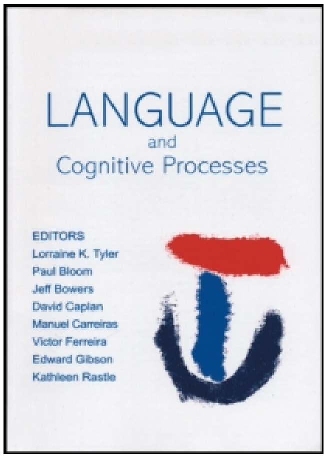

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Do orthotactics and phonology constrain the transposed-letter effect?

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Do orthotactics and phonology constrain the transposed-letter effect?

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Transposing two internal letters of a word produces a perceptually similar item (as in *cholocate*). To determine the precise nature of the encoding of letter position within a word, it is important to examine the role of orthography and phonology in the transposed-letter effect. Experiment 1 examined whether transposed-letter effects are affected by the legality of the letter transposition in a masked priming paradigm (e.g., *comsos-COSMOS* vs. *vebral-VERBAL*; '*ms*' is an illegal bigram in Spanish). Results showed a greater transposed-letter priming effect when the transposed bigram was illegal than when it was legal. In Experiment 2, we examine the role of phonology by exploiting the context-dependent pronunciation of the consonant letter '*c*' in a masked priming paradigm with the lexical decision task. Results showed that the magnitude of the transposed-letter effect was approximately the same for pairs like *cholocate-CHOCOLATE* vs. *chodonate-CHOCOLATE* and for pairs like *racidal-RADICAL* vs. *ramibal-RADICAL*. We examine the implication of these findings for models of letter position coding.

One key issue for any computational model of visual word recognition is to determine the mechanisms responsible for the coding of letter position in a word. Nearly 50 years ago, Bruner and O'Dowd (1958) reported that transposing two internal letters of a word (e.g., *cholocate*) results in a

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perceptually similar item that can be read with little cost. This observation has been confirmed in a growing number of experiments in recent years: transposed-letter pseudowords are easily confusable with their base word (i.e., participants tend to read *chocolate* instead of the stimulus item *cholocate*; see O'Connor & Forster, 1981; Perea & Estévez, 2008; Perea & Fraga, 2006; Perea, Rosa, & Gómez, 2005). Furthermore, using the masked priming technique, transposed-letter nonword primes not only produce form-priming effects relative to the appropriate orthographic control (e.g., *jugde-JUDGE* vs. *jupte-JUDGE*; Perea & Lupker, 2003b; see also Christianson, Johnson, & Rayner, 2005; Forster, Davis, Schoknecht, & Carter, 1987; Schoonbaert & Grainger, 2004), but also associative-priming effects (e.g., *jugde-COURT* vs. *ocaen-COURT*; Perea & Lupker, 2003a). Likewise, transposed-letter effects have been found during normal silent reading, when the participant's eye movements are monitored (see Johnson, Perea, & Rayner, 2007; Rayner, White, Johnson, & Liversedge, 2006).

The presence of transposed-letter effects falsifies the input coding scheme of the interactive activation model and its successors ('position-specific' coding schemes; e.g., the interactive-activation model, Rumelhart & McClelland, 1982; dual-route cascaded model, Coltheart, Rastle, Perry, Ziegler, & Langdon, 2001; multiple read-out model, Grainger & Jacobs, 1996). In recent years, several input coding schemes have been proposed in which transposed-letter similarity effects are a natural consequence of the letter encoding process: the SOLAR model (Davis, 1999), the SERIOL model (Whitney, 2001), the open-bigram model (Grainger & van Heuven, 2003), and the overlap model (Gómez, Ratcliff, & Perea, 2007). In these input coding schemes, the assignment of letter position occurs quite early in the process of visual word recognition, at an orthographic stage. (For instance, the SOLAR model uses a spatial coding scheme in which letter codes are position-independent, so that CAUSAL and CASUAL share the same set of letter nodes, and they are perceptually very similar; see Davis, 1999.) There are, however, two issues at stake here. First, it remains to be examined whether higher-order sublexical units (e.g., the legality of the bigram created by the transposed letters) may affect the magnitude of the transposed-letter effect. Second, it is unclear whether or not (and how) phonology is involved in this process. These are the two issues under scrutiny in the present lexical decision experiments. The aim of Experiment 1 is to examine the influence of orthotactic knowledge (i.e., illegal vs. legal bigrams; e.g., *comsos-COSMOS* and *vebral-VERBAL*) on transposed-letter priming effects, while that of Experiment 2 is to analyse the influence of phonology on transposed-letter priming effects.

Orthotactics and letter position coding

Three decades ago, Rumelhart (1977) reported a tachistoscopic letter identification experiment in which participants were presented with legal and illegal letter strings and found that participants tended to transpose the illegal pairs (but not the legal pairs). Rumelhart indicated that 'our apprehension of orthographically irregular strings is often distorted to allow us to perceive the string as being orthographically regular' (p. 580). In other words, the perception of a certain letter in a certain position would depend on what we perceive in adjacent positions (Rumelhart, 1977). If we extend this finding to the literature of letter position coding, this would imply that the transposed-letter *jugde* would look more like its base word than *ditry* would; the reason being that, unlike *tr* in *ditry*-*dirty*, *gd* is not a legal bigram in English.

There is some empirical evidence in the visual word recognition literature that supports the use of orthotactic knowledge, that is, knowledge of the well-formed letter sequences in the orthography of a language (see Buchwald & Rapp, 2006, for patient data, or see Treisman & Souther, 1986, for the phenomenon of illusory words). In a series of lexical decision experiments, Perea, Rosa, and Gómez (2001, 2005) observed that, with briefly presented items in a lexical decision task, participants committed a rather high percentage of errors on illegal transposed-letter (Spanish) pseudoword such as *meczla* (the base word is *mezcla*, the English for *mixture*; note that '*cz*', or '*zl*' are illegal bigrams in Spanish). In contrast, the percentage of errors for orthographically regular and legal transposed-letter pseudowords was substantially smaller. (Note that, intuitively, one might have predicted that 'illegal' transposed-letter pseudowords would be easy to classify as nonwords, but it was the other way around.) The same pattern holds in English for briefly presented stimuli in lexical decision with pronounceable vs. unpronounceable nonwords (Frankish & Turner, 2007). More specifically, Frankish and Turner found that (briefly presented) nonwords formed by transposing two letters were more likely to be misclassified as words if the nonwords were unpronounceable (*sotrm*) than if they were pronounceable (*strom*).

There is a caveat, however. A single presentation experiment under limited viewing conditions may not be the best situation to ascertain the locus of the legality of bigrams created by the transposed letters –leaving aside the issue of pronounceability. Instead, a masked priming procedure where the (critical) prime is not available to conscious processing is perhaps a better window onto automatic processes that occur in the early stages of word recognition. To this end, Experiment 1 used a masked priming paradigm in which the transposition of two adjacent consonants would produce either legal or illegal bigrams (e.g., *vebral*-*VERBAL* and *comsos*-*COSMOS*, respectively; *ms* is not a legal bigram in Spanish). To avoid a potential confound with pronounceability, both legal and illegal transposed-letter nonwords were easily pronounceable (i.e., the transposition affected two adjacent consonants that were preceded and followed by vowels; e.g., the transposed-letter nonwords '*comsos*' or '*jamzín*' have illegal bigrams, but they can be pronounced easily).

