Memory & Cognition
2010, 38 (4), 513-518
doi:10.3758/MC.38.4.513

Does LGHT prime DARK? Masked associative priming with addition neighbors

Manuel Perea
Universitat de València, València, Spain

and

Pablo Gomez
DePaul University, Chicago, Illinois

We present two masked priming lexical decision experiments in which we examined whether a nonword prime word would activate associative/semantic information from its corresponding addition neighbor (e.g., *lght*–DARK via the addition neighbor *light*), producing associative/semantic priming. The rationale was the following: If a nonword prime with a missing letter produced a semantic/associative priming effect, this would clearly indicate that this nonword was activating the lexical/semantic representations of its base word, thereby reinforcing the models of visual-word recognition in which the orthographic representations produced by *lght* (or *ligt*) and *light* are quite similar (e.g., SOLAR, SERIOL, open-bigram, and overlap models). The results showed that the magnitude of the masked associative priming effect with subset primes was remarkably similar to that of the priming effect with the corresponding word prime. Furthermore, the magnitude of the associative priming effect was similar when the deleted letter was a vowel and when the deleted letter was a consonant.

In recent years, there has been growing interest in the search for an appropriate orthographic coding scheme for models of visual word recognition. To achieve this goal, it is important that one examine which words are being activated by a given stimulus item. There is ample consensus that, upon visual presentation of a letter string, the lexical units corresponding to words that can be created by changing a single letter of the stimulus are partially activated (i.e., the *substitution* neighbors). For instance, using a masked priming paradigm, which is a technique particularly useful for examining early effects in visual word recognition (Forster & Davis, 1984; cf. Grainger, 2008), Bourassa and Besner (1998) showed that a brief presentation of the nonword *judpe* (i.e., a substitution neighbor of the word *judge*) activated COURT, an associate of its base word, relative to presentation of the unrelated nonword prime *oceln*. More recent research has shown that a complete characterization of a word's orthographic neighborhood should include items created by transposing two letters: Perea and Lupker (2003) demonstrated that the brief presentation of the transposed-letter nonword *jugde* activated COURT more than did the unrelated nonword prime *ocaen*.

The focus of the present article is to examine whether *addition* neighbors produce a pattern of effects similar to those found with substitution and *transposed-letter* neighbors. We define an *addition neighbor* as a word that involves the addition of a single letter to a given stimulus item (see Davis & Taft, 2005; e.g., the word *house* is an addition neighbor of the word *hose* and of the nonword *huse*). Specifically, we examine whether a nonword prime (e.g., *lght*) activates associative/semantic information from its corresponding addition neighbor (DARK via the addition neighbor *light*), producing associative/semantic priming.

Evidence for an influence of addition neighbors in a masked form priming paradigm has already been established. de Moor and Brysbaert (2000) found an inhibitory effect of high-frequency word primes that were addition neighbors of the prime relative to unrelated control primes—similar to what occurs with substitution neighbors (see Segui & Grainger, 1990). In addition, Schoonbaert and Grainger (2004) found a facilitative masked priming effect, relative to an unrelated priming condition, when the related primes were nonwords formed by removing a single letter of the target (e.g., *mircle*–MIRACLE). However, it is important to mention that the presence of masked associative/semantic priming would be a stronger demonstration of the role of addition neighbors than would the presence of form-priming effects (e.g., *lgth* priming LIGHT). The reason is that form-priming effects may be due (at least in part) to activation of the sublexical units used in the creation of the orthographic representation, rather than due to activation of the lexical unit for the base word. Elucidating whether addition neighbors activate lexical instead of sublexical representations of words would allow us to interpret recent findings in the field

M. Perea, mperea@valencia.edu

of visual word identification. Bowers, Davis, and Hanley (2005) found that participants took more time to decide that *seep* (which has the addition neighbor *sheep*) was not a type of animal than to decide that it was not a type of vehicle. Furthermore, using a lexical decision task, Davis, Perea, and Acha (2009) found slower and substantially less accurate *no* decisions for nonwords with addition neighbors (e.g., *luxry*; the base word is *luxury*) relative to control nonwords. Davis et al. also found an interference effect from higher frequency addition neighbors for word stimuli (e.g., *hose* because of *house*) in a lexical decision task and in a normal reading experiment in which the participants' eye movements were monitored.

