*). If letter frequency is a key, the transposed-letter prime advantage should be larger for the low-frequency letter targets than for the high-frequency letter targets.

Method

Participants. Seventy-eight undergraduate students from the University of Western Ontario received course credit for participating in this experiment. All of them either had normal or corrected-to-normal vision and were native speakers of English.

Materials. The word targets were 72 six- to ten-letter English words. Half of these words have two high-frequency consonants (*t*, *n*, *s*, *r*, *l*, or *d*) (Mayzner & Tresselt, 1965) in two internal letter positions which are separated by one letter position. Their mean word frequency in the CELEX count is 6.1 (range: 0–103.3), their mean number of letters is 8.3 (range: 7–10) and their mean number of orthographic neighbours is 0.1 (range: 0–1). The other 36 words have two low-frequency consonants (*g*, *p*, *v*, *b*, *j*, *x*, *q*, or *z*) (Mayzner & Tresselt, 1965) in two internal letter positions which are separated by one letter position. Their mean word frequency (per million) in the CELEX count is 3.7 (range: 0.3–39.3), their mean number of letters is 8.3 (range: 6–10) and their mean number of orthographic neighbours is 0.1 (range: 0–1). The targets were presented in upper-case and were preceded by primes in lower-case that were (1) the same as the target except for the transposition of the two selected letters, or (2) the same as the target except for the replacement of the two selected letters. The primes were always nonwords. An additional set of 72 six- to ten-letter nonword targets was included for the purposes of the lexical decision task. The prime manipulation for the nonword targets was the same as that for the word targets. Two lists of materials were constructed so that each target appeared once in each list. In one list, half the targets were primed by transposed-letter primes and half were primed by replacement-letter primes. In the other list, targets were assigned to the opposite prime conditions. Half of the subjects were presented with each list.

Equipment. The experiment was run on DMDX experimental software (Forster & Forster, 2003). Stimuli were presented on an IBM-clone computer system with a Pentium 4 processor. The monitor was a Samsung SyncMaster (Model No. 753DF) with a 16 ms refresh rate. The keyboard was used to record responses. Participants were requested to press the right < shift > key if the item was a word and the left < shift > key if the item was not a word.

Procedure. The procedure was the same as in Experiment 1a.

Results

Incorrect responses (13.7% of the data for word targets) and response times less than 250 ms or greater than 1500 ms (3.3% of the data for word targets) were excluded from the latency analysis. The mean response times and error percentages from the subject analysis for the word data are presented in Table 3. (The data from nonwords will not be considered further.) ANOVAs based on the subject and item mean correct response times and error rates were conducted based on a 2 (Prime type: transposition, replacement) × 2 (Letter frequency of transposition/replacement: low, high) × 2 (List: list 1, list 2) design.

TABLE 3
Mean lexical decision times (in ms) and percentage of errors (in parentheses) for word targets in Experiment 2

	Type of Prime		
	TL	*RL*	*TL Priming*
Low-frequency letters	722 (14.6)	756 (15.2)	34 (0.6)
High-frequency letters	738 (12.4)	749 (12.6)	11 (0.2)

Notes: TL = Transposed-Letter prime, RL = Replacement-Letter prime.
The mean correct nonword latency was 819 ms (11.2% of the nonword trials were errors).

Targets preceded by transposed-letter primes were responded to 22 ms faster than the targets preceded by replacement-letter primes, producing a main effect of Prime type, $F_1(1, 76) = 18.65$, $MSE = 2088$, $p < .001$; $F_2(1, 68) = 19.27$, $MSE = 1445$, $p < .001$. The main effect of Letter Frequency of transposition/replacement did not approach significance, both Fs < 1. More important, the interaction of the two factors was significant, $F_1(1, 76) = 4.59$, $MSE = 2328$, $p < .05$; $F_2(1, 68) = 2.90$, $MSE = 1445$, $p < .10$. There was a significant 34-ms transposed-letter prime advantage when the transposed consonants were low frequency, $F_1(1, 76) = 18.83$, $MSE = 2402$, $p < .001$; $F_2(1, 34) = 32.64$, $MSE = 822$, $p < .001$ whereas there was a nonsignificant (11 ms) trend towards a transposed-letter prime advantage when the transposed consonants were high frequency, $F_1(1, 76) = 2.19$, $MSE = 2014$, $p = .14$; $F_2(1, 34) = 2.52$, $MSE = 2069$, $p = .12$.

