Research Article

On the Flexibility of Letter Position Coding During Lexical Processing

The Case of Thai

Manuel Perea,[1] Heather Winskel,[2] and Theeraporn Ratitamkul[3]

[1]Universitat de València, Spain, [2]Southern Cross University, Coffs Harbour, Australia, [3]Chulalongkorn University, Bangkok, Thailand

Abstract. In Indo-European languages, letter position coding is particularly noisy in middle positions (e.g., *judge* and *jugde* look very similar), but not in the initial letter position (e.g., *judge* vs. *ujdge*). Here we focus on a language (Thai) which, potentially, may be more flexible with respect to letter position coding than Indo-European languages: (i) Thai is an alphabetic language which is written without spaces between words (i.e., there is a degree of ambiguity in relation to which word a given letter belongs to) and (ii) some of the vowels are misaligned (e.g., แบน/ɛ:bn/ is pronounced as /bɛ:n/), whereas others are not (e.g., อาบ/a:p/ is pronounced as /a:p/). We conducted a masked priming lexical decision experiment with 3–4 letter Thai words (with vs. without an initial misaligned vowel) in which the prime was: (i) identical to the target, (ii) a nonword generated by transposing the two initial letters of the target, or (iii) a replacement-letter control nonword. Results showed a significant masked transposed-letter priming effect in the initial letter positions, which was similar in size for words with and without an initial misaligned vowel. These findings reflect that: (i) letter position coding in Thai is very flexible and (ii) the nature of the obtained priming effects is orthographic rather than phonological.

Keywords: letter coding, masked priming, lexical decision

In the past years, one topic that has attracted a great deal of attention in the area of visual-word recognition and reading is how the cognitive system encodes letter position within a word. Indeed, nonwords created by transposing two internal letters (e.g., *jugde*) resemble closely their base words, and this phenomenon occurs along a wide range of languages and orthographic systems (e.g., English: O'Connor & Forster, 1981; French: Schoonbaert & Grainger, 2004; Spanish: Perea & Lupker, 2004; Japanese: Perea, Nakatani, & van Leeuwen, 2011; Hebrew: Velan & Frost, 2011; Arabic: Perea, Abu Mallouh, García-Orza, & Carreiras, 2011; Korean: Lee & Taft, 2009). Most experiments on letter transpositions have employed the Forster and Davis (1984) masked priming paradigm, usually combined with the lexical decision task: A given target word (e.g., *JUDGE*) is responded to more rapidly when it has been briefly preceded by a forwardly masked transposed-letter prime (e.g., *jugde*) than when it has been preceded by an orthographic control (e.g., the replacement-letter prime *jupte*). Importantly, letter transposition effects also occur during normal silent reading (e.g., when using parafoveal previews instead of foveally presented primes; see Johnson, Perea, & Rayner, 2007).

Transposed-letter effects are generally interpreted as reflecting some degree of perceptual uncertainty along strings of objects (i.e., letters) (see Davis, 2010; Gómez, Ratcliff, & Perea, 2008; Norris, Kinoshita, & van Casteren, 2010), in particular for internal positions. For instance, in the overlap model (Gómez et al., 2008), there is a degree of perceptual uncertainty associated with each letter position and, more importantly, the perceptual noise is much reduced for the initial letter position than for the other letter positions (see Gómez et al., 2008, Figure 14). In other words, *jugde* closely resembles *judge*, while *ujdge* does not. Although the idea of a "perceptual uncertainty" principle of position assignment may be universal to all orthographic systems, the specific characteristics of a given language may constrain the transposed-letter effect. For instance, transposed-letter effect in Semitic languages does not occur when two letters from the root are transposed (see Perea et al., 2010; Velan & Frost, 2011), which suggests that letter position coding is quite precise for the root letters in Semitic languages – unlike Indo-European languages (see Perea et al., 2010).