It is important to note that masked word primes activate—to a small extent—associative/semantic information, as is demonstrated by the presence of faster responses to the target NURSE when it is preceded by the related prime *doctor* than when it is preceded by the unrelated prime *butter* (the effect sizes are around 6–18 msec; see, e.g., Bodner & Masson, 2003; Bourassa & Besner, 1998; Duyck, 2005; Grossi, 2006; Perea & Gotor, 1997; Perea & Lupker, 2003; Perea & Rosa, 2002). Masked associative priming effects have also been reported when the dependent variables are the fixation times during normal reading ("fast priming" technique; Sereno & Rayner, 1992), the ERP waves (Grossi, 2006), and the BOLD signal (Gold & Rastle, 2007). Particularly relevant for the present study was that masked associative priming can also be observed with nonword primes that resemble their corresponding base words. As indicated earlier, Bourassa and Besner (1998) found a small (around 6–7 msec) but significant masked associative priming effect when using substitution nonword primes (e.g., *judpe*–COURT faster than *oceln*–COURT), and Perea and Lupker (2003) found similar evidence with transposed-letter nonword primes (around 10–12 msec; e.g., *jugde*–COURT faster than *ocaen*–COURT).

In sum, the main question of the present study was whether masked associative/semantic priming can be obtained for subset prime stimuli. If a nonword prime with a missing letter (e.g., LGHT) produces a semantic/associative priming effect, this would clearly indicate that this nonword activates the lexical/semantic representations of its base word, thereby reinforcing the models of visual word recognition in which the orthographic representations produced by *lght* (or *ligt*) and *light* are quite similar.

All recently proposed letter position coding schemes predict an effect of addition neighbors (SOLAR model, Davis, 1999; SERIOL model, Whitney, 2001; open-bigram model, Grainger & van Heuven, 2003; overlap model, Gomez, Ratcliff, & Perea, 2008). That is, all these models predict that inserting one letter from a given word produces a perceptually similar item (*juge–judge*) (see Davis, 2006; Grainger, 2008, for recent reviews). What we should note here is that the front end of these orthographic coding schemes does not predict any differences depending on whether the deleted/inserted letter is a vowel or a consonant. However, some empirical evidence does show that consonants and vowels may be processed differently (e.g., Caramazza, Chialant, Capasso, & Miceli, 2000; Carreiras, Gillon-Dowens, Vergara, & Perea, 2009; Lupker, Perea, & Davis, 2008; New, Araújo, & Nazzi, 2008; Perea & Lupker, 2004). To examine the role of consonant/vowel status as a modulating factor of masked associative priming with addition neighbors in a lexical decision task, we used nonword primes whose addition neighbors differed by a vowel in Experiment 1 (e.g., *lght*–DARK vs. *clth*–DARK), whereas we employed nonword primes whose addition neighbors differed by a consonant in Experiment 2 (e.g., *ligt*–DARK vs. *cloh*–DARK). For purposes of comparison, we also included a priming condition with the words spelled correctly (*light*–DARK vs. *cloth*–DARK).

EXPERIMENT 1

Method

Participants. Seventy-two students from DePaul University participated in the experiment in exchange for course credit. All were native speakers of English and had either normal or corrected-to-normal vision.