The ANOVA on the error data only showed an effect of Letter Frequency of transposition/replacement in the subject analysis, $F_1(1, 76) = 8.43$, $MSE = 52.7$, $p = .005$; $F_2 < 1$, $MSE = 519.4$, *n.s.*

Discussion

The present results show a robust transposed-letter prime advantage for word targets when the transposition involved two nonadjacent consonants, replicating the results of Experiment 1a and Perea and Lupker's (2004) results in Spanish. More important, they also show that the *frequency* of the transposed consonants plays a role in the magnitude of the transposed-letter prime advantage. There was a robust (34 ms) transposed-letter prime advantage when the consonants were low frequency and a substantially smaller (11 ms), and nonsignificant, transposed-letter prime advantage when the transposition involved two high-frequency consonants.

The implication of these results is that letter frequency *does* matter in a way that could explain at least part of the transposed-letter prime advantage for C-C primes over V-V primes in Experiment 1a and in Experiment 3 of Perea and Lupker (2004) (and presumably, the pattern of results in the parallel experiments using these primes as nonwords in an unprimed lexical decision task). These results do not, of course, prove that the difference between transposed-letter effects for C-C primes versus V-V primes (or C-C nonwords versus V-V nonwords) in those experiments is completely due to the frequency difference between consonants and vowels. At present, however, what this result does suggest is that models like the SOLAR model, the overlap model and open-bigram coding models can attempt to account for that difference without proposing that consonants and vowels are processed differently during the letter-coding process. What these models would only need, of course, is to come up with a principled way of incorporating the impact of letter frequency on the coding process. Ideas for how that might be done are considered in the General Discussion.

GENERAL DISCUSSION

The results of the experiments reported here provide further evidence of a difference in the way that letter position is coded for vowels versus consonants, as well as suggesting a possible explanation for this difference. Experiment 1a showed a greater transposed-letter prime advantage for primes formed by transposing consonants than for primes formed by transposing vowels, replicating the effect originally reported in Perea and Lupker's (2004) Experiment 3. Experiment 1b showed a larger transposed-letter nonword disadvantage (in comparison to replacement-letter nonwords) in a lexical decision task when the letters in question were consonants rather than vowels, replicating the results reported in Perea and Lupker's (2004) Experiment 4. These results argue against the possibility that the differences observed by Perea and Lupker (2004) can be attributed to factors that are specific to Spanish stimuli, such as the nature of Spanish's syllabic structure or the nature of its letter-sound correspondences. Rather, the parallel findings in English and Spanish suggest that nonwords formed by transposing consonants (e.g., *CANISO*, *AMINAL*) are more similar to their base words than nonwords formed by transposing vowels (e.g., *CISANO*, *ANAMIL*).

The obvious next question is why is there this vowel-consonant difference? A possible explanation is suggested by the results of Experiment 2. In this experiment there was a large transposed-letter prime advantage when low-frequency consonants were transposed, but a small, nonsignificant, advantage when high-frequency consonants were transposed. Thus, it appears that the frequency of the transposed consonants affects the perceptual similarity of the transposed-letter prime to its base word target. A possible implication is that the position of low-frequency letters may be coded in a relatively loose fashion, so that these letters are quite vulnerable to perceptual transpositions. By contrast, when letters are of high frequency, the relative position of these letters may be coded more strictly, making these letters less vulnerable to perceptual transpositions. Thus, nonwords formed by transposing two high-frequency letters will not be much more perceptually similar to the base word than double-replacement-letter nonwords are.

With respect to the vowel-consonant difference observed in Experiment 1, it is therefore possible that this difference could merely reflect differences created by letter frequency. Vowels are among the highest frequency letters. Thus, it follows that nonwords formed by transposing two vowels should be relatively less effective as primes (and less word-like when presented alone) than nonwords formed by transposing consonants, in accord with the results reported here and by Perea and Lupker (2004).