Here we examine how the transposed-letter priming effect is modulated across orthographies. Specifically, we focus on a language that may be particularly flexible with respect to letter position coding: Thai. This is so for two reasons. First, Thai is an alphabetic language in which there are no spaces between words (e.g., the sentence เมื่อวานนี้เขาเอาหนังสือไปห้องสมุดวิทยาลัยในจังหวัดอยุธยา); this implies that, during normal reading, there

DOI: 10.1027/1618-3169/a000127

is a degree of ambiguity in relation to which word a given letter belongs to, and this is even more relevant when reading short Thai words. Importantly, previous research with the boundary technique has shown that the magnitude of transposition effects during normal silent reading in Japanese Kana (e.g., *a.ri.me.ka–a.me.ri.ka* [アリメカ–アメリカ] vs. *a.ka.ho.ka–a.me.ri.ka* [アカホカ–アメリカ]), which also lacks spaces between words, is greater than the magnitude of the transposed-letter effects in English (e.g., *jugde-judge* vs. *jupte-judge*; see Perea et al., 2010, for evidence in Japanese, and Johnson et al., 2007, for evidence in English). (Note that Perea et al., 2010, manipulated the internal letter positions rather than the external letter positions, though.) Second, several vowels in Thai precede the consonant in writing but follow it in speech (e.g., แบน/ɛ:bn/"flat" is spoken as /bɛ:n/, while บาท/ba:t/ "Baht" is spoken as /ba:t/). More specifically, Thai has five vowels (i.e., เ_/e:/, แ_/ɛ:/, โ_/o:/, ไ_/aj/, ใ_/aj/) that precede the consonant and produce a mismatch between the spoken and written sequence (i.e., misaligned vowels), whereas other Thai vowels (e.g., _ะ /a/, _า/a:/, _อ/ɔ:/, _ำ/am/) produce a consistent pattern between the spoken and written sequence (i.e., aligned vowels). This again implies that position coding in Thai needs to be flexible enough so that readers may appropriately encode the letter positions of words (and create the appropriate phonological codes) with or without misaligned vowels.

One strategy to examine the (potential) high degree of flexibility of letter position coding in Thai is to study whether Thai exhibits masked transposed-letter priming effects in the initial letter position. The initial letter position is usually thought to have a privileged role during lexical processing, which is also reflected in the more influential input coding schemes (e.g., see Davis, 1999, 2010; Gómez et al., 2008; Whitney, 2001; see also Rumelhart & McClelland, 1982). For instance, in the SERIOL model (Whitney, 2001), the estimated similarity between *judge* and *jugde* (.90) is much greater than the estimated similarity between *judge* and *judge* (.60). Likewise, in the SOLAR model (Davis, 1999), the estimated similarity between *judge* and *jugde* (.92) is much greater than the estimated similarity between *judge* and *judge* (.78).[1] A similar prediction can be obtained in other letter coding schemes that accommodate transposed-letter effects (e.g., Gómez et al.'s, 2008, overlap model; Grainger & van Heuven's, 2003, open-bigram model). This is the reason why most research on transposed-letter priming effects has focused on the transposition of internal letter positions. Indeed, there is very little empirical evidence supporting a transposed-letter priming effect when the initial letter position is involved. Schoonbaert and Grainger (2004; Experiment 3) failed to find a masked transposed-letter priming effect for five-letter French words from primes generated by transposing the first two letters. Similarly, Perea and Lupker (2007) failed to find any signs of a masked transposed-letter priming effect (i.e., a −1 ms priming effect) relative to an orthographic control condition when the initial letter position was transposed in a lexical decision experiment in Spanish. Likewise, Kinoshita, Castles, and Davis (2009; Experiment 1) found a significant masked transposed-letter priming effect, relative to an unrelated condition, in a lexical decision task for internal letter positions (e.g., scuot-*SCOUT*) but not for initial letter positions (e.g., *csout-SCOUT*). In addition, Johnson et al. (2007) conducted a parafoveal preview study in which the initial positions of a parafoveally presented item were transposed or replaced; they failed to find a transposed-letter effect for first-fixation durations or for single fixation durations, whereas they could only obtain a transposition effect for gaze durations which was not significant by items. Finally, Gómez et al. (2008) employed a forced two-choice task in which a briefly presented target (e.g., *rudge*) was immediately followed by the same stimulus and by a foil (*rudge* and *rupte*). Gómez et al. found more accurate responding when the foil was a replacement-letter stimulus than when the stimulus was a transposed-letter stimulus. Interestingly, this effect occurred when the transposition/replacement occurred in internal/final letter positions, but not when the transposition involved the initial letter position. Taken together, these data suggest that, at least for Indo-European languages, the identification of a word's initial letter may be "dependent on absolute letter position and plays a special role in word recognition" (Johnson et al., 2007, p. 218).