The predictions for Experiment 1 are clear. If the cognitive system first perceives the letters in a stimulus, and then puts them together into higher-order units (as suggested by Rumelhart, 1977), the effect of transposing two letters may produce quite a different pattern of results for legal and for illegal transpositions. That is, the illegal bigram '*gd*' in the transposed-letter pseudoword *jugde* may produce (e.g., via top-down feedback in an activation model or, alternatively, via some bottom-up letter-cluster filter) a low level of activation of the (illegal) bigram '*gd*' – indeed, the cognitive system might even activate the (legal) bigram '*dg*'. This would not be the case in the case of the legal (and frequent) bigram '*tr*' in the transposed-letter pseudoword *ditry*. The outcome of this process is that *jugde* and *judge* would be more perceptually similar than *ditry* and *dirty*. If this is so, masked priming effects should show a greater transposition-letter priming effect for illegal transpositions (e.g., *comsos*-*COSMOS* vs. *covnos*-*COSMOS*) than for legal transpositions (*vebral*-*VERBAL* vs. *vednal*-*VERBAL*). Alternatively, if the process of letter position coding is blind to higher-order units (i.e., it is initially a bottom-up similarity match across a perceptual stimulus and the word node which occurs at the letter level), then the transposed-letter priming effect should be approximately the same magnitude for legal and for illegal letter transpositions. We must bear in mind that the recently proposed input coding schemes specify that the perceptual similarity match between *jugde*-*JUDGE* and *ditry*-*DIRTY* should be the same. Both *jugde*-*JUDGE* and *ditry*-*DIRTY* would produce the same number of open bigrams in the SERIOL model and the open-bigram model, the same spatial coding scheme in the SOLAR model, and the same degree of perceptual overlap in the overlap model.

In Experiment 1 we opted for including not only a transposed-letter condition and a (control) double-substitution condition, but also an identity condition (e.g., *cosmos*-*COSMOS*). As indicated above, nonwords that contain an illegal bigram are likely to be very close to the lexical representation of the base word. Therefore, it is of interest to compare the activation produced by the transposed-letter condition with the one produced by the identity prime (see also Christianson et al., 2005; Johnson et al., 2007; Perea & Carreiras, 2006a; Perea & Lupker, 2003a, for other transposed-letter experiments that included an identity condition), and not just the difference between the double-substitution condition and the transposed-letter condition.

EXPERIMENT 1

Method

Participants. Twenty-four students from the Universitat de València received course credit for participating in the experiment. All of them either had normal or corrected-to-normal vision and were native speakers of Spanish.

Materials. The targets were 96 Spanish words that were six to seven letters long. The targets were presented in uppercase and were preceded by primes in lowercase that were: (i) the same as the target (identity condition), (ii) the same as the target except for a transposition of two (internal) adjacent consonants (transposed-letter condition), and (iii) the same except for the substitution of these two consonants (double-substitution condition). Forty-eight nonword-word pairs involved the transposition of two adjacent consonants so that the resulting nonword (prime) would contain an illegal bigram (e.g., *comsos*-*COSMOS*; mean word frequency of the targets in the Spanish database, Davis & Perea, 2005: 37 per million, range 3–250; mean number of letters: 6.5, range: 6–7; mean-N: 0.3, range: 0–1). The other 48 word pairs involved the transposition of two adjacent consonants so that the resulting nonword (prime) would contain a legal bigram (*vebral*-*VERBAL*; mean word frequency of the targets: 41 per million, range 3–410; mean number of letters: 6.4, range: 6–7; mean-N: 0.5 range: 0–4). The letter transposition did not affect the morphemic boundaries of the word target (Christianson et al., 2005; Duñabeitia, Perea, & Carreiras, 2007). The double-substitution nonword primes, for both the legal and illegal pairs, were created by replacing the two critical consonants with an illegal bigram (*covnos*-*COSMOS* and *vednal*-*VERBAL*). The position of the transposition/substitution was around the word centre: 3.6 for the legal transpositions and 3.4 for the illegal transpositions. (See the Appendix for a complete list of target words and primes.) An additional set of 96 target pseudowords that were six to seven letters long was included for the purposes of the lexical decision task. The nonwords had been created by changing the initial letters of real Spanish words. The manipulation of the pseudoword trials also included an identity condition, a transposed-letter condition, and a double-substitution condition. Three lists of materials were constructed so that each target appeared once in each list, but each time in a different priming condition. Different groups of participants were assigned to each list.

Procedure. Participants were tested in groups of two or three in a quiet room. Presentation of the stimuli and recording of response times were controlled by PC compatible computers. The experiment was run using

DMDX (Forster & Forster, 2003). Reaction times were measured from target onset until the participant's response. On each trial, a forward mask consisting of a row of hash marks (#) was presented for 500 ms in the centre of the screen. Next, the prime was presented in lower-case in 12-pt Courier, and stayed on the screen for 50 ms (3 cycles; each cycle corresponding to 16.6 ms on the CRT monitor). The prime was followed immediately by the presentation of the target stimulus in uppercase. Both prime and target were presented in the same screen location as the forward mask. The target remained on the screen until the participants responded. Participants were instructed to press one of two buttons on the keyboard to indicate whether the upper-case letter string was a legitimate word or not. Participants were instructed to make this decision as quickly and as accurately as possible. They were not informed of the presence of lower-case items. Each participant received a different order of trials. Each participant received a total of 20 practice trials (with the same manipulation as in the experimental trials) prior to the 192 experimental trials. The whole session lasted approximately 10 min.

Results and discussion

Incorrect responses (7.2% of the data for word targets) and reaction times less than 250 ms or greater than 1500 ms (1.8% of the data for word targets) were excluded from the latency analysis. The mean latencies for correct responses and error rates are presented in Table 1, and participant and item ANOVAs based on the participant and item response latencies and error percentage were conducted based on a 2 (Word type: legal bigram, illegal bigram) × 3 (Type of prime: identity, transposition, double-substitution) × 3 (List: list 1, list 2, list 3) design. List was included as a dummy factor in the ANOVAs to extract the

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

	Type of Prime				
	Identity	*Transp-Letter*	*Double-Subs*	*TL-Id*	*DS-TL*
Word trials					
Legal bigram	652 (7.6)	682 (9.9)	676 (7.6)	30 (2.3)	−6 (−2.3)
Illegal bigram	632 (3.9)	634 (4.7)	660 (9.6)	2 (0.8)	26 (4.9)
Nonword trials	780 (5.5)	779 (6.4)	786 (7.3)	−1 (0.9)	7 (0.9)

Note: *TL-Id* reflects the difference between the transposed-letter condition and the identity condition. *DS-TL* reflects the difference between the double-substitution condition and the transposed-letter condition.

variance due to the error associated with the lists (Pollatsek & Well, 1995). All significant effects had p values less than the .05 level.