One question that may occur to readers is whether the results in Experiment 2 might be due to letter frequency affecting the coding of letter identity, rather than letter position. It is certainly conceivable that high-frequency letters like *T* could be identified more rapidly than low-frequency letters like *Z* and, if so, there might be an impact on the efficacy of the different primes. It seems unlikely, however, that this factor could account for the differences observed in Experiment 2. Suppose that the identities of the lower frequency letters of a briefly presented prime were perceived more slowly than the identities of high-frequency letters. If so, a TL prime like *sibazle* (for the target *SIZABLE*) should not be much more effective than the double-replacement prime *sivaple*, because the identities of the critical (low-frequency) letters *B*, *Z*, *V*, and *P* will often not be registered correctly prior to the onset of the target. By contrast, a TL prime like *heteric* (for the target *HERETIC*) should be much more effective than the double-replacement prime *helesic*, given that the identity of the critical (high frequency) letters *T*, *R*, *L* and *S* should be determined quite rapidly. That is, an account based on the premise that letter frequency affects speed of letter identification would predict that TL primes with low-frequency transposed letters will be *less* effective than those with high-frequency transposed letters, contrary to the observed findings. It appears, therefore, that the findings of Experiment 2 reflect the effect of letter frequency on the coding of letter position, rather than the coding of letter identity.

This conclusion does, of course, raise the question of why letter frequency affects the accuracy of letter position coding. One speculation would go as follows. Suppose that the activities of letter units in models like SOLAR or the overlap model represent the combined activity of multiple neurons. Suppose further that the number of neurons associated with any given letter is a function of the frequency of that letter, such that frequent letters are coded by a larger population of neurons than less frequent letters. If each of these neurons codes letter position, with some associated error, it follows that the standard deviation of the position code will be smaller for letters coded by larger populations (i.e., for letters of higher frequency). Thus, in a model of this sort, the accuracy of the position code for a given letter will be positively correlated with the frequency of the corresponding letter. For example, in the overlap model (Gomez et al., 2007), one merely needs to assume that the level of ‘noise’ in a given letter position (i.e., the spread of association) is dependent on letter frequency. A similar analysis applied to the frequencies of the open-bigrams might also help the open-bigram models explain the present data.

Even if this analysis is correct, of course, what the present data do not allow us to do is to conclude that letter frequency (or bigram frequency) is the sole cause of the observed vowel-consonant differences. If letter frequency is not the sole cause, what other factors might be at work here? One factor, of course, might be phonology. For example, Frankish and Turner (2007) have recently claimed that the pronounceability of the TL letter string affects its processing. In particular, Frankish and Turner found that (briefly presented) nonwords formed by transposing two letters were less likely to be misclassified as words if the nonwords were pronounceable (e.g., *STROM*) than if they were unpronounceable (e.g., *GLVOE*). They suggested that the greater ease of rejecting pronounceable nonwords like *STROM* could be explained in terms of inhibitory processes. According to this account, viable phonological representations can be constructed for pronounceable nonwords like *STROM* but not for nonwords like *GLVOE*. Hence, there will be substantially more inhibitory feedback from the phonological level to the representation of the base word *STORM*, than there will be to the representation for the base word *GLOVE*. As a result, it is much less likely that readers would interpret *STROM* as *STORM* than they would interpret *GLVOE* as *GLOVE*.

Although the present data say nothing about the viability of Frankish and Turner's (2007) hypothesis concerning the nature of TL priming effects in general, their hypothesis clearly cannot explain our vowel-consonant differences. Due to the nature of how we constructed our TL and RL stimuli (only substituting vowels for vowels and consonants for consonants), virtually all of our primes, both consonant-based and vowel-based, were readily pronounceable (even if readers might disagree about the correct pronunciation, e.g., is the *C* in *ADACEMY* or *ACEDAMY* hard or soft?). Hence, virtually all of our primes should have provided reasonable levels of inhibitory feedback to their base words (e.g., *ACADEMY*).