If, as hypothesized above, the process of letter position coding in Thai is highly flexible, a masked transposed-letter priming effect would presumably occur in the initial letter position. What is more, we employed short words in the experiment (three- and four-letter Thai words). Several researchers have reported that transposed-letter effects are greater for longer rather than for shorter words (e.g., Davis & Andrews, 2001; Perea & Lupker, 2003) and that masked priming effects are smaller with words extracted from high-density neighborhoods (Forster, Davis, Schoknecht, & Carter 1987; Perea & Rosa, 2000; see also Kinoshita et al., 2009) – as most short Thai words are. Therefore, the presence of a reliable masked transposed-letter priming effect in Thai with very short words and transpositions in the first two letters would be an unequivocal indication of the high degree of flexibility of letter position coding in this language.

In the present study, we conducted a masked priming lexical decision experiment in which the initial letter positions were transposed (e.g., for บาท/ba:t/"Baht", าบท/a:bt/ was used as the prime); as usual, the control condition was a replacement-letter condition (e.g., พอท). Note that a significant transposed-letter priming effect in Thai would imply that the status of the initial letter position may vary across languages. To assess the specific role of letter position over letter identity, we also included an identity priming condition. That is, if there is a similar disadvantage of the replacement-letter condition with respect to the identity and transposed-letter priming condition, this would suggest that letter position information is not obtained at the early

[1] We obtained these matching values from Colin Davis' MatchCalculator application, which is available at http://www.pc.rhul.ac.uk/staff/c.davis/Utilities/MatchCalc/index.htm.

stages of word processing. Alternatively, the presence of an advantage of the identity condition over the transposed-letter condition would suggest that letter position information is, to some degree, attained in the word-recognition system in the early stages of processing (see Johnson et al., 2007; Kinoshita et al., 2009).

The present experiment had a second aim. As indicated earlier, vowels in Thai may be misaligned (e.g., แบน/ε:bn/ [VCC] "flat" pronounced as /bε:n/). Here we examined whether the pattern of transposed-letter priming effect would differ for words with an initial misaligned vowel (e.g., แบน/ε:bn/, pronounced as /bε:n/), for words with an initial aligned consonant (e.g., บาท/ba:t/[CVC] "Baht" pronounced as /ba:t/), and for words with an initial aligned vowel (e.g., อาบ/a:p/[VCC] "wash" pronounced as /a:p/). If phonological information from the primes is extracted in the early stages of processing (see Carreiras, Ferrand, Grainger, & Perea, 2005), then the magnitude of priming effects may differ for the different types of words. We must bear in mind that words with an initial misaligned vowel (e.g., แบน/ε:bn/which is pronounced as /bε:n/) would be preceded by a transposed-letter prime in the correct phonological order (e.g., บแน/bε:n/), whereas words without an initial misaligned vowel (e.g., บาท/ba:t/ which is pronounced as /ba:t/) would be presented with transposed-letter primes in the wrong phonological order (e.g., าบท/a:bt/). Although prior research has consistently failed to find any clear role of phonology in letter transposition experiments (e.g., see Acha & Perea, 2010; Perea & Carreiras, 2006; Perea, Nakatani, & van Leeuwen, 2011, for reviews), one should be cautious of accepting the null hypothesis (i.e., positive evidence is more informative than negative evidence).

As occurs in other orthographies (e.g., Hebrew, Japanese, Korean), Thai does not have a lowercase/uppercase distinction. Therefore, in order to avoid physical continuity between primes and targets in a masked priming paradigm, primes were presented in 14-point font, and targets were presented in 20-point font (e.g., บแน-แบน vs. ไฟน-แบน; see Velan & Frost, 2011, for a similar procedure).

Method

Participants

Thirty-three students and staff from Chulalongkorn University, Bangkok, participated for payment in the experiment. All of them either had normal or corrected-to-normal vision and were native speakers of Thai. None of them reported having any reading disability.

Materials

The targets were 180 Thai monosyllabic and bisyllabic words that were three and four letters long. A third of the words were either words with an initial misaligned vowel (e.g., แบน/ε:bn/VCC "flat" pronounced as /bε:n/), or words with an initial aligned consonant (e.g., บาท/ba:t/CVC "Baht' pronounced as /ba:t/), or words with an initial aligned vowel (e.g., อาบ/a:p/VCC "wash" pronounced as /a:p/). As indicated in the Introduction section, Thai has five vowels (i.e., เ_/e:/, แ_/ε:/, โ_/o:/, ไ_/aj/, ใ_/aj/) that precede the consonant and produce a mismatch between the spoken and written sequence (termed misaligned vowels). They always occur in this position and if the sequence is altered to match the spoken form (e.g., แบน/ε:bn/VCC changed to บแน/bε:n/CVC), the words become nonwords. Similarly, when the initial letters in the aligned consonant and aligned vowel words were transposed, this also resulted in nonwords.