Materials. Seventy-six associatively/semantically related pairs (e.g., *light*–DARK) were selected from the Nelson, McEvoy, and Schreiber (1998) free-association norms, with the first member of the pair used as a prime and the second as target. The mean associative strength (i.e., the probability of a word being the first associative response to the prime) in these norms was 36%. In the experiment, a target word (e.g., DARK) could be preceded by (1) an associate of the target (*light*), (2) an associate of the target in which one vowel was deleted (*lght*; note that adding a letter to the string could only produce a single English word; e.g., *frst* could not be used since it generates two words: *first* and *frost*), (3) an unrelated word (*cloth*), or (4) an unrelated word in which the vowels were deleted (*clth*). Word primes and nonword primes were rotated throughout the related and unrelated conditions so that each target word was primed by each of the four types of primes across the experiment (see Perea & Lupker, 2003, for a similar procedure). Thus, four lists of stimuli were created to counterbalance the materials so that each target appeared only once in each list, but in a different priming condition. Different participants were assigned to each list.

Target words had a mean length of 4.9 letters (range: 3–9) and a frequency of 196 occurrences per million, whereas prime words had a mean length of 5.2 letters (range: 5–6) and a frequency of 71 occurrences per million in the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995; see Davis, 2005). Given the constraints at play in selecting the stimuli, it was not possible to select prime words/nonwords with no substitution neighbors; nonetheless, mean Coltheart's *N* was very low: 2.4 and 1.7 for the prime words and nonwords, respectively. The list of stimuli and the average response times per item are presented at www.uv.es/mperea/lght.pdf. An additional set of 76 orthographically legal nonwords in English were created for the purposes of the lexical decision task. As occurred with word trials, nonword targets were preceded by a word prime or a nonword prime.

Procedure. Participants were tested individually or in groups of up to 3 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). On each trial, a forward mask consisting of a row of hash marks (#s) was presented for 500 msec in the center of the screen. Next, the prime was presented for 50 msec (three cycles; each cycle corresponding to 16.6 msec on the CRT monitor). The prime was followed immediately by the presentation of the target stimulus in uppercase. Response times were measured from target onset to the participant's response. All the strings were presented centered, in Courier New 12-point font colored in black, on a white background. Participants were instructed to press the "M" button if the string formed an existing English word and the "Z" button if the string was a nonword. They were not informed of the presence of lowercase items. Each participant received a different order of trials. None of the participants reported having seen the lowercase stimuli when asked after the experiment. The whole experimental session lasted about 12 min.

Results and Discussion

Incorrect responses (1.9% of the data for targets), and response times less than 250 msec or greater than 1,500 msec (less than 2% of the data) 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 were conducted according to a 2 (type of prime–target relationship: associatively related, unrelated) × 2 (type of prime: correctly spelled, nonword with missing vowel) × 4 (list: list1, list2, list3, list4) design. All significant effects had p values less than the .05 level.

The ANOVA revealed that, on average, response times were 7 msec faster in the associatively/semantically related conditions than in the unrelated conditions (580 vs. 587 msec, respectively) [$F_1(1,68) = 5.82$, $MS_e = 478.0$, $p < .05$, $\eta^2 = .08$; $F_2(1,72) = 4.19$, $MS_e = 688.0$, $p < .05$, $\eta^2 = .06$]. The other effects did not approach significance (all Fs < 1).

The ANOVA on the error rates did not reveal any significant effects (all Fs < 1.4).

In sum, there was a small (but reliable) associative priming effect. Importantly, this priming effect was not smaller for prime words without vowels (*lght*–DARK vs. *clth*–DARK) than for correctly spelled prime words (*light*–DARK vs. *cloth*–DARK).

The effect of masked associative priming was quite small (around 7 msec), and this is in line with the experiments of Bourassa and Besner (1998) and Perea and Lupker (2003) with substitution neighbors and transposed-letter neighbors, respectively. This implies that in order to obtain enough statistical power to detect the effect, the sample size must be rather large (e.g., 132 subjects in Bourassa & Besner's Experiment 1 and 120 subjects in Perea & Lupker's, 2003, Experiment 1).