Are there other ways in which phonology might have created the vowel-consonant difference? Possibly, however, what should be noted is that there is other research which also casts doubt on the idea that transposed-letter priming effects are phonologically based. For example, recently, Perea and Carreiras (2006a) exploited the pronunciations of the consonant letters *B* and *V* in Spanish – the pronunciation of these two letters in Spanish is exactly the same (/b/) – and examined whether there were differences between the response times to *relovución-REVOLUCIÓN*, *relobución-REVOLUCIÓN* (*relobución* and *relovución* have the same pronunciation) and (the orthographic control) *relodución-REVOLUCIÓN* in a lexical decision task. In Experiment 1, Perea and Carreiras found a significant advantage (15 ms) of the transposed-letter prime condition (*relovución-REVOLUCIÓN*) relative to the phonological prime condition (*relobución-REVOLUCIÓN*), whereas there was virtually no difference between the phonological prime and orthographic control conditions. Perea and Carreiras concluded that the nature of the transposed-letter priming effect was mainly orthographic.

Other researchers who have reached the same conclusion include Grainger, Kiyonaga, and Holcomb (2006). Grainger et al. examined orthographic priming using transposed-letter nonword primes (e.g., *barin*-*BRAIN*) and their orthographic controls (e.g., *bosin*-*BRAIN*), whereas phonological priming was examined using pseudohomophone primes (e.g., *brane*-*BRAIN*) and their controls (e.g., *brant*-*BRAIN*). They found that transposed-letter priming and pseudohomophone priming had distinct topographical distributions and different timing, with transposed-letter priming effects arising earlier than pseudohomophone priming effects. On balance, then, it seems likely that the difference between vowel and consonant transpositions, at least in masked priming, is due to differences in the nature of the orthographic representations for vowels and consonants, as opposed to phonological factors.

The different frequencies of vowels and consonants is, of course, only one way in which the nature of their orthographic representations may differ. What are some other possibilities? Neuropsychological studies of spelling disorders (e.g., Buchwald & Rapp, 2006; Caramazza et al., 2000; Cubelli, 1991; Miceli, Capasso, Benvegnu, & Caramazza, 2004) offer some suggestions. Cubelli (1991), for example, reported a patient, CW, who made significantly more errors on vowels than on consonants across a variety of spelling tasks. A patient with the opposite dissociation, that is, a strong tendency to make errors on consonants, but not vowels, was recently reported by Miceli et al. (2004). This double dissociation has been argued to provide evidence that there are neuroanatomically separate representations of consonants and vowels.

The implications of spelling errors in which either consonants or vowels are selectively preserved are discussed in a recent article by Buchwald and Rapp (2006). Their analysis of the preservation of CV status in letter substitution errors led them to favour a model in which orthographic representations include orthography-specific CV information. For example, the word *DRAIN* would be coded at the letter identity level as $D+R+A+I+N$, but also at an orthographic CV level as $C+C+V+V+C$, where C and V reflects the CV status of each letter.

If this particular analysis were correct and had something to do with the present effects, one implication is that transpositions involving a vowel and a consonant should produce a letter string that does not closely resemble its base word. That is, a letter string like *HOSRE* would have an orthographic code that is structurally different from that of its base word *HORSE* while any transpositions involving either two vowels or two consonants would have orthographic codes that were more similar to their base words. The expectation, therefore, would be for an even smaller priming effect in a C-V condition than that found in the V-V condition (i.e., it should be essentially nonexistent). Although this issue has not been systematically looked at, the post hoc analysis of Perea and Lupker's (2003a) data suggest that this is not what occurs. Thus, if there is indeed a separate orthographic CV level, it does not appear that this code is well enough constructed during the early stages of visual word processing to influence results in the masked priming paradigm.

Conclusion

The work presented here provides further evidence for a difference between vowels and consonants in the way in which letter position is coded in the early stages of visual word identification. It seems likely that this difference is reflected in orthographic representations, although whether it arises as a consequence of the particular nature of the representational units, or is simply a consequence of letter frequency, or some other mechanism, remains a question for future investigation.

