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Reading words in Spanish and English: Mapping orthography to phonology in two languages

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English-Spanish bilinguals named visually presented words aloud in each language. The words included cognates (e.g., *fruit-fruta)* and non-cognate translations (e.g., *pencil-ládpiz*). The cognates were selected so that the orthographic and phonological similarity of their lexical form in each language varied orthogonally. Cognate naming latencies were influenced by the cross-language match of the orthographic and phonological codes. When the orthographic forms were similar in the two languages, naming latencies were slowed by dissimilar phonology, providing evidence for feed-forward activation from orthography to phonology across languages. When the orthographic forms were dissimilar, the effects of the corresponding phonological match were not statistically reliable. The results suggest that lexical access is non-selective across bilinguals' two languages, and that the degree of consistency between orthographic and phonological codes influences the manner in which cross-language competition is manifest. Findings are discussed in terms of feed-forward and feed-backward activation dynamics across languages.

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A central concern in the psycholinguistic study of bilingualism has been the nature with which bilinguals activate lexical representations from both of their languages when reading or listening to a single language alone. There is now compelling evidence that even when bilinguals are exposed to only one language, they cannot avoid activating lexical information of both of their languages (Brysbaert, 1998; Dijkstra & Van Heuven, 1998; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998; Marian & Spivey, 2003; Van Heuven, Dijkstra, & Grainger, 1998). The brief parallel activity of both languages during word recognition is counterintuitive to bilinguals who are not consciously aware of activating aspects of the communicatively non-relevant language.

Given the evidence for non-selective bilingual lexical activation, the remaining issue is to specify the nature of the lexical codes that become active (e.g., orthographic, phonological, and/or semantic) and how the nature of this activation might vary as a function of the linguistic task and context. For example, in the monolingual domain, many studies have attempted to determine the extent to which phonological codes *within a language* are automatically activated during visual word identification. These studies have provided evidence that phonological codes do indeed become active and influence the visual identification of words (Glushko, 1979; Perfetti & Bell, 1991; Van Orden, 1987). There is also evidence that visual word identification is further influenced by the consistency of mappings between orthographic and phonological codes. When an orthographic code (e.g., *lead*) maps on to multiple phonological codes (e.g., [lid] and [lɛd]), feed-forward activation from those competing codes inhibits performance (Gottlob, Goldinger, Stone, & Van Orden, 1999; Hino, Lupker & Pexman, 2002; Stone, Vanhoy, & Van Orden, 1997). These studies were critical in demonstrating that, even in orthographically based tasks, phonological codes are activated and influence performance. Similarly, when a phonological code (e.g., [meɪd]) maps onto multiple orthographic codes (e.g., *maid, made*), feed-*backward* activation from those competing codes inhibits performance (Pexman, Lupker, & Jared, 2001; Pexman, Lupker, & Reggin, 2002; Stone et al., 1997). In the present study we asked whether similar orthographic to phonological dynamics occur *across languages.* More specifically, we examined whether the processing of cognates with a high degree of cross-language orthographic overlap across languages (e.g., *piano, base*), would be influenced by the corresponding cross-language match in phonology.

As in the monolingual domain, most research on bilingual word recognition has focused on orthographic processing. Recently there have been a number of studies that have examined cross-language activation in tasks such as word naming, which require selection of the full phonological code in order to produce the appropriate response (Jared & Kroll, 2001;

Jared & Szucs, 2002). In these experiments, cross-language phonological interference was observed; however, only after the non-target language was deliberately activated. In the present experiment we further examined the degree of phonological activation without the deliberate activation of the non-target language. Here we demonstrate that the consistency of the mappings between the orthographic and phonological codes across the bilingual's two languages influence word naming performance. To our knowledge, this study is the first to test for effects of feed-forward and feed-backward activation across languages. Before discussing the present experiment in more detail, we first briefly summarise previous research on cross-language activation of orthography and phonology in bilingual word recognition.

Although the evidence for language non-selectivity in lexical access has been supported by a range of results on word recognition and production, demonstrating parallel activation of both of the bilingual's languages does not, in and of itself, specify the nature of the information that is available. Recent studies have examined the contribution of orthographic, phonological, and semantic codes. Evidence for the cross-language activation of orthographic codes has been particularly robust and frequently reported (e.g., Altenberg & Cairns, 1983; De Groot, Delmar, & Lupker, 2000; Dijkstra, De Bruijn, Schriefers, & Ten Brinke, 2000; Van Heuven, Dijkstra, & Grainger, 1998). Across a variety of tasks, word recognition performance has been shown to be affected by the presence of orthographically identical words from the non-target language such as interlingual homographs, words that share form but not meaning across languages (e.g., Beauvillain & Grainger, 1987; Dijkstra et al., 1998) and cognates, words that share both form and meaning across languages (e.g., Dijkstra et al., 1999; Lemhöfer, Dijkstra, & Michel, 2004). If bilinguals are able to function in one language alone, then their performance should resemble that of monolinguals, with little difference between words that are language ambiguous and those that are not. What is striking about the results that have been reported is not only that bilinguals are sensitive to cross-language ambiguity, but that their performance does not appear to depend on the deliberate instruction or expectation to use both languages. For example, Van Hell and Dijkstra (2002) showed that even when Dutch-English bilinguals performed lexical decision in their native and dominant language, Dutch, with no knowledge that English or any other language was relevant to the task, they were faster to judge cognates than unambiguous controls. Thus, the expectation to use another language is not a requirement for observing the consequences of the non-target language and for relatively proficient bilinguals, cross-language effects can be obtained even from the L2 to the L1.