Word data. The ANOVA on the latency data showed a main effect of Word type, $F_1(1, 21) = 14.25$, $MSE = 1975.7$; $F_2(1,90) = 5.43$, $MSE = 14558.6$, and a main effect of Type of prime, $F_1(2, 42) = 7.60$, $MSE = 1064.0$; $F_2(2, 180) = 8.85$, $MSE = 2233.1$. More importantly, there was a significant interaction between these two factors, $F_1(2, 42) = 3.51$, $MSE = 981.4$; $F_2(2, 180) = 3.22$, $MSE = 2233.1$. This interaction reflected that, for the 'illegal' bigram pairs, there was a significant 30 ms advantage of the transposed-letter condition over the double-substitution condition, $F_1(1, 21) = 11.59$, $MSE = 650.2$; $F_2(1, 45) = 11.45$, $MSE = 1242.7$, and a negligible advantage (2 ms) of the identity condition over the transposed-letter condition (both $p\text{s} > .25$). In contrast, for the 'legal' bigram pairs, there was a nonsignificant transposed-letter priming effect (-6 ms, both $p\text{s} > .25$), and a significant 26 ms advantage of the identity condition over the transposed-letter condition, $F_1(1, 21) = 7.55$, $MSE = 1414.9$; $F_2(1, 45) = 6.84$, $MSE = 3973.4$.

The ANOVA on the error data also showed a significant interaction between Word type and Type of prime, $F_1(2, 42) = 4.89$, $MSE = 39.41$; $F_2(2, 180) = 5.95$, $MSE = 68.65$. This interaction reflected a pattern analogous to the response time data: For the 'illegal' pairs, there was a significant transposed-letter priming effect (relative to the double-substitution condition; 4.7 vs. 9.6% of errors), $F_1(1, 21) = 9.76$, $MSE = 30.11$; $F_2(1, 45) = 6.68$, $MSE = 83.00$, whereas for the 'legal' pairs, there was some (nonsignificant) advantage of the identity over the transposed-letter condition (7.6 vs. 9.9% of errors, both $p\text{s} > .10$).

Nonword data. The ANOVAs on the latency/error data did not reveal any significant effects.

The results of this experiment are clear-cut. There was a greater transposed-letter priming effect when the transposition of letters produced an illegal bigram (*comsos-COSMOS*) than when the transposition of letters involved a legal bigram (*vebral-VERBAL*). Furthermore, when the transposition of letters involved an illegal bigram, response times were virtually the same as in the identity condition. We examine the implications of these results in the General Discussion.

One finding that deserves some comment is the absence of a transposed-letter priming effect (relative to the double-substitution condition) for the 'legal' bigram condition (i.e., no significant differences between *vebral-VERBAL* and *vednal-VERBAL*). It is well documented that transposed-letter priming effects occur even when two nonadjacent consonants are transposed and all bigrams are legal (as in *caniso-CASINO*; Perea & Lupker, 2004; see also Perea & Carreiras, 2006a, 2006b, or Johnson, 2007, for eye-movement evidence). Therefore, it is clear that the 'legality' of the bigrams is not solely responsible for the vanishing transposed-letter priming effect. One possible interpretation for the absence of a transposed-letter priming effect in the 'legal' bigram condition could be related to the fact that the target words were, on average, shorter than in prior experiments, and that transposed-letter effects are typically stronger with longer words (Perea & Lupker, 2003b; Schoonbaert & Grainger, 2004). Indeed, in Experiment 2 (see below), we found a transposed-letter priming effect when the transpositions always produced legal bigrams in longer words (average 8.5 letters). An alternative interpretation may be related to the choice of the double-substitution condition (see Perea & Lupker, 2003a, for discussion). In the present experiment, double-substitution primes always used illegal bigrams (instead of the transposed letters): this kept constant, in most cases, the syllable structure between prime and target; in contrast, due to the characteristics of Spanish orthography, the 'legal' transposed primes tended to have a syllable structure different from that of the base word (e.g., *verbal* has a CVC.CVC structure, the same as the double-substitution prime *vednal*, whereas the transposed-letter nonword *vebral* has a CV.CCVC structure; see Carreiras and Perea, 2002, for evidence of syllabic effects in masked priming). Perhaps this factor may have affected the size of the transposed-letter priming effect (relative to the double-substitution condition) in the 'legal' pairs. In any case, this does not limit the scope of the present findings: if we use the identity condition to assess the transposed-letter priming effect, there is a negligible 2 ms difference between the identity condition and the transposed-letter condition for the 'illegal' pairs; in contrast, there is a substantial advantage (30 ms) of the identity condition over the transposed-letter condition for the 'legal' pairs.

Interestingly, one could argue that the 'bigram' priming effect obtained might be due, in part, to phonological rather than orthographic processing (e.g., see Frankish & Turner, 2007). In this view, phonological feedback modulates transposed-letter priming effects: when the letter transposition forms a legal/pronounceable sequence, the activation of the corresponding phonemes can then stabilise the transposed-letter sequence via feedback connections from phonemes to letters. In other words, sublexical input phonology sends feedback that maintains the incorrect letter order, and this will not happen with illegal (and/or unpronounceable) bigrams. If this is so, one would expect some influence of phonology on the magnitude of transposed-letter priming effects. This is the issue under consideration in Experiment 2.

PHONOLOGY AND LETTER POSITION CODING

At present, only one of the recently-proposed input coding schemes addresses phonological processing: the SERIOL model. Using a letter-tagging coding scheme, the SERIOL model (Whitney, 2001) codes each letter by the ordinal position it holds in a letter string. Each ordered pair of letters is then activated as a bigram. The word *judge*, then, would be coded as $J=1$, $U=2$, $D=3$, $G=4$, $E=5$ and would activate the bigrams *JU*, *JD*, *JG*, *JE*, *UD*, *UG*, *UE*, *DG*, *DE*, and *GE*. This activation pattern can be compared to that of the two pseudowords *jugde* and *jupte*. The transposed-letter pseudoword *jugde* shares more bigrams with the base word than does the double-substitution pseudoword (nine vs. three, respectively). The SERIOL model thus correctly predicts a transposed-letter similarity effect. The original version of the SERIOL model (Whitney, 2001) did not include phonological processing, but in a recent paper, Whitney and Cornelissen (2005) extended the model by including a phonological route. They argued that 'biphone encoding would activate lexical items via the same type of mechanism as the bigram encoding' (p. 288). That is, both open bigrams and open biphones would be activated during identification of a written word.

There is little doubt that phonology plays an important role in visual word recognition (e.g., Carreiras, Ferrand, Grainger, & Perea, 2005; Ferrand & Grainger, 1994; Frost, 1998; Rastle & Brysbaert, 2006). For instance, using a masked priming technique and a lexical decision task, Carreiras et al. (2005) found a significant priming effect for the first phonological syllable (*fomie-FAUCON* vs. *pemie-FAUCON*). This finding is consistent with proposals of an early (and possibly mandatory) activation of phonology in reading ('strong phonological theory'; see Frost, 1998). Given the theoretical relevance of the nature of the mechanism of assigning letter position in visual word recognition, it is important to examine whether this mechanism has an orthographic and/or a phonological basis – bear in mind that transposing two letters usually confounds orthography and phonology. To reach firm conclusions on how letter position information is processed, the effects of orthography and phonology need to be disentangled.