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APPENDIX

Word targets and primes in Experiment 1a (the primes were also the nonword targets in Experiment 1b)

Word targets	*V-V TL*	*C-C TL*	*V-V RL*	*C-C RL*
ACADEMY	acedamy	adacemy	acidomy	abanemy
ADVISORY	advosiry	adsivory	advasery	adnicory
AMATEUR	ametaur	atameur	amutiur	afaneur
ANIMAL	anamil	aminal	anemol	asiral
BELOVED	belevod	bevoled	belavid	bewoted
BENEFIT	benifet	befenit	benafot	betemit
BESIDE	bisede	bedise	basude	bebine
CAFETERIA	cefateria	cateferia	cifuteria	caleberia
CAMERA	cemara	carema	cimura	casena
CAPACITY	capicaty	cacapity	capecoty	casagity
CAPITAL	capatil	catipal	capotel	cafigal
CARDINAL	cirdanal	carnidal	cerdenal	carminal
CATEGORY	catogery	cagetory	catagury	capefory
CEREMONY	ceromeny	cemerony	ceramuny	cenesony
CLINICAL	clinacil	clicinal	clinucel	clisimal
COMEDY	cemody	codemy	cimudy	cobeny
CONSIDER	cinsoder	condiser	censader	conbicer
COVERAGE	covarege	corevage	covurige	cocewage
CRIMINAL	crimanil	crinimal	crimonel	crisival
DEBATE	dabete	detabe	dobute	delahe
DECADE	dacede	dedace	dicude	debave
DELICATE	delacite	decilate	delocete	desifate
DENSITY	dinsety	dentisy	donsuty	denficy
DISPUTE	duspite	distupe	daspote	disluge
DOMINANT	domanint	donimant	domenunt	docirant
EDITOR	edotir	etidor	edatur	efibor
ELABORATE	elobarate	elarobate	eluberate	elacodate
EVIDENT	evedint	edivent	evadunt	ebiwent
FORTUNE	furtone	fornute	fertane	formuke
GRATEFUL	gretaful	grafetul	grotiful	gralekul
HERITAGE	heratige	hetirage	herotuge	helicage
INDICATE	indacite	incibate	inducete	insibate
LIBERAL	libarel	lirebal	liborul	linedal
LITERAL	litarel	liretal	litorul	linefal
LOCATE	lacote	lotace	lucete	lofase
LOGICAL	logacil	locigal	logecul	losipal
MARGINAL	mirganal	marnigal	mergonal	marmipal
MARINE	mirane	manire	morene	macise
MEDICINE	midecine	mecidine	maducine	mesibine
MEMORY	momery	meromy	mumary	menowy
MILITARY	milatiry	mitilary	milutery	mifikary
MISTAKE	mastike	miskate	mosteke	mishafe
MOBILE	mibole	molibe	mebale	motide
MODERATE	modarete	moredate	modurite	monebate
NUMERICAL	numirecal	nuremical	numurocal	nunewical

APPENDIX (*Continued*)

OPERATOR	oparetor	orepator	opuritor	onegator
OPTIMAL	optamil	opmital	optomel	opcifal
ORIGINAL	origanil	orinigal	origonel	orimipal
PACIFIC	picafic	paficic	pecofic	patisic
PARENT	perant	panert	porint	pamest
POLICY	pilocy	pocily	pelacy	posity
POPULAR	popalur	polupar	popelir	potugar
PROPOSAL	propasol	prosopal	propusel	procogal
PROVIDE	privode	prodive	prevude	probice
QUALIFY	quilafy	quafily	quelofy	quakity
QUALITY	quilaty	quatily	quolety	quafidy
RADICAL	radacil	racidal	radocel	rasibal
RAPIDLY	ripadly	radiply	repodly	rabigly
REFUSAL	refasul	resufal	refosil	renutal
REGULAR	regalur	relugar	regolir	retupar
RELATIVE	relitave	retalive	reletove	refakive
RELIGION	rilegion	regilion	ralugion	repifion
REMOTE	romete	retome	ramute	relone
REMOVAL	remavol	revomal	remuvel	reconal
RESIDENT	resedint	redisent	resadunt	rebicent
RESUME	ruseme	remuse	rasime	revune
RETIRE	ritere	rerite	ratore	recile
ROMANTIC	ramontic	ronamtic	remuntic	rovastic
SALINE	silane	sanile	selone	samite
SENATOR	senotar	setanor	senutir	selamor
SENTIMENT	sintement	senmitent	sontament	senvilent
SPECIFIC	spicefic	speficic	spocafic	spetisic
SPECIMEN	specemin	spemicen	specuman	speniven
STOLEN	stelon	sloten	stalun	skofen
STORAGE	staroge	stogare	sturege	stopave
STRATEGY	stretagy	stragety	strotigy	strapely
TRIBUTE	trubite	tritube	trabete	trilude
VALIDITY	viladity	vadility	voledity	vabifity
VELOCITY	velicoty	vecolity	velecaty	vesofity
VETERAN	vetaren	veretan	veturin	vecelan