Non-selective activation of orthographic codes has also been observed when there is only partial orthographic overlap, as in the case of cross-language neighbours [e.g., *gato* (meaning "cat")/*gate* in Spanish and English]. Although effects of neighbourhood density have been repeatedly observed within language (see Andrews, 1997, for a review), Van Heuven et al. (1998) showed that bilingual word recognition is influenced not only by the number of orthographic neighbours in the target language, but also by neighbourhood density in the non-target language.

Recent studies have extended the results on cross-language activation of orthographic codes to phonology as well. In a masked phonological priming study, Brysbaert, Van Dyck, and Van de Poel (1999) found that Dutch-French bilinguals could more accurately identify a French word if it was preceded by a Dutch homophonic prime [e.g., *wie* ("who")/*oui* ("yes")]. It may not be surprising to observe the effects of cross-language phonology in languages such as Dutch and French that share the same alphabet, but it is striking that these interactions appear to occur even in the absence a similar orthographic code. Gollan, Forster, and Frost (1997) observed masked translation priming for cognates in Hebrew and English, suggesting that the phonology of both languages is active even in the absence of orthographic overlap.

To investigate the interaction of orthographic and phonological codes in bilingual word recognition, Dijkstra et al. (1999) examined lexical decision performance for words that varied in their orthographic and phonological similarity in Dutch and English. The critical items consisted of a set of English words that varied according to the degree with which they shared orthography, phonology, semantics, or some combination of the three codes with words in Dutch. They reported evidence that both phonological and orthographic codes were active in the non-target language even when the task was performed in one language alone. Furthermore, the activation of these codes appeared to have differential effects on processing. Dijkstra et al. found that recognition latencies for words that shared either orthography or a combination of orthography and semantics (e.g., *film, chaos*) were facilitated. However, when words shared phonology alone [e.g., *cow*/*kou* (meaning "cold" in Dutch)], recognition latencies were delayed relative to controls. They argued that the differential effects of phonology and orthography could be understood by recognising that while it is possible to find words across languages that share identical orthography, it is almost never the case that the same type of identical overlap exists for the phonology. Thus two distinct phonological codes appear to be activated and to compete for selection.

Further evidence of cross-language activation of phonology was reported by Jared and Szucs (2002) in a study in which bilinguals named words in both L1 and L2. French-English and English-French bilinguals named words in three blocks of trials; two in English only and a third in French separating the two English blocks. The English words included heterophonic homographs of French words [e.g., *pain* (meaning "bread")] and unambiguous controls (e.g., *perch*). If phonological representations from the non-target language are active, then competition between alternative pronunciations of the same word should delay naming for the heterophonic homographs. The French naming block was included to test the hypothesis that the requirement to produce in the non-target language would further increase this cost. When bilinguals named words in their weaker L2, there were increased latencies for the interlingual homographs, both before and after the French naming block. When bilinguals named words in their more dominant L1, English, there was once again a cost for naming the homographs, however the effects were observed only after the L2 was activated by a block of French word naming. These results provide support for the claim that bilinguals simultaneously activate phonological codes from both of their languages, even when reading in their more dominant language. However, the presence of effects in L1 depends on how recently the L2 has been activated.

Using a similar paradigm, Jared and Kroll (2001) asked whether analogous cross-language effects could be obtained for sublexical phonology in reading. English-French bilinguals named English words that either had word body enemies in French (e.g., *pain*), English (e.g., *steak*) or no enemies in either French or English (e.g., *stump*). It is well known that in English, naming latencies are slower for words with inconsistent word bodies (e.g., Jared, McRae, & Seidenberg, 1990). If bilinguals activate spelling-sound correspondences from both of their languages, then they should be slower to name words that have word body enemies in either English or French. The pattern of results closely paralleled those reported by Jared and Szucs (2002). English-French bilinguals naming in English took longer to name words that had word-body enemies in French. However, this cost was observed only following the French word naming block. Taken together, these studies suggest that effects of cross-language activation are constrained when production is in the L1 and lexical selection is required by the task.

The present study extended the examination of cross-language interactions by asking whether the nature of phonological activation is modulated by the degree of orthographic overlap. Furthermore, we examined how orthographic-phonological interactions differ as a function of the language of production. In the studies reported by Jared and colleagues the language of production was held constant while the participants' bilingualism varied. Here we provided a complementary approach in which the participants' bilingualism was held constant (all participants were English-Spanish bilinguals) while the language of production was varied.

Like Dijkstra et al. (1999), we used cognates as the critical materials. Unlike interlingual neighbours, cognates are representative words in each of the bilingual's languages. Furthermore, they tend to be similar in frequency (see Dijkstra et al., 1998) and are not limited to four and five letter words. The main question in the present study was how the requirement to name a cognate reflects the cross-language activation of orthographic and phonological codes. Cognates vary in the degree to which they are orthographically and phonologically similar. To illustrate, the English-Spanish cognate *base* maps on to very distinct pronunciations ([beɪs] vs. ['ba.se]), whereas *piano* is pronounced much more similarly (['pjæ.noʊ]/['pja.no]). In the present study we demonstrate that when bilinguals are required to fully specify a word's phonology, production latencies are influenced by these seemingly subtle differences in the consistency of the orthographic-to-phonological mappings across languages.