The question then was whether we would obtain a parallel effect when the missing letter was a consonant, not a vowel. It has been claimed that consonants bear the main burden of distinguishing lexical items (Mehler, Peña, Nespor, & Bonatti, 2006), so that a missing vowel could be less damaging for a word's identification than would a missing consonant. Obviously, without this control condition with a missing consonant, there was no way of knowing whether the cognitive system is not just resilient to the amount of material that is missing in the stimuli, irrespective of whether that material is a vowel or not. Thus, the primary question of Experiment 2 was whether masked associative/semantic priming could be obtained for nonword subset primes with a missing consonant (e.g., *ligt*–DARK vs. *cloh*–DARK); again, for purposes of comparison, we included a priming condition with the words spelled correctly (*light*–DARK vs. *cloth*–DARK).

EXPERIMENT 2

Method

Participants. One hundred twelve students from DePaul University participated in the experiment in exchange for course credit. All were native speakers of English and had either normal or corrected-to-normal vision. None had participated in Experiment 1.

Materials. Seventy-six associatively/semantically related pairs (e.g., *light*–DARK) were selected from the Nelson et al. (1998) free-association norms, with the first member of the pair used as a prime and the second as target. Most of the pairs were the same as in Experiment 1; an item like CHART (CHRT), which was used in Experiment 1, could not be used in Experiment 2 because it would generate two subset word primes: CART and CHAT. The mean associative strength in the Nelson et al. norms was 49%.[1] In the experiment, a target word (e.g., DARK) could be preceded by (1) an associate of the target (*light*), (2) an associate of the target in which an internal consonant was deleted (*ligt*; note that adding an internal letter to the string could only produce a single English word), (3) an unrelated word (*cloth*), or (4) an unrelated word in which one consonant was deleted (*cloh*). Word primes and nonword primes were rotated throughout the related and unrelated conditions so that each target word was primed by each of the four types of primes across the experiment. Thus, four lists of stimuli were created to counterbalance the materials so that each target appeared only once in each list, but in a different priming condition. Different participants were assigned to each list.

Target words had a mean length of 5.6 letters (range: 5–9) and a mean frequency of 59 occurrences per million, whereas prime words had a mean length of 5.2 letters (range: 5–9) and a mean frequency of 59 occurrences per million in the CELEX database (Baayen et al., 1995; see also Davis, 2005). For the prime words and nonwords, mean Coltheart's Ns were 2.7 and 1.5, respectively. The list of stimuli and the average response times per item are presented at www.uv.es/mperea/lght.pdf. As in Experiment 1, an additional set of 76 orthographically legal nonwords in English was employed for the purposes of the lexical decision task. As occurred with word trials, nonword targets were preceded by a word prime or a nonword prime.

Procedure. This was the same as in Experiment 1.

Results and Discussion

Incorrect responses (2.0% of the data for targets), and response times less than 250 msec or greater than 1,500 msec (less than 2.5% of the data) were excluded from the latency analysis. The mean latencies for correct responses and error

Table 1
Mean Lexical Decision Times (RT, in Milliseconds), Standard Error Response Times [RT(*SE*)], and Percentages of Errors (PE) for Word Targets in Experiment 1

	Type of Prime								
	Related			Unrelated			Priming		
Target Type	RT	RT(*SE*)	PE	RT	RT(*SE*)	PE	RT	RT(*SE*)	PE
Correctly spelled	579	7.9	1.8	585	7.6	1.5	6	3.7	−0.3
Missing vowel	581	7.3	2.3	588	7.6	2.0	7	3.6	−0.3

Note—Mean nonword response times and error rates were 681 msec and 7.3%.

rates are presented in Table 2, and participant and item ANOVAs based on the participant and item response latencies were conducted according to a 2 (type of prime–target relationship: associatively related, unrelated) × 2 (type of prime: correctly spelled, nonword with missing consonant) × 4 (list: list1, list2, list3, list4) design.