The mean length of the initial misaligned vowel words (3.23 letters), the initial aligned consonants (3 letters), and the initial aligned vowel words (3.45 letters) was not significantly different. The mean frequency in Thai (obtained from the database of Luksaneeyanawin, 2004) of the misaligned vowel words (726.2) and the mean frequency of the aligned consonant words (847.8) were not significantly different, but were significantly higher than the aligned vowel (mean word frequency = 147.8; $t(59) = 1.91$, $p < .05$ and $t(59) = 2.39$, $p < .01$, respectively). The targets were presented in 20-point Courier Thai font and were preceded by primes in 14-point Courier Thai font with initial letter positions transposed or replaced. The primes were always nonwords. An additional set of 180 target pseudowords that were three and four letters long were included for the purposes of the lexical decision task. The manipulation of the pseudoword trials was the same as that for the word trials. 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 individually in a quiet room. Presentation of the stimuli and recording of response times were controlled by a Windows computer running DMDX (Forster & Forster, 2003). On each trial, a forward mask consisting of a row of hash marks (#'s) was presented for 500 ms in the center of the screen. Then, the prime was presented in 14-point Courier Thai font and stayed on the screen for 50 ms (i.e., three refresh cycles). The prime was immediately followed by the presentation of the target stimulus in 20-point Courier Thai font. Both prime and target were presented in the same screen location as the forward mask. The target stimulus remained on the screen until the participant's response – or until 2,500 ms had elapsed. Participants were told that words and nonwords would be displayed on the monitor in front of them, and that they should press the "yes" button to indicate if the stimulus was an existing Thai word or the "no" button if the stimulus was not a word. They were instructed to respond as quickly as possible whereas maintaining a high level of accuracy. Each participant received a different random order of stimuli.

Table 1. Mean lexical decision times (in milliseconds) and percentage of errors (in parentheses) for the words and nonword targets in the experiment

	Type of target		
Type of prime	Misaligned (VC)	Aligned (CV)	Aligned (VC)
Word stimuli			
Identity	567 (3.0)	549 (1.5)	601 (5.5)
Transposed-letter	583 (2.4)	561 (2.4)	612 (5.9)
Replacement-letter	590 (3.3)	574 (1.4)	623 (5.0)
Nonword stimuli			
Identity	617 (3.6)	641 (5.5)	619 (2.0)
Transposed-letter	614 (2.6)	647 (4.4)	624 (2.9)
Replacement-letter	619 (2.4)	651 (5.2)	625 (4.2)

Each participant received a total of 20 practice trials prior to the experimental phase. The session lasted approximately 14 min.

Results

Incorrect responses (3.4% of the data for words and 3.6% for nonwords) and response times less than 250 ms or greater than 1,500 ms (less than 4% of trials) were excluded from the latency analysis. The mean response times and error percentages from the subject analysis are presented in Table 1. For word and nonword stimuli, ANOVAs based on the participant and item response latencies and error percentage were conducted based on a 3 (type of target: misaligned word, aligned word [CV], aligned word [VC]) × 3 (type of prime: identity, transposed-letter, replacement-letter) × 3 (List: list 1, list 2, list 3) design. Planned comparisons were conducted to examine the two comparisons of interest: identity condition versus transposed-letter condition and transposed-letter condition versus replacement-letter condition. List was included as a factor in the statistical analyses to extract the variability due to the counterbalancing lists.