The critical materials consisted of four sets of cognates whose orthographic and phonological similarity (either more similar [+] or less similar [−]) across the two languages were orthogonally manipulated. This produced the following conditions: +O+P, +O−P, −O+P, −O−P (see Table 1). Thus, the cognate pair *piano/piano* was classified as a +O+P cognate because of its high orthographic and phonological similarity, whereas the cognate pair *mark/marca* ([maɹk] vs. ['mar.ka]), was classified as a −O−P pair due to its distinct orthographic and phonological codes (see below for a description of how these classifications were obtained). By including an orthogonal manipulation of O and P consistency we were able to test for both feed-forward activation from orthography to phonology across languages, as well as feed-backward activation from phonology to orthography. If there is feed-forward activation across languages from orthogra-

TABLE 1
An illustration of critical materials and their orthographic and phonological properties

	Cognates		*Similarity ratings*		*Length*[a]		
Type	*Spanish*	*English*	*Orthographic*	*Phonological*	*Spanish*	*English*	*Frequency*[b]
+O+P ($N=28$)	piano	piano	.91	5.3	6.3	6.1	44
+O−P ($N=31$)	base	base	.89	2.8	6.2	5.9	48
−O+P ($N=19$)	tren	train	.50	5.0	6.2	5.9	46
−O−P ($N=26$)	marca	mark	.54	2.8	6.4	5.9	48
	Non-cognates						
------	lápiz	pencil	------	------	6.5	6.1	49

[a]Based on number of letters.
[b]Based on Francis & Kucera, 1982.

phy to phonology, then one would predict that cognates with a high degree of orthographic similarity across languages that map on to two, highly distinct phonological representations (e.g., *base*) would take longer to process than cognates for which both codes are highly consistent across languages. If there is feed-backward activation across languages from phonology to orthography, then one should observe a cost for cognates with a high degree of phonological similarity that map on to different orthographic representations (e.g., *train* [tɹeɪn]/*tren* [tɾen]). Thus, we predicted that naming performance would be inhibited when highly similar lexical codes (either orthographic or phonological) map on to multiple, distinct codes across languages.

METHOD

Participants

The bilingual participants consisted of 18 students enrolled in advanced Spanish courses at the Pennsylvania State University. Participants were paid for their participation. To determine language dominance, a mean rating was computed for each participant based on their self-assessed language proficiency in English and Spanish. The language with the highest mean rating was identified as the dominant language. If both languages were rated equally, English was identified as the dominant language on the assumption that these individuals were immersed in an English speaking environment. Using this procedure, two native speakers of Spanish were identified as English dominant. The remaining 16 participants were native English speakers also dominant in English.

Materials

A total of 240 Spanish words and their English translations comprised the experimental materials. Half of the words were initially considered by the experimenters to be cognates across the two languages and half to be noncognates. A measure of the orthographic similarity of the cognates was computed using the algorithm described by Van Orden (1987). This algorithm provides an objective measure of the graphemic similarity of word pairs and has been used extensively in prior research (Sparrow & Miellet, 2002; Van Orden, 1987; Van Orden, Johnston, & Hale, 1988; Yates, Locker, & Simpson, 2003). The orthographic similarity score derived from this algorithm is based on a ratio between the graphemic similarity of the word pair relative to the graphemic similarity of the member word to itself. Graphemic similarity in turn is computed based on a formula that assigns different weights to: (1) the number of pairs of adjacent letters shared in order, (2) the number of pairs of adjacent letters shared in reversed order, (3) the number of single letters shared, (4) the average word length of the two words, (5) the ratio of the word length of the shorter word to the longer, and (6) whether initial and final letter positions are shared. Thus, a pair such as *echo*-*eco* receives a higher similarity score relative to *cube*-*cubo* since the latter does not have shared letters in the final position. Furthermore, the orthographic similarity score is directly proportional to the length of the words in the pair such that longer words receive higher scores. In this way a pair such as *triangle*-*triángulo* would receive a higher score relative to *ángel*-*angel.* In computing graphemic similarity across languages, the presence of a diacritical marking in Spanish rendered an otherwise identical letter as distinct. The average orthographic similarity for the 120 cognate pairs was .71. Cognate pairs whose orthographic similarity was .70 or greater were classified as being more similar and pairs with a similarity score of less than .70 were classified as being less similar. Note that because this classification was performed within translation pairs designated as cognates, even pairs categorised as relatively dissimilar for this purpose were more similar than non-cognate translations.

To obtain a measure of subjective phonological similarity of the cognates, we recorded two fluent bilingual speakers, each of whom spoke one member of the cognate pair. Half of the items were recorded with the English word spoken first and the other half were recorded with the Spanish word spoken first. An independent group of 29 monolingual English speakers then rated the perceived phonological similarity of the cognates on a scale from 1 to 7, where 1 was not at all similar and 7 was highly similar. We deemed it most appropriate to use the ratings for English monolinguals since the participants were native or dominant English speakers and previous research has demonstrated that even highly proficient bilinguals phonetically perceive their L2 in a non-native way (Pallier, Colomé, & Sebastián-Gallés, 2001). We used these measures to create four conditions in which the orthographic and phonological similarity of the cognates was varied orthogonally. Of the initial 120 cognate pairs, we sampled 104 pairs to achieve a set of cognates matched on the lexical properties of word frequency (Francis & Kučera, 1982) and word length in number of letters (see Table 1). A similar subset of 104 non-cognates was matched to the critical cognate pairs. The remaining 16 cognates and 16 non-cognates were included in the experiment as filler trials. The complete set of materials, including the similarity measures for each cognate pair, is given in the Appendix.

Design and procedure

English-Spanish bilingual participants named words in two blocks of trials, one in Spanish and one in English. The cognates and non-cognates were randomly mixed. The order of the blocks was counterbalanced and two versions of the materials were constructed such that no individual ever named a word in one language and also its translation in the other language. In a control condition, 15 monolingual participants named all cognates and non-cognates in a single English naming block.