Word targets and primes in Experiment 2

Low-frequency letter targets	*TL Prime*	*RL Prime*
CABBAGE	cabgabe	cabpaze
APOLOGIZE	apolozige	apolojive
SIZABLE	sibazle	sivaple
GARBAGE	gargabe	garjaze
EPIGRAM	egipram	ejivram
UBIQUITY	uqibuity	upiguity
OPAQUE	oqapue	ojague
HEXAGON	hegaxon	hevazon
FLEXIBLE	flebixle	flezijle

APPENDIX (*Continued*)

REFLEXIVE	reflevixe	reflezige
TAXABLE	tabaxle	tazajle
EXUBERANT	ebuxerant	ezujerant
CONJUGAL	congujal	conpuval
SPAGHETTI	sgaphetti	sbazhetti
MISGIVING	misviging	misxizing
NAVIGATOR	nagivator	naxizator
OBSERVABLE	obserbavle	obserzaple
EXAGGERATE	egaxgerate	ezavgerate
RAVAGE	regave	rezaxe
RAMPAGE	ramgape	ramjaxe
SALVAGE	salgave	salzaxe
SAVAGERY	sagavery	sazaxery
MAGAZINE	mazagine	maxavine
PROPAGATE	progapate	projazate
CLEAVAGE	cleagave	cleazaxe
REJUVENATE	revujenant	repuzenant
REPUGNANT	regupnant	rejuznant
SCAPEGOAT	scagepoat	scabejoat
TOPOGRAPHY	togopraphy	tobozraphy
AMBIGUOUS	amgibuous	ampivuous
AMBIVALENT	amvibalent	ampizalent
MARZIPAN	marpizan	marvijan
REALIZABLE	realibazle	realivaple
FORGIVING	forviging	forxizing
MOVABLE	mobavle	mozaple
SOLVABLE	solbavle	solqawle

High-frequency letter targets	*TL Prime*	*RL Prime*
STENCILED	snetciled	srelciled
BOTANIST	bonatist	boralist
CONCRETE	conctere	concnele
VALENTINE	vaneltine	vatestine
UMBRELLA	umblerla	umbsetla
RESETTLE	retestle	reneltle
SHORTEST	shorsett	shordent
STOUTEST	stousett	stoulent
AGELESS	agesels	agetens
HERETIC	heteric	heselic
CELESTIAL	ceseltial	cetertial
REPLENISH	repnelish	reptesish
CAUSALITY	caulasity	cautanity
TERMINATE	termitane	termisale
WAVELENGTH	wavenelgth	wavedergth
RELENTING	renelting	reterting
TITANIUM	tinatium	tilasium
URINATE	uritane	urisade
ECSTASY	ecssaty	ecsdany

APPENDIX (*Continued*)

ENTIRELY	enritely	endinely
TURBULENCE	turbunelce	turbuterce
PRETEXT	pterext	pnedext
CONSOLE	conlose	conrote
DISSOLVE	dislosve	disnotve
ISOLATE	ilosate	irotate
PULSATING	pultasing	pulnading
CAUSATION	cautasion	caunadion
DISTASTE	dissatte	dislante
SIGNATURE	sigtanure	sigsalure
ENROLMENT	enlorment	ensotment
ASTROLOGY	astlorogy	astnodogy
EMERALD	emelard	emesatd
BROADEST	broasedt	broatent
VERSATILE	vertasile	vernalile
PHONETIC	photenic	phosedic
OPPORTUNE	oppornute	opporduse