The ANOVA revealed that, on average, response times were 6 msec faster in the associatively related conditions than in the unrelated conditions (606 vs. 612 msec, respectively) [$F_1(1,108) = 5.82$, $MS_e = 708.2$, $p < .02$, $\eta^2 = .05$; $F_2(1,72) = 4.56$, $MS_e = 612.9$, $p < .04$, $\eta^2 = .04$]. In addition, responses to words preceded by a nonword prime were 5 msec faster than responses to words preceded by a word prime, although the effect did not reach statistical significance [$F_1(1,108) = 3.87$, $MS_e = 708.9$, $p = .052$, $\eta^2 = .035$; $F_2(1,72) = 2.44$, $MS_e = 437.1$, $p = .12$, $\eta^2 = .033$]. More important, as in Experiment 1, there were no signs of an interaction between the two factors (both Fs < 1).

The ANOVA on the error data failed to show any significant effects (all Fs < 1).

The present experiment again showed a small, but significant, associative priming effect. Parallel to the findings of Experiment 1, this associative priming effect was not smaller for prime words with a missing consonant (*ligt*–DARK vs. *cloh*–DARK) than for correctly spelled prime words (*light*–DARK vs. *cloth*–DARK). (See note 1.)

A combined analysis of Experiments 1 and 2, including consonant/vowel status of the two missing letter prime nonwords, revealed an effect of masked associative priming from the nonword primes [$F(1,176) = 6.98$, $MS_e = 524.3$, $p < .01$, $\eta^2 = .04$], and there were no signs of an interaction ($F < 1$) between the two factors. Thus, the consonant/vowel status of the missing letter does not seem to matter in modulating the semantic/associative information from the base word. We acknowledge that one should be cautious in accepting a null interaction hypothesis when the effect sizes are very small—beyond the fact that associative priming can be obtained for nonwords primes with a missing consonant and for nonword primes with a missing vowel. Nonetheless, further statistical analyses including only the target words employed in both Experiments 1 and 2 also failed to reveal a significant consonant/vowel difference in the size of the priming effects.

Finally, in Experiments 1 and 2, there was a negligible inhibitory trend (around −0.3%) in the error data. Even though a 0.3% difference in accuracy merely reflects an average difference of 0.057 incorrect responses per condition, we conducted a pooled analysis of the error data across experiments. These analyses failed to reveal any signs of a speed–accuracy trade-off in the experiments (e.g., the size of the priming effect in the response times did not correlate with the size of the priming effect).

GENERAL DISCUSSION

The present findings are straightforward and can be summarized as follows. First, it is possible to obtain early access to associative/semantic information from the addition neighbors of a nonword prime (i.e., LGHT facilitates the processing of DARK via its addition neighbor LIGHT)—even though the effect size is small (around 6–7 msec). Second, the magnitude of the masked associative priming effect with subset primes is remarkably similar when the deleted letter is a vowel and when the deleted letter is a consonant. Taken together, these findings are consistent with the front end of the recent models of letter position coding. Importantly, the "standard" methods of input coding, such as the orthographic coding schemes employed in the interactive activation model (McClelland & Rumelhart, 1981) and its extensions (dual-route cascaded model, Coltheart, Rastle, Perry, Ziegler, & Langdon, 2001; multiple read out model, Grainger & Jacobs, 1996; Jacobs, Rey, Ziegler, & Grainger, 1998; the lexical route in the CDP+ model, Perry, Ziegler, & Zorzi, 2007) cannot predict an effect of addition neighbors.

As in prior work, the magnitude of the associative priming effect with nonword primes was numerically similar to that with word primes (see Perea & Lupker, 2003, for a similar finding with transposed-letter stimuli; see also Duñabeitia, Carreiras, & Perea, 2008).[2] This is consistent with the view that written language employs a highly redundant code, so that some of the letters may be deleted (or replaced, or transposed) without much cognitive cost. In this light, it is reasonable to assume that in sparse neighborhoods—as was the case for most of the present word/nonword primes—the presence of small discrepancies in the stimulus item may be tolerated by the cognitive system. Indeed, masked form/repetition priming effects are greater for words with sparse neighborhoods than for words with large neighborhoods (see Forster, Davis, Schoknecht, & Carter, 1987; Perea & Rosa, 2000). Similarly, orthographic priming can be obtained when some of the letters in the prime are deleted (see Grainger, Granier, Farioli, Van Assche, & van Heuven, 2006; Peressotti & Grainger, 1999). That is, the cognitive system is somewhat resilient to the amount of material that is missing from the stimuli (see Perea, Duñabeitia, & Carreiras, 2008).[3]