Participants were presented with words to name aloud, one at a time, in the centre of a computer screen. Spoken responses were tape recorded for later coding of accuracy. Participants were instructed to respond quickly and accurately and to guess if they did not know a word's pronunciation. Prior to the presentation of each word, a fixation cross was presented until the participant initiated the beginning of the trial by pressing a key on the computer keyboard. The words were presented until the participant made a verbal response. Reaction time (RT) was recorded in milliseconds from the onset of stimulus presentation to the onset of articulation. Participants were given 20 practice trials prior to the critical blocks.

After completing the naming task participants completed a paper and pencil language history questionnaire. In addition to reporting their specific language experiences (e.g., native language, age of L2 acquisition) participants rated their proficiency in both English and Spanish along four dimensions (reading, writing, speaking, speech comprehension) on a scale of 1–10, with 10 indicating highest proficiency.

RESULTS AND DISCUSSION

Language history data

The participants were relatively early learners of Spanish who had been studying the language for an average of 13 years. Their self-rated proficiency on each of the sub-skills is given in Table 2. These data indicate that although they considered themselves relatively proficient in Spanish (mean rating = 8.5), they were clearly more dominant in English (mean rating = 9.8).

Analyses of variance were performed on naming latencies and mean percent error scores using both subject and item means as random factors. In the subject analyses, both language and cognate status were treated as within-subjects variables. In the item analyses, language was treated as a within-items variable and cognate status was treated as a between-items variable. Mean naming latencies (in milliseconds) and percent error rates for naming cognates and non-cognates in English (L1) and Spanish (L2) are reported in Table 3. Data from 6% of the trials were excluded due to microphone failure. Naming latencies that exceeded 2000 ms were considered outliers and excluded from the analyses. For each participant, naming trials with an RT that exceeded 2.5 standard deviations above or below the mean

TABLE 2
Mean self-ratings of native language (L1) and second language (L2) proficiency based on a 10-point scale

	Language	
Skill	*English (L1)*	*Spanish (L2)*
Reading	9.8	8.5
Speaking	9.8	8.5
Writing	9.8	7.8
Listening	9.9	9.0

were also excluded. All analyses were performed on the subset of 208 critical items and fillers were not included.

Latency data

A two-way ANOVA was performed to determine whether there was an overall effect of language and cognate status (i.e., cognate vs. non-cognate). There was significant effect of language, $F_1(1, 17) = 17.63$, $p < .05$, $MSE = 12597.28$; $F_2(1, 206) = 328.01$, $p < .05$, $MSE = 4016.29$, reflecting longer naming latencies in L2 than L1. This main effect was qualified by an interaction with cognate status in the subject analysis, $F_1(1, 17) = 4.85$, $p < .05$, $MSE = 386.6$. Paired *t*-tests performed with a Bonferroni correction showed that cognates were named *slower* than non-cognates in L1, $t_1(1, 17) = -6.10$, $p < .05$, this difference in latency was not observed in L2, $t_1(1, 17) = 0.17$, $p > .05$. The longer cognate naming latency was likely due to the competitive activation dynamics between orthographic and phonological codes of the cognates across languages. These competitive dynamics are analysed and discussed in more detail below.

Three-way (language × orthographic similarity × phonological similarity) ANOVAs were performed on the mean naming latencies and percent error rates for the cognates in each of the four cognate conditions across the two

TABLE 3
Mean naming latencies (in milliseconds) and percent error rates (in parentheses) for cognates and non-cognates in L1 (English) and L2 (Spanish)

Cognate status	*English (L1)*	*Spanish (L2)*
Non-cognate controls	490 (0.4%)	611 (1.7%)
Cognates	509 (0.6%)	610 (2.6%)

languages. The mean naming latencies and error rates for the four cognate conditions are graphed separately by language (see Figures 1–4).

In the analysis of naming latencies, the main effect of language was significant, $F_1(1, 17) = 16.35$, $p < .05$, $MSE = 22399.95$; $F_2(1, 100) = 163.71$, $p < .05$, $MSE = 3370.15$ indicating longer latencies for cognates named in Spanish relative to those named in English. More central to the research question addressed in the present study was the significant interaction between the orthographic and phonological similarity of the cognates, $F_1(1, 17) = 8.14$, $p < .05$, $MSE = 2398.30$; $F_2(1, 100) = 8.87$, $p < .05$, $MSE = 5745.47$. Follow-up *t*-tests with a Bonferroni correction indicated that naming latencies for cognates with a high degree of orthographic similarity (e.g., *piano, base*) were slowed when the corresponding phonology was more distinct (e.g., *base* [beɪs] vs. ['ba.se]), $t_1(1, 35) = 5.27$, $p < .05$; $t_2(1, 116) = 2.57$, $p < .05$. Thus, naming latencies were delayed when a highly similar orthographic representation mapped on to two, more distinct phonological representations (see Figures 1 and 2). This provides evidence for feed-forward activation from orthography to phonology across languages.

When the orthographic representations of the cognates were more distinct (e.g., *train/tren*, *mark/marca*), there was not a significant difference in latency associated with differences in phonological match (all *p*