In a recent series of experiments, Perea and Carreiras (2006a) examined the involvement of phonology in transposed-letter similarity effects. They used a masked priming paradigm by exploiting the pronunciations of the consonant letters *B* and *V* in Spanish –the pronunciation of these two letters in Spanish is *exactly* the same (/b/). Specifically, Perea and Carreiras examined whether there were differences between the response times to *relovución-REVOLUCIÓN*, *relobución-REVOLUCIÓN* (*relobución* is pronounced the same as *relovución*), and the orthographic control *relodución-REVOLUCIÓN* in a lexical decision task. Perea and Carreiras (2006a, Experiment 1) found a significant advantage (15 ms) of the transposed-letter priming condition relative to the phonological condition, whereas there was virtually no difference between the phonological and the orthographic conditions. [1]In a single-presentation lexical decision experiment, Perea and Carreiras (2006a; Experiment 3) found a small effect of phonology (i.e., a difference between pseudowords like *RELOBUCIÓN* and *RELODUCIÓN*). However, this effect was restricted to the false alarm rates (an effect of around 5%) and it did not occur in the latency analysis (a 2 ms difference). Perea and Carreiras (2006a) concluded that the nature of the transposed-letter similarity effect was mainly orthographic.

One potential limitation of the Perea and Carreiras (2006a) study is that the critical comparison between the phonological and orthographic conditions involved just two consonants that sounded the same (*B* and *V* are pronounced /b/ in Spanish). There is empirical evidence of a differential processing of consonants and vowels (e.g., Berent & Perfetti, 1995; Lee, Rayner, & Pollatsek, 2001), but more importantly for the present purposes, these differences have also been found in transposed-letter experiments. Perea and Lupker (2004) found that transposed-letter priming effects occurred especially to consonant transpositions rather than to vowel transpositions (i.e., *relovución*-*REVOLUCIÓN* rather than *revulolción*-*REVOLUCIÓN*). Likewise, Carreiras, Vergara, and Perea (2007) found a different timing and location for the effects of transposing two consonants vs. two vowels using electrophysiological measures. Taken together, these findings cannot be readily accommodated by the SOLAR, SERIOL, open-bigram, or overlap models, because these models do not differentiate between consonant/vowel processing. One explanation is that consonant/vowel differences arise at a (prelexical) phonological level rather than at the orthographic level (see Perea & Lupker, 2004). Thus, a more definitive test of the role of phonology in transposed-letter priming effects would be to switch context-dependent letters (e.g., *racidal*-*RADICAL* vs. *cholocate*-*CHOCOLATE*) rather than having two consonants that are pronounced the same way.

In Experiment 2, we test phonological involvement in transposed-letter priming effects by exploiting the context-dependent pronunciation of the letter '*c*' in Spanish (which is analogous to English and several other Western

[1] Perea and Carreiras (2006a) also conducted a second experiment designed to examine whether a masked phonological priming effect could be obtained when the letters of the prime were in the right order. They found a significant advantage (16 ms) of the pseudohomophone condition (*rebolución*-*REVOLUCIÓN*) relative to the orthographic control condition (*redolución*-*REVOLUCIÓN*), whereas there was only a nonsignificant 4 ms difference between the pseudohomophone and identity conditions (*rebolución*-*REVOLUCIÓN* and *revolución*-*REVOLUCIÓN*).

languages)[2]. There is ample evidence that shows phonologically based effects using pseudowords with context-sensitive letters ('*c*' and/or '*g*'; see Pollatsek, Perea, & Carreiras, 2005; Ziegler & Jacobs, 1995). For instance, in a recent masked priming study in Spanish, Pollatsek et al. (2005) found that lexical decision times to a target word like *CANAL* were faster when it was preceded by a one-letter different nonword prime that shared all phonemes but one (*conal*) than when it was preceded by a one-letter different nonword prime that shared all phonemes but two (*cinal*), whereas priming to *PANEL* from *ponel* and *pinel* were virtually identical. Interestingly, this pattern of effects would be predicted by the use of open biphones in the SERIOL model (Whitney & Cornelissen, 2005): *conal* and *CANAL* share more open biphones than *cinal* and *CANAL* – note that the two prime nonwords would share the *same* number of open bigrams with their base word.

EXPERIMENT 2

If transposed-letter priming effects have a purely orthographic basis, the magnitude of the transposed-letter effect (relative to the appropriate orthographic control condition) should be approximately the same when prime and target have a 'consistent vowel' (*cholocate*-*CHOCOLATE*; note that the letter '*c*' keeps its sound) and when they have an 'consistent vowel' (*racidal*-*RADICAL*; note that the letter '*c*' changes its sound). In contrast, if there is a phonological component in transposed-letter priming effects, the magnitude of the priming effect for the condition with 'inconsistent vowel' changes should be less than the magnitude of the priming effect for the condition with 'consistent vowel' changes. To examine whether the inclusion of a context-sensitive letter such as '*c*' – independently of whether it involves a consistent/inconsistent vowel – could affect the size of the transposed-letter priming effect (i.e., another index of phonological involvement), we also include a transposed-letter priming condition in which the letter transposition did not involve the letter '*c*' (e.g., *maretial*-*MATERIAL* vs. *manebial*-*MATERIAL*).

To sum up, we employ three types of transposed-letter prime-target pairs: (i) the transposition involves a change in the sound of the letter '*c*' (e.g., inconsistent vowel change: *racidal*-*RADICAL*), (ii) the transposition involves the letter '*c*' but keeping the sound (e.g., consistent vowel change: *cholocate*-*CHOCOLATE*), and (iii) the transposition does not involve the letter '*c*' (e.g., *maretial*-*MATERIAL*). As in previous work (e.g., Perea & Lupker,

[2] As in English, the letter '*c*' in Spanish has two separate sounds. When appearing in the combinations '*ca*', '*co*', and '*cu*', the letter '*c*' is pronounced as /k/. When appearing in the combinations '*ce*' and '*ci*', the letter '*c*' is pronounced as /θ/.

2004; see also Perea & Carreiras, 2006a, 2006b), we include double-substitution primes as orthographic controls. The letter transposition always involved two nonadjacent (internal) consonants – note that the syllabic structure of the pseudoword primes was always the same as the syllabic structure of their corresponding target words.

Method

Participants. Thirty-two students from the Universitat de València received course credit for participating in the experiment. All of them either had normal or corrected-to-normal vision and were native speakers of Spanish.