Table 2
Mean Lexical Decision Times (RT, in Milliseconds), Standard Error Response Times [RT(*SE*)], and Percentages of Errors (PE) for Word Targets in Experiment 2

	Type of Prime								
	Related			Unrelated			Priming		
Target Type	RT	RT(*SE*)	PE	RT	RT(*SE*)	PE	RT	RT(*SE*)	PE
Correctly spelled	609	6.4	2.0	615	6.5	1.8	6	3.7	−0.2
Missing consonant	604	6.4	2.2	610	6.6	1.9	6	3.2	−0.3

Note—Mean nonword response times and error rates were 714 msec and 7.5%.

The present data are compatible with the claim made by the front end of models of visual word recognition (SOLAR model, SERIOL model, overlap model, open-bigram model): Addition neighbors form part of an item's neighborhood. Importantly, the present findings seem to suggest that the front end of these models is not sensitive to consonant/vowel status (Gomez et al., 2008; see also Perea & Acha, 2009): Associative priming effects were quite similar in magnitude when the addition neighbor differed in a vowel or in a consonant. Indeed, unpublished research in our lab, using a lexical decision task, has shown that when only one internal letter is delayed for around 50 msec, response times are virtually the same as those in a condition with no delayed letters, and this occurs to the same degree for the delay of a vowel or a consonant. That is, nonwords such as *lght* or *ligt* tend to activate their addition neighbor LIGHT at a ceiling level—which is close to the activation from the stimulus item *light*—and this is the reason why they activate associative/semantic information. Consistent with this view, nonwords with addition neighbors tend to produce a very high percentage of false positives in the lexical decision task (see Davis et al., 2009). What we should also indicate is that Carreiras et al. (2009), who found an effect of consonant/vowel status in a delayed letter paradigm, opted for delaying two letters—rather than one—because performance was at ceiling values when only one consonant or only one vowel was delayed in pilot work. One might argue, however, that a more extreme manipulation (e.g., deleting two consonants/vowels) would maximize the chances to obtain an effect of consonant/vowel status (as in Carreiras et al., 2009). However, this manipulation would make it more difficult to obtain a reliable masked associative priming effect.

In summary, the present experiments demonstrate the existence of masked associative priming with subset nonword primes (i.e., LGHT activates DARK). This is consistent with the prediction of recent orthographic input schemes that assume that stimuli such as LGHT and LIGHT are perceptually very similar (e.g., SOLAR, SERIOL, open-bigram, and overlap models). Furthermore, masked associative priming effects occurred to a similar degree when the missing letter was a vowel and when the missing letter was a consonant. This is consistent with the idea that the front end of the various letter position coding schemes that have been proposed recently do not need to be modified to account for the consonant/vowel status of the constituent letters.

AUTHOR NOTE

The research reported in this article has been partially supported by Grants PSI2008-04069/PSIC from the Spanish Ministry of Education and Science to Manuel Perea and NSF SES-0446869 to Pablo Gomez. We thank Glen Bodner, Colin Davis, and Wouter Duyck for helpful and insightful comments on an earlier version of the manuscript. Correspondence concerning this article should be addressed to M. Perea, Departamento de Metodología, Facultad de Psicología, Av. Blasco Ibáñez, 21, 46010-Valencia, Spain (e-mail: mperea@valencia.edu).

REFERENCES

Baayen, R. H., Piepenbrock, R., & Gulikers, L. (1995). The CELEX lexical database (CD-ROM). Philadelphia: Linguistic Data Consortium, University of Pennsylvania.

Bodner, G. E., & Masson, M. E. J. (2003). Beyond spreading activation: An influence of relatedness proportion on masked semantic priming. *Psychonomic Bulletin & Review*, **10**, 645-652.