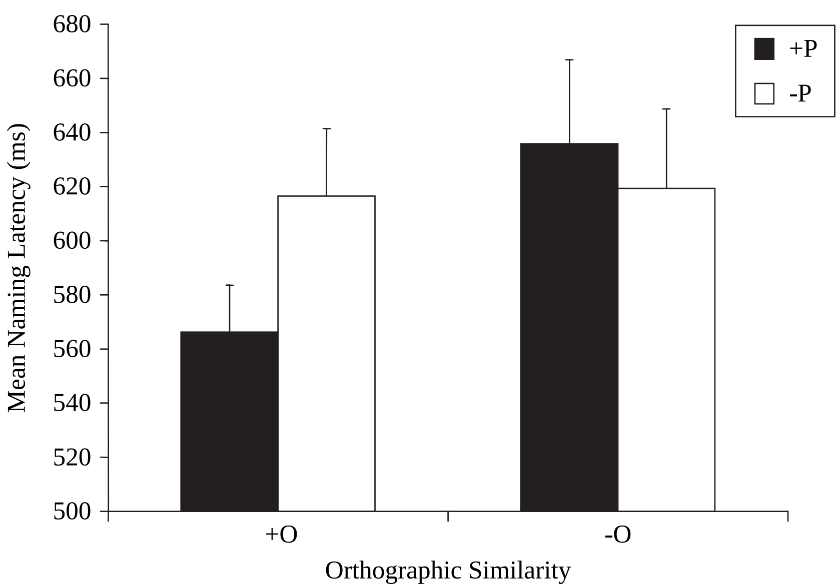

Figure 1. Mean Spanish (L2) word naming latencies for the four O – P cognate conditions.

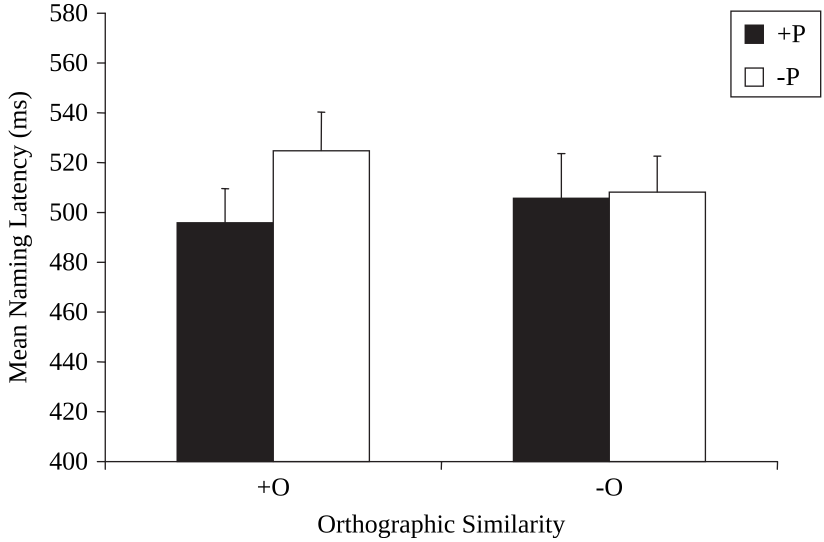

Figure 2. Mean English (L1) word naming latencies for the four O – P cognate conditions.

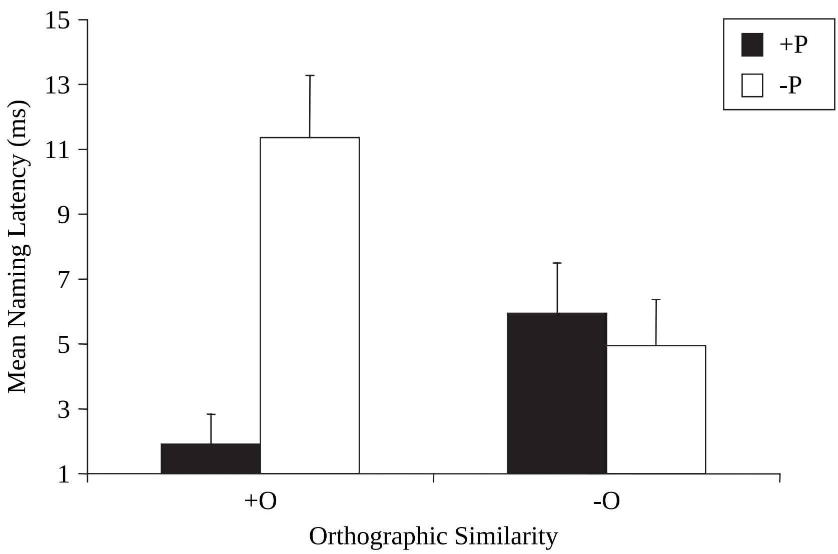

Figure 3. Mean percent error rates for naming Spanish (L2) words in the four O – P cognate conditions.

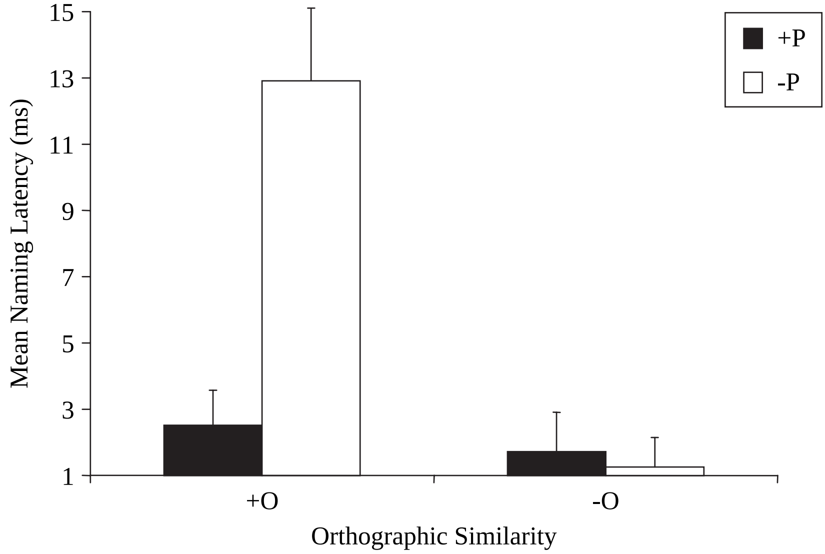

Figure 4. Mean percent error rates for naming English (L1) words in the four O −P cognate conditions.

values <.05). Thus, unlike the +O cognates, naming responses for the −O cognates were not delayed by competing phonological codes. This was likely due to the fact that the orthographic representation was actually presented to the participants (via visual presentation), allowing for stronger feed-forward activation from orthography to the two, competing phonological representations within the +O−P condition. In the −O+P condition, on the other hand, the highly similar phonological code was not actually presented to the participant, resulting in weaker feed-backward activation. Furthermore, feed-backward activation to the competing orthographic representation from the non-target language may have been diminished due to the need for activation to spread across languages.