Materials. The targets were 138 Spanish words that were six to eleven letters long. The targets were presented in upper-case and were preceded by primes in lower-case that were: (i) the same as the target except for a transposition of two nonadjacent consonants (transposed-letter condition), and (ii) the same except for the substitution of these two consonants (double-substitution condition). Forty-six nonword-word pairs involved the transposition of the letter '*c*' so that it sounded different in prime and target ('*inconsistent vowel*' pairs; e.g., *racidal-RADICAL*; mean word frequency of the targets in the Spanish database, Davis & Perea, 2005: 39 per million, range 11–108; mean number of letters: 8.5, range: 6–11; mean-N: 0.5), 46 nonword-word pairs involved the transposition of the letter '*c*' so that it kept the same sound in prime and target ('*consistent vowel*' pairs; *cholocate-CHOCOLATE*; mean word frequency of the targets: 41 per million, range 12–120; mean number of letters: 8.5, range: 6–11; mean-N: 0.4), and 46 nonword-word pairs did not involve the transposition of the letter '*c*' ('*unique vowel*' pairs; *maretial-MATERIAL*; mean word frequency of the targets: 42 per million, range 11–251; mean number of letters: 8.5, range: 6–11; mean-N: 0.7). The position of the transpositions/substitutions never occurred in the initial syllable; instead, it was around the word centre, the mean position was 4.5, 4.4, and 4.4 for the 'inconsistent vowel', 'consistent vowel', and 'unique vowel' priming conditions, respectively. We did not include any transpositions of the letter '*g*', which is another context-sensitive letter in Spanish (as in other Romance languages). (See the Appendix for a complete list of target words and primes.) An additional set of 138 target pseudowords that were six to eleven letters long was included for the purposes of the lexical decision task. The pseudowords were created by changing two/three letters of a real Spanish word, keeping the syllable structure intact (i.e., all the nonwords were orthographically legal). The manipulation of the pseudoword trials was the same as that for the word trials. Two lists of materials were constructed so that each target appeared once in each list, but each time in a different priming condition. Different groups of participants were assigned to each list.

Procedure. This was the same as in Experiment 1.

Results

Incorrect responses (2.6% of the data for word targets) and reaction times less than 250 ms or greater than 1500 ms (0.4% of the data for word targets) were excluded from the latency analysis. The mean latencies for correct responses and error rates are presented in Table 2, and participant and item ANOVAs based on the participant and item response latencies and error percentage were conducted based on a 3 (Word type: consistent vowel, inconsistent vowel, unique vowel) $\times$ 2 (Type of nonword: transposition, double-substitution) $\times$ 2 (List: list 1, list 2) design.

Word data. The ANOVA on the latency data showed that words preceded by a transposed-letter prime were responded to 21 ms faster than the words preceded by a double-substitution prime, $F_1(1, 30) = 28.78$, $MSE = 758.9$; $F_2(1, 126) = 29.31$, $MSE = 1019.0$. The main effect of Word type did not approach significance (both Fs < 1). The magnitude of the transposed-letter effect was similar for the three types of primes, as deduced by the lack of a significant interaction between Word type and Type of prime (both Fs < 1): inconsistent vowel (16 ms), consistent vowel (23 ms), and unique vowel (25 ms). All these three transposed-letter priming effects were significant, all ps $<$ .01. (We should also note that, if we exclude the *maretial-MATERIAL*

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

	Type of Prime		
	Transposed-letter	*Double-substitution*	*Substituted-Transposed*
Word trials			
Inconsistent vowel	633 (3.4)	649 (2.9)	16 (−0.5)
Consistent vowel	630 (2.7)	653 (2.6)	23 (0.1)
Unique vowel	628 (1.6)	653 (2.3)	25 (0.7)
Nonword trials			
Inconsistent vowel	783 (6.4)	805 (8.2)	22 (1.4)
Consistent vowel	768 (5.5)	798 (8.1)	30 (2.6)
Unique vowel	777 (6.4)	790 (7.2)	13 (0.8)

condition in the ANOVA, the interaction between Word type and Type of prime remains nonsignificant, both $F\text{s} < 1$.)

The ANOVA on the error data did not show any significant effects (all $p\text{s} > .20$).

Nonword data. In the latency analyses, there was an advantage of nonwords preceded by a transposed-letter prime relative to the nonwords preceded by a double-substitution prime, $F_1(1, 30) = 15.07$, $MSE = 1466.6$; $F_2(1, 126) = 5.76$, $MSE = 6699.4$. The other effects were not significant.

The ANOVAs on the error data only showed that participants made more errors on nonwords preceded by a double-substitution prime than on nonwords preceded by a transposed-letter prime, $F_1(1, 30) = 5.58$, $MSE = 25.29$; $F_2(1, 126) = 2.34$, $MSE = 82.09$, $p = .13$.

The results of the present experiment are straightforward. There was a robust transposed-letter priming effect, which was similar in magnitude in all three experimental conditions: when the transposition involved the letter '*c*' and kept the same sound (*cholocate-CHOCOLATE*), when the transposition involved the letter '*c*' and modified its sound (*racidal-RADICAL*), and when the transposition did not involve the letter '*c*' (*maretial-MATERIAL*). This result extends the findings reported by Perea and Carreiras (2006a), suggesting that transposed-letter priming effects are orthographic – rather than phonological – in origin. (We discuss these results in the General Discussion section.)

In addition, nonword targets also showed a significant transposed-letter priming effect (see also Acha & Perea, in press; Duñabeitia et al., 2007; Perea & Lupker, 2007, for a similar pattern). Although we acknowledge that the presence of masked transposed-letter priming effects with nonword targets is not a completely stable phenomenon (e.g., present Experiment 1; see also Perea & Lupker, 2004), this finding suggests that transposed-letter effects occur very early during word processing, probably at a prelexical orthographic/graphemic stage.

GENERAL DISCUSSION

The main findings of the present masked priming experiments can be summarised as follows: (i) the magnitude of the transposed-letter priming effect is greater if the letter transposition creates an illegal bigram than if it creates a legal bigram, and (ii) the magnitude of the transposed-letter priming effect does not diminish when one of the switched letters modifies the sound of the stimulus item (from /θ/ to /k/ or vice versa). These two findings have important implications for models of the letter encoding process.

The role of orthotactics in letter position coding

As suggested by Rumelhart (1977), letters in a word are not processed in an isolated form, and thus letter position coding is not immune to orthotactic rules. Specifically, the present data showed that masked transposed-letter priming effects occur to a larger degree when the transposed letters form an illegal bigram (*ms* in *comsos*-*COSMOS*) than when the transposed letters form a legal bigram (*br* in *vebral*-*VERBAL*). Indeed, when the transposed letters form an illegal bigram (as in *comsos*-*COSMOS*), the resulting nonword primes behave quite similarly to an identity condition (*cosmos*-*COSMOS*). In other words, the process of letter position coding seems to be sensitive to the legal sequences and positions of letters in a written language.