Bourassa, D. C., & Besner, D. (1998). When do nonwords activate semantics? Implications for models in visual word recognition. *Memory & Cognition*, **26**, 61-74.

Bowers, J. S., Davis, C. J., & Hanley, D. A. (2005). Automatic semantic activation of embedded words: Is there a "hat" in "that"? *Journal of Memory & Language*, **52**, 131-143.

Caramazza, A., Chialant, D., Capasso, D., & Miceli, G. (2000). Separable processing of consonants and vowels. *Nature*, **403**, 428-430.

Carreiras, M., Gillon-Dowens, M., Vergara, M., & Perea, M. (2009). Are vowels and consonants processed differently? Event-related potential evidence with a delayed letter paradigm. *Journal of Cognitive Neuroscience*, **21**, 275-288.

Coltheart, M., Rastle, K., Perry, C., Ziegler, J., & Langdon, R. (2001). DRC: A dual-route cascaded model of visual word recognition and reading aloud. *Psychological Review*, **108**, 204-256.

Davis, C. J. (1999). *The self-organising lexical acquisition and recognition (SOLAR) model of visual word recognition*. Unpublished doctoral dissertation, Macquarie University. Available at www.maccs.mq.edu.au/~colin.

Davis, C. J. (2005). N-Watch: A program for deriving neighborhood size and other psycholinguistic statistics. *Behavior Research Methods*, **37**, 65-70.

Davis, C. J. (2006). Orthographic input coding: A review of behavioral data and current models. In S. Andrews (Ed.), *From inkmarks to ideas: Current issues in lexical processing* (pp. 180-206). New York: Psychology Press.

Davis, C. J., Perea, M., & Acha, J. (2009). Re(de)fining the orthographic neighborhood: The role of addition and deletion neighbors in lexical decision and reading. *Journal of Experimental Psychology: Human Perception & Performance*, **35**, 1550-1570.

Davis, C. J., & Taft, M. (2005). More words in the neighborhood: Interference in lexical decision due to deletion neighbors. *Psychonomic Bulletin & Review*, **12**, 904-910.

de Moor, W., & Brysbaert, M. (2000). Neighborhood-frequency effects when primes and targets have different lengths. *Psychological Research*, **63**, 159-162.

Duñabeitia, J. A., Carreiras, M., & Perea, M. (2008). Are coffee and toffee served in a cup? Ortho-phonologically mediated associative priming. *Quarterly Journal of Experimental Psychology*, **61**, 1861-1872.

Duyck, W. (2005). Translation and associative priming with cross-lingual pseudohomophones: Evidence for nonselective phonological activation in bilinguals. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **31**, 1340-1359.

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, & 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*, **39A**, 211-251.

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

Gold, B., & Rastle, K. (2007). Neural correlates of morphological decomposition during visual word recognition. *Journal of Cognitive Neuroscience*, **19**, 1983-1993.

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

Grainger, J. (2008). Cracking the orthographic code: An introduction. *Language & Cognitive Processes*, **23**, 1-35.

Grainger, J., Granier, J.-P., Farioli, F., Van Assche, E., & van Heuven, W. J. E. (2006). Letter position information and printed word perception: The relative-position priming constraint. *Journal of Experimental Psychology: Human Perception & Performance*, **32**, 865-884.

Grainger, J., & Jacobs, A. M. (1996). Orthographic processing in visual word recognition: A multiple read-out model. *Psychological Review*, **103**, 518-565.

Grainger, J., & van Heuven, W. J. B. (2003). Modeling letter position coding in printed word perception. In P. Bonin (Ed.), *The mental lexicon* (pp. 1-23). New York: Nova Science.

Grossi, G. (2006). Relatedness proportion effects on masked associative priming: An ERP study. *Psychophysiology*, **43**, 21-30.