It is interesting to note that the interaction between orthographic similarity and phonological similarity was further qualified by a three-way interaction with language, which was significant by subjects, $F_1(1, 17) = 5.77$, $p < .05$, $MSE = 635.69$, but not by items, $F_2(l, 100) = 2.11$, $p = .15$, $MSE = 3370.15$. This was indicative of the larger magnitude in the O −P interaction in L2 relative to L1. The observed difference in the magnitude across languages was likely due to the corresponding differences in language proficiency. Lexical representations in the L2, even for relatively proficient bilinguals, are weaker than those in the LI, thus lengthening the time in which information becomes activated and increasing the likelihood that competitive dynamics will influence processing (see Kroll, Tokowicz, Michael, and Dufour, 2002, for a similar result in a word naming task).

Error data

A two-way ANOVA (language × cognate status) revealed a main effect of language, reflecting increased error rates in L2 relative to L1, which was significant by subjects, $F_1(1, 17) = 10.55$, $p < .05$, $MSE = 4.6$, but not by items, $F_2(1, 206) = 3.10$, $p > .05$, $MSE = 55.5$. There was no effect of cognate status on error rates nor did this factor interact with language in either the subject or item analyses.

A three way (language × orthographic similarity × phonological similarity) ANOVA was performed on the mean percentage of errors in the four cognate conditions across the two languages. The main effect of language was not significant by subjects, $F_1(1, 17) = 0.91$, $p > .05$, $MSE = 82.53$; but was significant by items, $F_2(1, 100) = 4.32$, $p < .05$, $MSE = 68.12$. More critically, there was an interaction between orthographic similarity and phonological similarity of the cognates, significant by subjects, $F_1(1, 17) = 57.37$, $p < .05$, $MSE = 17.83$, but not by items, $F_2(1, 100) = 0.71$, $p > .05$, $MSE = 66.70$. Follow-up *t*-tests with a Bonferroni correction indicated that cognates with a high degree of orthographic similarity (e.g., *piano, base*) were named less accurately when the corresponding phonology was more distinct (e.g., *base*) than when it was more similar (e.g., *piano*), $t_1(1, 35) = 6.64$, $p < .05$ (see Figures 3 and 4). Thus, naming accuracy was facilitated only when there was a consistent mapping from orthography to phonology, providing converging evidence for feed-forward activation from orthography to phonology across languages. As with the naming latency data, there was not a significant difference in latency associated with differences in phonological match when the orthographic representations of the cognates were more distinct (e.g., *train/tren, mark/marca*) (all p values $< .05$).

Monolingual comparison

An important question in the interpretation of the present results is the degree to which the observed effects are due to the bilingualism of the participants rather than to aspects of the materials. Although we controlled for lexical factors such as word frequency and length, it was not possible to control for all variables that may influence naming performance across the critical O – P conditions, such as phonological onset. To address this concern, 15 native English monolingual speakers named the cognates and non-cognate controls in English only. For these participants, the O – P distinctions should have no consequence. Each monolingual also completed a language history questionnaire. Analysis of these ratings confirmed the much lower Spanish proficiency of the monolinguals (mean rating $=2.3$) relative to the bilinguals, $F_1(1, 17)=305.6$, $p<.05$. Most critically, an analysis of the English naming latencies for the monolinguals across the four O − P conditions revealed no significant main effects or interactions, $F_1(1, 14)=0.82$, $p>.05$; $F_2(1, 100)=0.14$, $p>.05$.

GENERAL DISCUSSION

The present results demonstrate that bilingual lexical processing is influenced by the consistency of the orthographic to phonological mappings across languages. Specifically, the naming of cognates with high orthographic similarity across languages was slower and more error prone when the corresponding phonological codes were more distinct relative to when the corresponding phonological codes were highly similar. This provided evidence for feed-forward activation from orthography to phonology across languages. Similar effects of feed-forward activation have been observed within a single language (e.g., Gottlob et al., 1999; Stone et al., 1997), and the present study provides the first extension of these dynamics across languages. It is particularly striking that such dynamics were observed in both the weaker L2 as well as in the more dominant, L1. Since the L1 is characterised by more robust lexical representations and faster processing, one might assume that the consistency of an L1 orthographic code with an L2 phonological code would not be of any consequence. Furthermore, it is interesting to consider the effects L2 language proficiency might have on the manifestation of these dynamics. The bilingual participants in the present study were all native English speakers, but they rated their Spanish proficiency fairly high. It is possible that effects of L2 phonology are more likely to be observed in proficient bilinguals who can rapidly activate lexical codes from their second language.

Evidence for cross-language feed-backward activation, from phonology to orthography was not as strong in the present study. Although the trend in naming latencies and error rates across both languages was in the direction predicted by feed-backward mechanisms, the differences were not statistically reliable. More specifically, naming latencies were *slower* when there was a high degree of phonological overlap (e.g., *train/tren*) relative to when the phonological codes were more distinct (e.g., *mark/marca*) (see Figure 3). This suggests that naming latencies in the −O+P condition (e.g., *train/tren*) might have been delayed due to feed-backward activation from the highly similar phonological code to the more distinct, and therefore competing cross-language orthographic representations. These dynamics are similar to those that have been observed in previous monolingual studies in which processing of an ambiguous phonological code (e.g., [meɪd]) is inhibited by competing orthographic representations.