This finding may seem, at first sight, at odds with the input coding schemes of the SERIOL, open-bigram, SOLAR, and overlap models. After all, *jugde* and *judge* have exactly the same perceptual matching score as *ditry* and *dirty* –i.e., the legality of the bigrams is not a factor when computing a similarity match (e.g., when one uses the application MatchCalculator on these input coding schemes). [3]But this is the case if one merely considers the similarity matches between two letter strings. In normal reading, these similarity values are just the 'front end' of models of visual word recognition, and we need to take into account the whole dynamics of the network during the lexical access process. For instance, it has been suggested that letters may be represented as separate entities before being concatenated to form words (Treisman & Souther, 1986), and hence illegal bigrams might be 'normalised' into legal bigrams (e.g., the transposed-letter pseudoword *comsos* would be processed, at an early stage, as its base word, *cosmos*). Therefore, it is necessary to implement these input coding schemes in the framework of a 'lexical access' module. For instance, as Brundson, Coltheart, and Nickels (2005) pointed out, the dual route model can employ an orthographic coding scheme other than a channel-specific one (e.g., the coding scheme of the SOLAR model of Davis, 1999). Likewise, as indicated by Gómez et al. (2007), the overlap model may work as a 'front-end' of any model of lexical access, but it would require feedback from higher level components to account for the word-superiority effects found in identification tasks. Simulations on an implemented version of these input coding schemes need to be carried out to examine whether or not this 'bigram' priming effect can be easily captured by these models.

We believe that the 'bigram' priming effect may be somewhat related to the 'density constraint' effect. As documented by Forster and colleagues (Forster & Davis, 1991; Forster, Davis, Schoknecht, & Carter, 1987; see also

[3] The application MatchCalculator is available at Colin Davis' website (http://www.pc.rhul.ac.uk/staff/c.davis/Utilities/MatchCalculator.exe).

Perea & Rosa, 2000), masked form priming using single-substitution primes (e.g., *brivk-BRICK*) shows that targets from low density neighbourhoods show robust form priming effects, while targets from high density neighbourhoods do not. (A word's neighbourhood density refers to the number of other words that can be created by changing one letter in a word; see Coltheart, Davelaar, Jonasson, & Besner, 1977). As recently shown by Lupker, Perea, and Davis (2005), the density constraint also applies to priming from transposition-letter primes. That is, the priming effect (relative to an unrelated control condition) for low-density items (e.g., *forst-FROST*) is greater than the priming effect for high-density items (e.g., *strak-STARK*). Alternatively, one could argue that the 'bigram' priming effect is not related to orthotactic constraints but, instead, that these effects arise at the lexical level (via lexical competition). [4]The idea is that priming may be reduced when a prime activates more lexical competitors. By definition, the legal bigrams are more frequent than the illegal bigrams, and hence, the primes with legal bigrams may have activated lexical competitors of the target more strongly than the primes with illegal bigrams. This reasoning also applies to the density constraint: a prime for a target in a large neighbourhood will activate more competitors than for a target in a small neighborhood. The lexical interpretation would be consistent with the recent findings reported by Binder, Medler, Westbury, Liebenthal, and Buchanan (2006) using an fMRI methodology. Specifically, Binder et al. found that activation in the left mid-fusiform gyrus increases with bigram probability, which suggests that a likely bigram should induce stronger orthographic activation and facilitation. Because the observed priming effects in Experiment 1 went in the opposite direction, this may suggest that the locus of the 'bigram' priming effect is lexical rather than orthographic.

Phonology and letter position coding

The presence of transposed-letter priming effects of similar magnitude for *racidal-RADICAL* pairs and for *cholocate-CHOCOLATE* pairs strongly suggests that these priming effects are mostly due to the mechanism that maps letter representations onto whole-word orthographic representations, rather than due to the mechanism that maps phonemes onto whole-word representations. One could argue, however, that there was a 7 ms nonsignificant trend between the consistent vowel condition ('*cholocate-CHOCOLATE*') and the inconsistent vowel condition ('*racidal-RADICAL*'; see Table 1). To further examine this difference, we conducted a post hoc analysis to examine the proportion of participants who showed a greater transposed-letter effect for the '*cholocate-CHOCOLATE*' pairs than for the

[4] We thank Carol Whitney for pointing this out.

'*racidal-RADICAL*' pairs; the idea was that it could be the case that most of the participants showed this advantage. However, the proportion was just over 50% (53%; 17 out of 32 participants).

What we should also note is that one might argue that lexical decision is an orthographic task, and hence the role of phonology is fairly limited. However, there is substantial evidence of masked phonological effects in lexical decision in Spanish (e.g., Álvarez, Carreiras, & Perea, 2004; Perea & Carreiras, 2006a; Pollatsek et al., 2005). Furthermore, there is evidence from ERPs that also suggests that transposed-letter priming effects do not behave as phonological priming effects. More specifically, a recent study of Grainger, Kiyonaga, and Holcomb (2006) examined orthographic priming using transposed-letter nonword primes (e.g., *barin-BRAIN*) and their orthographic controls (e.g., *bosin-BRAIN*). In addition, phonological priming was examined using pseudohomophone primes (e.g., *brane-BRAIN*) and their controls (e.g., *brant-BRAIN*). Grainger et al. found that transposed-letter priming and pseudohomophone priming had distinct topographical distributions and different timing, with transposed-letter effects arising earlier than pseudohomophone effects. Although Grainger et al. did not directly assess whether or not transposed-letter priming effects were orthographic or phonological, their findings are consistent with the idea that transposed-letter priming effects are orthographic rather than phonological in origin. Thus, taken together, the most parsimonious explanation is that the transposed-letter priming effect occurs (mainly) at a prelexical orthographic stage.

If we assume a general model that includes phonology and orthography (see Figure 1; see also Grainger & Ferrand, 1994, for a bimodal interactive-activation model that includes orthography and phonology), the differences across priming conditions could result from a variety of sources: (i) different relative strengths of orthography versus phonology, (ii) differences in the nature of orthographic versus phonological representations (e.g., a flat orthographic encoding versus a syllable phonological encoding), and (iii) differences in the number of lexical competitors activated (i.e., the amount of lateral inhibition within the word level). In other words, reduced priming could come from reduced similarity to the target, and /or from increased similarity to the competitors. In this light, it may be of interest to summarise the results of recent lexical decision experiments in our lab and their implications (see Table 3). Taken together, these results indicate that orthography has a considerably stronger influence than phonology with masked/briefly presented primes. Furthermore, the cumulative results suggest that phonological encoding is serial and syllabic, while orthographic encoding is not syllabic.

What are the implications of this finding for the choice of an input coding scheme in visual word recognition? As we indicated in the Introduction, the current version of the SERIOL model (Whitney &

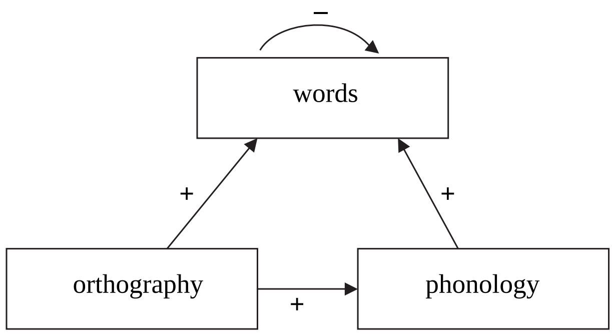

Figure 1. A general model that describes the (possible) links between the orthographic, phonological, and lexical levels. The dotted line indicates lateral inhibition at the lexical level (i.e., lexical competition).