Word Data

The ANOVA on the latency data showed a main effect of type of target, $F1(2, 60) = 59.14$, $MSE = 1107$, $p < .001$; $F2(2, 171) = 14.28$, $MSE = 9561$, $p < .001$; post hoc analyses using the Bonferroni adjustment ($p < .05$) revealed longer RTs for the words with an initial aligned vowel than for the other two types of words.[2] The main effect of type of prime was also significant, $F1(2, 60) = 18.18$, $MSE = 749$, $p < .001$; $F2(2, 342) = 15.45$, $MSE = 1943$ $p < .001$: This reflected a 10-ms transposed-letter priming effect, $F1(1, 30) = 6.30$, $MSE = 788$, $p < .018$; $F2(1, 171) = 6.71$, $MSE = 1845$, $p < .01$, and a 13-ms advantage of the identity priming condition over the transposed-letter condition, $F1(1, 30) = 15.91$, $MSE = 555$, $p < .001$; $F2(1, 171) = 8.52$, $MSE = 2090$, $p < .005$. More important, the magnitude of the priming effects was similar across type of target, as deduced from the lack of an interaction between the two factors, both Fs < 1.

The ANOVA on the error data only showed a main effect of type of target, $F1(2, 60) = 21.44$, $MSE = 16.4$, $p < .001$; $F2(2, 171) = 6.65$, $MSE = 96.0$; as in the RT analysis, post hoc analyses using the Bonferroni adjustment ($p < .05$) revealed more errors for the words with an initial aligned vowel than for the other two types of words. Neither the main effect of type of prime nor the interaction between the two factors approached significance, all Fs < 1.

Nonword Data

The ANOVA on the error data only showed a main effect of type of target, $F1(2, 60) = 13.77$, $MSE = 1771$, $p < .001$; $F2(2, 171) = 4.96$, $MSE = 8546$; post hoc analyses ($p < .05$) reflected longer RTS for the nonwords with an initial aligned consonant than for the other types of nonwords. Neither the main effect of type of prime nor the interaction between the two factors approached significance, all ps > .17.

The ANOVA on the error data showed a main effect of type of target, $F1(2, 60) = 6.10$, $MSE = 22.7$, $p < .005$; $F2(2, 171) = 3.30$, $MSE = 76.4$, $p < .04$; post hoc analyses ($p < .05$) reflected differences between the nonwords with an initial aligned nonword and the other two types of nonwords in the analyses by participants – but not in the analyses by items. The main effect of type of prime was not significant, both Fs < 1. The interaction between the two factors reached the criterion for significance in the analysis by participants, $F1(4, 120) = 2.45$, $MSE = 11.5$, $p = .05$; $F2(4, 342) = 1.80$, $MSE = 28.6$, $p = .13$.

[2] The overall RT/error difference between the words with an initial aligned vowel and the other types of words is not surprising because this condition had a lower frequency of occurrence in the experiment (see Method section).

Discussion

The present masked priming experiment has shown that transposed-letter priming effects can be obtained in Thai even when the initial letter is involved even in short words – the magnitude of the effects is around 10 ms. Furthermore, the pattern of priming effects was similar in magnitude when the transposition affected words with misaligned vowels (e.g., แบน/ɛ:bn/ but pronounced as /bɛ:n/; บแน-แบน vs. ไฟน-แบน [TL condition vs. RL condition]), words with aligned vowels (e.g., อาบ/a:p/, pronounced as /a:p/; าอบ-อาบ vs. วะบ-อาบ [TL condition vs. RL condition]), and words with an initial aligned consonant (e.g., บาท/ba:t/, pronounced as /ba:t/, าบท-บาท vs. พะท-บาท [TL condition vs. RL condition]). We now examine the implications of these data for the input coding schemes of models of visual-word recognition.

As indicated in the Introduction section, evidence concerning transposition effects on lexical processing when the initial letter is involved is very weak in Indo-European languages. This has traditionally been interpreted as a result of the special status of the initial letter position in visual-word recognition and reading. However, the role of the initial letter position may be less critical in a language such as Thai, in which (i) there are no spaces between words, and (ii) the ordering of the letters does not necessarily reflect the ordering of a word's phonemes. Indeed, we found a significant 10-ms transposed-letter priming when the initial letter position was involved. Thus, the parameters responsible for the special status of the initial letter position in the different orthographic coding schemes (e.g., SERIOL model, Whitney, 2001; overlap model, Gómez et al., 2008; SOLAR model, Davis, 2010; open-bigram model, Grainger & van Heuven, 2003; noisy-coding Bayesian Reader model, Norris et al., 2010) should be considered (to some degree) as language-dependent. Interestingly, ongoing research in our laboratory using jumbled words in a normal reading situation, both in the usual unspaced scenario and when spaces were added between words, showed that letter transposition effects in Thai are similar in size for internal and initial letter transpositions; this again suggests that letter position coding in Thai is highly flexible and initial letter positions do not enjoy a particular role in the process of lexical access. In any case, we should indicate that we also found a significant 13-ms advantage of the identity condition over the transposed-letter condition. This implies that, beyond the presence of some perceptual uncertainty in the assignment of letter position, letter position information was also being attained in the masked primes.