There are several factors that may have contributed to the absence of a strong effect from phonology to orthography. First, effects of feed-backward activation may be more difficult to observe in tasks in which word stimuli are visually presented. It should be noted that several monolingual studies have observed feed-backward effects in visual tasks (e.g., Pexman et al., 2001; Pexman et al., 2002; Stone et al., 1997). However, effects resulting from such dynamics may be further dampened when activation must spread across different languages. Thus, the major findings from the present study (strong effects of cross language feedforward activation/no effects of feed-backward activation) place important constraints on cross-language non-selectivity. More specifically, the present results suggest that the degree to which competing lexical codes become activated across languages depends critically on the direction of the flow of activation (i.e., feed-forward versus feed-backward) and whether the activation must flow across multiple languages.

As in the present study, Gottlob et al. (1999) found that words that mapped on to two phonological representations (e.g., *lead*) were delayed in a naming task. They explained this effect of phonological ambiguity within a resonance approach to lexical access. According to this view, word recognition occurs through resonance, which is achieved when feedforward and -backward activation between orthographic, phonological, and semantics codes is mutually reinforcing. Thus, lexical processing will be delayed whenever there is a mismatch between the O – P – S codes.

The resonance framework can be extended to the bilingual case to understand why naming latencies were a function of the cross-language O – P match. In the +O conditions, like the example of *lead* above in the Gottlob et al. (1999) study, the orthographic input is ambiguous. In this case, the high degree of orthographic overlap will lead to activation of the phonological codes of both language versions of the cognate and thereby increase competition and delay naming. When the orthographic codes of the cognate pair are more distinct (i.e., –O), however, there is less activation overall of the non-target lexical representation of the cognate. The degree of activation is potentially increased via highly similar phonological codes, which can produce feed-backward activation of the orthographic representation from the other language, thereby inhibiting performance (see Dijkstra & Van Heuven, 2002, for a related proposal in the BIA+ model, and Thomas & Van Heuven, 2005, for a similar mechanism within the SOPHIA model). The differential magnitude of cross language activation as a function of the similarity of the orthographic input is compatible with recent work demonstrating that under some circumstances language-specific orthographic cues can be used in word recognition (Vaid & Frenck-Mestre, 2002, but see Thomas & Allport, 2000).

The present results are also compatible with previous findings on cross-language activation of lexical codes. Like Dijkstra et al. (1999) we demonstrated that the facilitatory effects associated with lexical overlap across languages can be reduced or turned into inhibition when there is not a consistent mapping across all codes. These findings extend previous demonstrations of non-selectivity across a bilingual's two languages in that they demonstrate that the dynamics of cross-language interaction appear to be modulated by the nature of the activated codes, the relative dominance of the two languages, and the requirements of the task. In particular, factors that affect the time course of processing may determine the degree to which cross language influences are apparent in bilingual word recognition. In future research it will be critical to understand whether and how these interactions are constrained by contextual support in situations that may better reflect the real-life language experience of bilinguals.

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APPENDIX
Stimulus set

	English			Spanish		Similarity ratings	
Condition	*Word*	*Length*[a]	*Frequency*[b]	*Word*	*Length*	*O*[c]	p[d]
+O+P	actor	5	40	actor	5	1.0	6.3
+O+P	band	4	64	banda	5	0.7	4.3
+O+P	calm	4	7	calma	5	0.7	5.1
+O+P	canal	5	4	canal	5	1.0	5.5
+O+P	cereal	6	21	cereal	6	1.0	4.3
+O+P	correct	7	40	correcto	8	0.8	5.6
+O+P	crystal	7	31	cristal	7	0.9	6.4
+O+p	director	8	121	director	8	1.0	4.0
+O+P	echo	4	15	eco	3	0.8	6.7
+O+P	error	5	80	error	5	1.0	4.9
+O+P	final	5	11	final	5	1.0	4.4
+O+P	formal	6	48	formal	6	1.0	6.1
+O+P	hospital	8	130	hospital	8	1.0	5.5
+O+P	insect	6	37	insecto	7	0.8	5.5
+O+P	inspector	9	15	inspector	9	1.0	6.4
+O+P	local	5	9	local	5	1.0	5.7
+O+P	metal	5	68	metal	5	1.0	5.7
+O+P	mortal	6	2	mortal	6	1.0	4.8
+O+P	perfect	7	58	perfecto	8	0.8	5.9
+O+P	piano	5	39	piano	5	1.0	7.0
+O+P	poet	4	144	poeta	5	0.7	4.3
+O+P	professor	9	78	profesor	8	1.0	6.4
+O+P	reform	6	41	reforma	7	0.8	4.0
+O+P	romantic	8	32	romántico	9	0.7	5.6
+O+P	superior	8	45	superior	8	1.0	4.6
+O+P	terror	6	26	terror	6	1.0	4.1
+O+P	tractor	7	31	tractor	7	1.0	5.6
+O+P	triple	6	4	triple	6	1.0	4.0
+O −P	acre	4	54	acre	4	1.0	2.0
+O −P	air	3	260	aire	4	0.7	1.7
+O −P	audible	7	4	audible	7	1.0	2.2
+O −P	base	4	102	base	4	1.0	2.0
+O −P	benign	6	1	benigno	7	0.8	2.0
+O −P	cable	5	6	cable	5	1.0	3.5
+O −P	canoe	5	8	canoa	5	0.7	3.1
+O −P	casual	6	22	casual	6	1.0	3.4
+O −P	debate	6	36	debate	6	1.0	3.2
+O −P	diagram	7	18	diagrama	8	0.8	3.6
+O −P	diet	4	24	dieta	5	0.7	3.0
+O −P	eligible	8	14	eligible	8	0.9	1.9
+O −P	escape	6	24	escape	6	1.0	3.1
−O −P	false	5	28	falso	5	0.7	3.9
+O −P	genuine	7	34	genuino	7	0.7	3.5