Cornelissen, 2005) predicts a role of phonology in transposed-letter effects via the activation of open biphones – which would work in the same way as the open bigrams. However, the present data show that the influence of the phonological component in the transposed-letter priming effect is (if any) rather small (see also Perea & Carreiras, 2006a). In fairness to Whitney and

TABLE 3
Summary of masked priming findings concerning the role of phonology in recently published lexical decision experiments

Experiment	*Issue*	*Effect?*
Carreiras et al. (2005)	Syllable (O –P+)	
	First vs. second	yes
Pollatsek et al. (2005)	Initial phoneme	
	O+P+ vs. O+P –	yes
Perea & Carreiras (2006a)		
Experiment 1	Internal phoneme/letter	
	O+P+ vs. O –P –	yes
	O –P+ vs. O –P –	no
Experiment 2	Internal syllable	
	O+P+ vs. O –P –	yes
	O –P+ vs. O –P –	yes
Present Experiment 1	Internal phoneme	
	O+P+ vs. O+P –	no

Note: O/P +/ – indicates whether or not the prime matched the target on (O)rthography and (P)honology.

Cornelissen (2005), we should note that theirs was an initial attempt to deal with the complicated issue of phonological processing and its potential deficits (e.g., dyslexia). More work on the SERIOL model will be needed to spell out the relations between the letter assignment position in the orthographic and the phonological systems (e.g., what would be the open biphones for the open bigrams *CA*, *CI* or *CO* in *CASINO*?). With respect to the other coding schemes (SOLAR model, open-bigram model, and overlap model), they capture the absence of a phonological component in transposed-letter priming effects. Nonetheless, this is so because these coding schemes do not have an implemented phonological route. Clearly, these input coding schemes need to be expanded to accommodate the presence of phonological effects in lexical decision and reading (e.g., the *conal*-*CANAL* effect; see Pollatsek et al., 2005). In the context of the SOLAR model, one possibility would be to implement a phonological system with a parallel coding structure to the (already implemented) orthographic system, with the restriction that the phonological system would feed from the letter position encoding obtained at the orthographic level. [5]In addition, Grainger, Granier, Farioli, Van Assche, and van Heuven (2006) discussed the implementation of a phonological system in the context of the open-bigram model. In any case, when comparing models of letter-position encoding, it is important to examine not just whether the implemented model already specifies encoding along the phonological route, but rather whether the existing levels of representation in a model can potentially support a viable phonological encoding. As Goswami and Ziegler (2006) recently indicated, 'the front end of visual word recognition must be shaped by phonology' (p. 143).

In sum, we found that the legality/illegibility of the letter transposition plays an important role in transposed-letter priming effects: this result strongly suggests that orthotactic knowledge has an impact on letter position coding. In addition, we failed to find any clear evidence supporting a relevant role of phonology in transposed-letter priming effects via the transposition of a context-sensitive letter ('c', as in *cholocate*-*CHOCOLATE* vs. *racidal*-*RADICAL*). We believe that these findings are of critical relevance to help constrain input coding schemes in visual word recognition.

[5] One might argue that this explanation leaves the differences between consonant/vowel processing unexplained. Although more research is needed, there is some empirical evidence that suggests that the consonant vs. vowel differences in transposed-letter effects could be due (at least in part) to the frequency of the letters (see Lupker, Perea, & Davis, 2008 this issue).

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APPENDIX

Pairs in Experiments 1–2

Experiment 1

The items are arranged in quadruplets in the following order: Identity prime, Transposed-letter prime, double-substitution prime, and target word.

Legal bigram: cordial, codrial, cotsial, CORDIAL; nuclear, nulcear, nudcear, NUCLEAR; féretro, fererto, férevlo, FÉRETRO; mártir, mátrir, mabnir, MÁRTIR; burdel, budrel, butsel, BURDEL; neutral, neurtal, neuzsal, NEUTRAL; liebre, lierbe, liemte, LIEBRE; cerebro, cererbo, cerevdo, CEREBRO; marfil, mafril, madnil, MARFIL; nublado, nulbado, nutfado, NUBLADO; fiebre, fierbe, fievte, FIEBRE; ningún, nignún, nijsún, NINGÚN; palpar, paplar, pagfar, PALPAR; fértil, fétril, fédnil, FÉRTIL; pueblo, puelbo, puefdo, PUEBLO; partir, patrir, padnir, PARTIR; disparo, dipsaro, digvaro, DISPARO; jardín, jadrín, jatsín, JARDÍN; perfil, pefril, petsir, PERFIL; respeto, repseto, regveto, RESPETO; cartón, catrón, cabzón, CARTÓN; cartel, catrel, cadnel, CARTEL; césped, cépsed, cégved, CÉSPED; verbal, vebral, vednal, VERBAL; después, depsués, degcués, DESPUÉS; matriz, martiz, mavfiz, MATRIZ; desliz, delsiz, detviz, DESLIZ; verdad, vedrad, vetsad, VERDAD; domingo, domigno, domipvo, DOMINGO; corpus, coprus, cogvus, CORPUS; ciclón, cilcón, citsón, CICLÓN; porción, pocrión, pozsión, PORCIÓN; parcial, pacrial, pamzial, PARCIAL; surgir, sugrir, supmir, SURGIR; furgón, fugrón, fupzón, FURGÓN; quebrar, querbar, quecfal, QUEBRAR; cuartel, cuatrel, cuadnel, CUARTEL; virtual, vitrual, vidzual, VIRTUAL; virtud, vitrud, vidcud, VIRTUD; suegra, suerga, suemja, SUEGRA; lengua, legnua, lepmua, LENGUA; niebla, nielba, niedfa, NIEBLA; pupitre, pupirte, pupimde, PUPITRE; calcio, caclio, cavfio, CALCIO; huésped, huépsed, huégved, HUÉSPED; cárcel, cácrel, cámzel, CÁRCEL; morder, modrer, mobzer, MORDER; triple, trilpe, tritye, TRIPLE

Illegal bigram: tranvía, travnía, tramzía, TRANVÍA; germen, gemren, gezsen, GERMEN; naranja, narajna, narapma, NARANJA; fuerza, fuezra, fuecva, FUERZA; sermón, semrón, seszón, SERMÓN; alarma, alamra, alacza, ALARMA; trampa, trapma, tragca, TRAMPA; hermano, hemrano, heczano, HERMANO; fórmula, fómrula, fószula, FÓRMULA; sondeo, sodneo, sotseo, SONDEO; normal, nomral, novnal, NORMAL; sistema, sitsema, sidnema, SISTEMA; gestión, getsión, gednión, GESTIÓN; romper, ropmer, rogver, ROMPER; mármol, mámrol, máczol, MÁRMOL; prestar, pretsar, prednar, PRESTAR; bestia, betsia, bedzia, BESTIA; pastel, patsel, padcel, PASTEL; afirmar, afimrar, afiszar, AFIRMAR; sostén, sotsén, sodnén, SOSTÉN; limpio, lipmio, ligvio, LIMPIO; campeón, capmeón, cagveón, CAMPEÓN; compás, copmás, cojvás, COMPÁS; agosto, agotso, agodco, AGOSTO; adoptar, adotpar, adohjar, ADOPTAR; ajuste, ajutse, ajudne, AJUSTE; celeste, celetse, celedne, CELESTE; bastón, batsón, bafnón, BASTÓN; abismo, abimso, abivno, ABISMO; cristal, critsal, cridnal, CRISTAL; leyenda, leyedna, leyetsa, LEYENDA; segunda, segudna, segutsa, SEGUNDA; nervio, nevrio, nezsio, NERVIO; triunfo, triufno, triudzo, TRIUNFO; ruptura, rutpura, rufyura, RUPTURA; plasma, plamsa, plazva, PLASMA; brindar, bridnar, britval, BRINDAR; reptil, retpil, refjil, REPTIL; fiesta, fietsa, fiedca, FIESTA; mundial, mudnial, mutsial, MUNDIAL; reserva, resevra, resesza, RESERVA; dormir, domrir, doczir, DORMIR; fervor, fevror, fezsón, FERVOR; triste, tritse, trifde, TRISTE; cosmos, comsos, covnos, COSMOS; reforma, refomra, refozsa, REFORMA; revista, revitsa, revidna, REVISTA; pistola, pitsola, pidzola, PISTOLA