Concerning the issue of phonological information in early stages of processing, we found a very similar pattern of masked priming effects when the transposed-letter prime produced a sequence which reversed the consonant/vowel phonological sequence and when transposed-letter prime produced a sequence which was consistent with the phonological sequence – note that a word like แบน/ɛ:bn/ is pronounced as /bɛ:n/, so that the transposed-letter prime had the correct phonological order: บแน/bɛ:n/. This reinforces once more the view that the nature of masked transposed-letter priming effects is orthographic rather than phonological (see Acha & Perea, 2010; Perea, Nakatani, & van Leeuwen, 2011).

One important issue for future research is to examine to what degree the flexibility of the orthographic coding scheme depends on the different languages that a given individual knows. In other words, one question would be to study whether or not bilingual Thai-English individuals whose first language is Thai would also show a similar pattern for English stimuli – and to what degree this modulation would depend on the proficiency of the L2 (i.e., English orthography). If masked transposed-letter priming effects can be obtained in Thai, but not in English with a sample of proficient Thai-English bilinguals, this would imply that the specific characteristics of a given orthography shape the process of letter position coding. In this respect, Hebrew-English bilinguals whose L1 is Hebrew show the typical transposed-letter effects when reading jumbled English materials, whereas they showed much more reduced transposed-letter effects when reading jumbled Hebrew words.

In sum, the present experiment has shown that the Thai orthographic system allows a very flexible process of letter position coding, as deduced from the presence of a reliable transposed-letter priming effect when the initial letter position was involved. This implies that the orthographic coding scheme should have a flexible parameter that modulates the role of the initial letter position depending on the specific orthography. One issue for further research is the extent at which young readers show transposed-letter effects, and whether misaligned and aligned vowels play a different role in the development of the processes underlying letter position coding in Thai (see Acha & Perea, 2008; Perea & Estévez, 2008, for evidence of transposed-letter effects in young readers).

Acknowledgments

The research reported in this article has been partially supported by Grants PSI2008-04069/PSIC and CONSOLIDER-INGENIO2010 CSD2008-00048 from the Spanish Ministry of Education and Science. We would also like to thank Chalong Saengsirivijam for assisting with participant recruitment and Ben Wood for assisting in data collection. We also thank Ken Forster for helpful comments on an earlier version of the paper.

References

Acha, J., & Perea, M. (2008). The effects of length and transposed-letter similarity in lexical decision: Evidence with beginning, intermediate, and adult readers. *British Journal of Psychology, 99*, 245–264.

Acha, J., & Perea, M. (2010). Does kaniso activate CASINO? Input coding schemes and phonology in visual-word recognition. *Experimental Psychology, 57*, 245–251.

Carreiras, M., Ferrand, L., Grainger, J., & Perea, M. (2005). Sequential effects of phonological priming in visual word recognition. *Psychological Science, 16*, 585–589.

Davis, C. J. (1999). The Self-Organising Lexical Acquisition and Recognition (SOLAR) model of visual word recognition (Unpublished doctoral dissertation). University of New South Wales, Sydney, Australia.

Davis, C. J. (2010). The spatial coding model of visual word identification. *Psychological Review, 117*, 713–758.

Davis, C. J., & Andrews, S. (2001, April). Inhibitory effects of transposed-letter similarity for words and nonwords of different lengths. *Paper presented at the 28th Annual Australian Experimental Psychology Conference*, Melbourne, Australia.

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10*, 680–698.

Forster, K. I., Davis, C., Schoknecht, C., & Carter, R. (1987). Masked priming with graphemically related forms: Repetition or partial activation? *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 39A*, 211–251.

Forster, K. I., & Forster, J. C. (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, and Computers, 35*, 116–124.

Gómez, P., Ratcliff, R., & Perea, M. (2008). The overlap model: A model of letter position coding. *Psychological Review, 115*, 577–601.

Grainger, J., & van Heuven, W. J. B. (2003). Modeling letter position coding in printed word perception. In P. Bonin (Ed.), *Mental lexicon: Some words to talk about words* (pp. 1–23). Hauppauge, NY: Nova Science.