Jacobs, A. M., Rey, A., Ziegler, J. C., & Grainger, J. (1998). MROM-p: An interactive activation, multiple readout model of orthographic and phonological processes in visual word recognition. In J. Grainger & A. M. Jacobs (Eds.), *Localist connectionist approaches to human cognition* (pp. 147-188). Mahwah, NJ: Erlbaum.

Lupker, S. J., Perea, M., & Davis, C. J. (2008). Transposed letter priming effects: Consonants, vowels and letter frequency. *Language & Cognitive Processes*, **23**, 93-116.

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

Mehler, J., Peña, M., Nespor, M., & Bonatti, L. L. (2006). The "soul" of language does not use statistics: Reflections on vowels and consonants. *Cortex*, **42**, 846-854.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). The University of South Florida word association, rhyme, and word fragment norms. Available at www.usf.edu/FreeAssociation/.

New, B., Araújo, V., & Nazzi, T. (2008). Differential processing of consonants and vowels in lexical access through reading. *Psychological Science*, **19**, 1223-1227.

Perea, M., & Acha, J. (2009). Does letter position coding depend on consonant/vowel status? Evidence with the masked priming technique. *Acta Psychologica*, **130**, 127-137.

Perea, M., Duñabeitia, J. A., & Carreiras, M. (2008). R34D1NG W0RD5 W1TH NUMB3R5. *Journal of Experimental Psychology: Human Perception & Performance*, **34**, 237-241.

Perea, M., & Gotor, A. (1997). Associative and semantic priming effects occur at very short SOAs in lexical decision and naming. *Cognition*, **62**, 223-240.

Perea, M., & Lupker, S. J. (2003). Does *jugde* activate COURT? Transposed-letter similarity effects in masked associative priming. *Memory & Cognition*, **31**, 829-841.

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

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

Perea, M., & Rosa, E. (2002). The effects of associative and semantic priming in the lexical decision task. *Psychological Research*, **66**, 180-194.

Peressotti, F., & Grainger, J. (1999). The role of letter identity and letter position in orthographic priming. *Perception & Psychophysics*, **61**, 691-706.

Perry, C., Ziegler, J. C., & Zorzi, M. (2007). Nested incremental modeling in the development of computational theories: The CDP+ model of reading aloud. *Psychological Review*, **114**, 273-315.

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

Segui, J., & Grainger, J. (1990). Priming word recognition with orthographic neighbors: Effects of relative prime–target frequency. *Journal of Experimental Psychology: Human Perception & Performance*, **16**, 65-76.

Sereno, S. C., & Rayner, K. (1992). Fast priming during eye fixations in reading. *Journal of Experimental Psychology: Human Perception & Performance*, **18**, 173-184.

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

NOTES

1. Because of the constraints in creating the prime–target pairs, mean associative strength was slightly higher in Experiment 2 than in Experiment 1 (49% vs. 36%, respectively). Nonetheless, it is important to mention that previous studies have reported masked semantic priming effects without association (e.g., Perea & Gotor, 1997).

2. In the Bourassa and Besner (1998) study, the masked associative priming effect with word primes was greater than that with substitution nonword primes. Nonetheless, we must keep in mind that substitution nonwords (e.g., *loght*) seem to be less perceptually similar to their base words than are transposed-letter nonwords (e.g., *lihgt*) or deletion nonwords (e.g., *lght*) (see Davis et al., 2009; Gomez et al., 2008; Perea & Lupker, 2003).

3. In the present experiments, as was also the case in Bourassa and Besner's (1998) Experiment 1 and in Perea and Lupker's (2003) Experiment 1, the nonword primes were presented in the same block as were the word primes. Thus, one might wonder whether the presence of associative priming effects with nonwords is modulated by the presence of word primes in the list (e.g., the presence of word primes may bootstrap the cognitive system into unconsciously tuning into the associative nature of the prime–target pairs). However, Perea and Lupker (2003, Experiment 3) reported a masked associative priming effect with transposed-letter nonwords (e.g., *jugde*–COURT) in a list with no intact (word) primes.

(Manuscript received July 20, 2009;
revision accepted for publication November 10, 2009.)