Experiment 2

The items are arranged in triplets in the following order: Transposed-letter prime, double-substitution prime, and target word.

Consistent vowel: vobaculario, vodanulario, VOCABULARIO; juscitia, jusnibia, JUSTICIA; enocomía, esoromía, ECONOMÍA; falicidad, fatinidad, FACILIDAD; procovado, promonado, PROVOCADO; expocisión, expominión, EXPOSICIÓN; opucación, ogusación, OCUPACIÓN; amuculación, asurulación, ACUMULACIÓN; desicivo, deminivo, DECISIVO; frasaco, framano, FRACASO; nesecidad, nemenidad, NECESIDAD; desapacerer, desagamerer, DESAPARECER; tracidional, tramibional, TRADICIONAL; renococer, remosocer, RECONOCER; icinial, irimial, INICIAL; perbicir, pertimir, PERCIBIR; cocolado, comotado, COLOCADO; cholocate, chobonate, CHOCOLATE; dicífiles, diníbiles, DIFÍCILES; ecudación, enutación, EDUCACIÓN; fecilidad, fesibidad, FELICIDAD; desición, denirión, DECISIÓN; deficinión, delivinión, DEFINICIÓN; tacabo, tamato, TABACO; círluco, círtumo, CÍRCULO; cacebera, canetera, CABECERA; psilocogía, psitomogía, PSICOLOGÍA; dédaca, détana, DÉCADA;

pedaco, petamo, PECADO; namiciento, nariniento, NACIMIENTO; sudecer, sutemer, SUCEDER; pacerido, pamenido, PARECIDO; articifial, artimitial, ARTIFICIAL; ocifial, ositial, OFICIAL; trancisión, tranmirión, TRANSICIÓN; apacirión, apasivión, APARICIÓN; pocilía, pomitía, POLICÍA; presición, premirión, PRECISIÓN; amacener, amasemer, AMANECER; nocitia, nomibia, NOTICIA; loruca, losuma, LOCURA; mecidina, mesitina, MEDICINA; preopucado, preogunado, PREOCUPADO; edicifio, edinibio, EDIFICIO

Inconsistent vowel: ecomión, esonión, EMOCIÓN; osación, omarión, OCASIÓN; maslucino, mastusino, MASCULINO; ejérticos, ejérlisos, EJÉRCITOS; dicifultad, dinitultad, DIFICULTAD; eslacera, esbamera, ESCALERA; parcitular, parsidular, PARTICULAR; ricídulo, rinídulo, RIDÍCULO; escapial, esnagial, ESPACIAL; genecarión, genemasión, GENERACIÓN; racidal, ramital, RADICAL; coconido, covomido, CONOCIDO; iconencia, imosencia, INOCENCIA; vecíhulo, vesídulo, VEHÍCULO; arcítulo, arnídulo, ARTÍCULO; repucerar, regunerar, RECUPERAR; esnecario, esmesario, ESCENARIO; soculión, somutión, SOLUCIÓN; alcamén, alnasén, ALMACÉN; libecarión, libesamión, LIBERACIÓN; complidicad, complitinad, COMPLICIDAD; peluciar, pebuniar, PECULIAR; dedacencia, detamencia, DECADENCIA; fíciso, fímino, FÍSICO; evoculión, evomutión, EVOLUCIÓN; mocélula, monébula, MOLÉCULA; vegecatión, vegematión, VEGETACIÓN; escatión, esnabión, ESTACIÓN; amecirano, amesinano, AMERICANO; vecolidad, vemotidad, VELOCIDAD; lóciga, lómipa, LÓGICA; opocisión, oporinión, OPOSICIÓN; recudir, renutir, REDUCIR; revecalión, revenadión, REVELACIÓN; menacismo, mesarismo, MECANISMO; máciga, másipa, MÁGICA; invicatión, inviradión, INVITACIÓN; pacalio, panatio, PALACIO; tencatión, tensalión, TENTACIÓN; doneca, doseva, DOCENA; catócila, catómita, CATÓLICA; circucalión, circusadión, CIRCULACIÓN; opecarión, opemasión, OPERACIÓN; revoculión, revomudión, REVOLUCIÓN

Unique vowel: soliradidad, solinatidad, SOLIDARIDAD; cárama, cávasa, CÁMARA; maretial, manebial, MATERIAL; potílico, pobídico, POLÍTICO; catipal, cabigal, CAPITAL; esmótago, esnólago, ESTÓMAGO; sotilario, sodibario, SOLITARIO; fansatía, fanmabía, FANTASÍA; cadaso, catamo, CASADO; polupar, podugar, POPULAR; sadiburía, satiluría, SABIDURÍA; privamera, prisanera, PRIMAVERA; fasoma, farona, FAMOSA; gerenación, gesemación, GENERACIÓN; sodino, sotimo, SONIDO; empedaror, empetanor, EMPERADOR; miresia, minemia, MISERIA; mefatísica, medalísica, METAFÍSICA; disivión, dimirión, DIVISIÓN; tolatidad, tobadidad, TOTALIDAD; potisivo, pobimivo, POSITIVO; matetámicas, matebáricas, MATEMÁTICAS; hitópesis, hibógesis, HIPÓTESIS; mavarilloso, masanilloso, MARAVILLOSO; denifitivo, demibinivo, DEFINITIVO; tempodara, tempotama, TEMPORADA; hudemad, hulenad, HUMEDAD; ternimado, tersirado, TERMINADO; arfiticial, arbilicial, ARTIFICIAL; predisente, pretirente, PRESIDENTE; fisólofo, finótofo, FILÓSOFO; emenigo, eserigo, ENEMIGO; diágolo, diápoto, DIÁLOGO; mefátora, mebálora, METÁFORA; aurotidad, aumobidad, AUTORIDAD; pernosaje, permoraje, PERSONAJE; labotarorio, labodasorio, LABORATORIO; fenemina, feresina, FEMENINA; anemaza, aseraza, AMENAZA; denifición, desitición, DEFINICIÓN; falimiar, fabisiar, FAMILIAR; dratámico, drabásico, DRAMÁTICO; utidilad, ulibidad, UTILIDAD; autovómil, autosóril, AUTOMÓVIL