Johnson, R. L., Perea, M., & Rayner, K. (2007). Transposed-letter effects in reading: Evidence from eye movements and parafoveal preview. *Journal of Experimental Psychology: Human Perception and Performance, 33*, 209–229.

Kinoshita, S., Castles, A., & Davis, C. (2009). The role of neighbourhood density in transposed letter priming. *Language and Cognitive Processes, 24*, 506–526.

Lee, C. H., & Taft, M. (2009). Are onsets and codas important in processing letter position? A comparison of TL effects in English and Korean. *Journal of Memory and Language, 60*, 530–542.

Luksaneeyanawin, S. (2004). *Thai word frequency based on two million word corpus of written genre texts*. Bangkok, Thailand: Center for Research in Speech and Language Processing. Faculty of Arts, Chulalongkorn University.

Norris, D., Kinoshita, S., & van Casteren, M. (2010). A stimulus sampling theory of letter identity and order. *Journal of Memory and Language, 62*, 254–271.

O'Connor, R. E., & Forster, K. I. (1981). Criterion bias and search sequence bias in word recognition. *Memory and Cognition, 9*, 78–92.

Perea, M., Abu Mallouh, R., & Carreiras, M. (2010). The search of an input coding scheme: Transposed-letter priming in Arabic. *Psychonomic Bulletin and Review, 17*, 375–380.

Perea, M., Abu Mallouh, R., García-Orza, J., & Carreiras, M. (2011). Masked priming effects are modulated by expertise in the script. *Quarterly Journal of Experimental Psychology, 64*, 902–919. doi: 10.1080/17470218.2010.512088

Perea, M., & Carreiras, M. (2006). Do transposed-letter similarity effects occur at a prelexical phonological level? *Quarterly Journal of Experimental Psychology, 59*, 1600–1613.

Perea, M., & Estévez, A. (2008). Transposed-letter similarity effects in naming pseudowords: Evidence from children and adults. *European Journal of Cognitive Psychology, 20*, 33–46.

Perea, M., & Lupker, S. J. (2003). Transposed-letter confusability effects in masked form priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: State of the art* (pp. 97–120). Hove, UK: Psychology Press.

Perea, M., & Lupker, S. J. (2004). Can CANISO activate CASINO? Transposed-letter similarity effects with nonadjacent letter positions. *Journal of Memory and Language, 51*, 231–246.

Perea, M., & Lupker, S. J. (2007). La posición de las letras externas en el reconocimiento visual de palabras. *Psicothema, 19*, 559–564.

Perea, M., Nakatani, C., & van Leeuwen, C. (2011). Transposition effects in reading Japanese Kana: Are they orthographic in nature? *Memory and Cognition, 39*, 700–707. doi: 10.3758/s13421-010-0052-1

Perea, M., & Pérez, E. (2009). Beyond alphabetic orthographies: The role of form and phonology in transposition effects in Katakana. *Language and Cognitive Processes, 24*, 67–88.

Perea, M., & Rosa, E. (2000). Repetition and form priming interact with neighborhood density at a short stimulus-onset asynchrony. *Psychonomic Bulletin and Review, 7*, 668–677.

Rumelhart, D. E., & McClelland, J. L. (1982). An interactive activation model of context effects in letter perception, Part II: The contextual enhancement effect and some tests and extensions of the model. *Psychological Review, 89*, 60–94.

Schoonbaert, S., & Grainger, J. (2004). Letter position coding in printed word perception: Effects of repeated and transposed letters. *Language and Cognitive Processes, 19*, 333–367.

Velan, H., & Frost, R. (2011). Words with and without internal structure: what determines the nature of orthographic and morphological processing? *Cognition, 118*, 141–156. doi: 10.1016/j.cognition.2010.11.013

Whitney, C. (2001). How the brain encodes the order of letters in a printed word: The SERIOL model and selective literature review. *Psychonomic Bulletin and Review, 8*, 221–243.

Received January 8, 2011
Revision received April 11, 2011
Accepted May 17, 2011
Published online September 14, 2011

Manuel Perea

Departamento de Metodología
Facultad de Psicología
Av. Blasco Ibáñez, 21
46010 Valencia
Spain
Fax +34 96 3864697
E-mail mperea@valencia.edu