	English			Spanish		Similarity ratings	
Condition	*Word*	*Length*[a]	*Frequency*[b]	*Word*	*Length*	*O*[c]	p[d]
+O −P	gradual	7	16	gradual	7	1.0	3.5
+O −P	grave	5	19	grave	5	1.0	3.6
+O −P	horrible	8	15	horrible	8	1.0	3.3
+O −P	image	5	156	imagen	6	0.8	2.5
+O −P	incurable	9	2	incurable	9	1.0	2.9
+O −P	judicial	8	16	judicial	8	1.0	1.8
+O −P	motor	5	108	motor	5	1.0	1.9
+O −P	notable	7	20	notable	7	1.0	3.5
+O −P	palm	5	30	palma	6	0.7	3.4
+O −P	radio	5	126	radio	5	1.0	3.6
+O −P	real	4	241	real	4	1.0	2.9
+O −P	severe	6	38	severo	6	0.7	3.0
+O −P	tiger	5	9	tigre	5	0.8	3.3
+O −P	triangle	8	5	triángulo	9	0.7	2.4
+O −P	vacant	6	11	vacante	7	0.8	2.4
+O −P	visible	7	34	visible	7	1.0	2.1
−O+P	acid	4	17	ácido	5	0.3	5.2
−O+P	camera	6	46	cámara	6	0.4	5.8
−O+P	compass	7	12	compás	6	0.6	4.0
−O+P	credit	6	67	crédito	7	0.6	5.1
−O+P	deficit	7	13	déficit	7	0.6	5.3
−O+P	dollar	6	144	dólar	5	0.5	5.4
−O+P	fruit	5	49	fruta	5	0.6	5.0
−O+P	guitar	6	22	guitarra	8	0.7	5.3
−O+P	merit	5	38	mérito	6	0.3	4.5
−O+P	notion	6	57	noción	6	0.5	4.6
−O+P	panic	5	20	pánico	6	0.3	4.7
−O+P	plastic	7	56	plástico	8	0.6	5.2
−O+P	symbol	6	90	símbolo	7	0.4	6.1
−O+P	solid	5	20	sólido	6	0.3	*4.5*
−O+P	sweater	7	18	suéter	6	0.4	6.8
−O+P	train	5	86	tren	4	0.5	4.8
−O+P	version	7	62	versión	7	0.7	4.0
−O+P	victim	6	50	víctima	7	0.6	4.3
−O+P	violin	6	13	violín	6	0.6	4.6
−O −P	agility	7	3	agilidad	8	0.7	1.7
−O −P	angel	5	45	ángel	5	0.6	3.0
−O −P	bank	4	110	banco	5	0.6	3.3
−O −P	circle	6	91	círculo	7	0.2	2.0
−O −P	cube	4	5	cubo	4	0.7	2.9
−O −P	evasion	7	2	evasión	7	0.7	3.8
−O −P	fault	5	29	falta	5	0.6	3.9
−O −P	guide	5	25	guía	4	0.5	1.5
−O −P	helicoptor	10	1	helicóptero	11	0.6	3.0

	English			Spanish		Similarity ratings	
Condition	Word	Length[a]	Frequency[b]	Word	Length	O[c]	p[d]
−O −P	hero	4	70	héroe	5	0.2	2.1
−O −P	ignition	8	5	ignación	8	0.5	3.2
−O −P	just	4	21	justo	5	0.7	2.0
−O −P	legion	6	8	legión	6	0.6	2.2
−O −P	logic	5	17	lógica	6	0.3	2.5
−O −P	machine	7	157	máquina	7	0.2	2.3
−O −P	mark	4	50	marca	5	0.6	3.9
−O −P	mission	7	94	misión	6	0.6	2.3
−O −P	muscle	6	73	músculo	7	0.2	3.2
−O −P	nature	6	198	naturaleza	10	0.6	3.0
−O −P	ocean	5	37	océano	6	0.6	2.9
−O −P	oxygen	6	47	oxígeno	7	0.6	2.2
−O −P	pension	7	20	pensión	7	0.7	3.8
−O −P	pure	4	56	puro	4	0.7	2.5
−O −P	terrific	8	5	terrífico	9	0.7	3.8
−O −P	ultimate	8	59	último	6	0.6	3.8
−O −P	vivid	5	25	vívido	6	0.6	3.2
Non-cognate	address	7	78	dirección	9	NA	NA
Non-cognate	advice	6	52	consejo	7	NA	NA
Non-cognate	avocado	7	11	avocado	8	NA	NA
Non-cognate	arrival	7	26	llegada	6	NA	NA
Non-cognate	attempt	7	72	intento	8	NA	NA
Non-cognate	beauty	6	77	belleza	6	NA	NA
Non-cognate	beer	4	36	cerveza	7	NA	NA
Non-cognate	blanket	7	39	manta	5	NA	NA
Non-cognate	blessing	8	10	bendición	9	NA	NA
Non-cognate	brick	5	24	ladrillo	7	NA	NA
Non-cognate	bullet	6	49	bala	4	NA	NA
Non-cognate	butter	6	27	mantequilla	10	NA	NA
Non-cognate	candle	6	23	vela	4	NA	NA
Non-cognate	carrot	6	19	zanahoria	9	NA	NA
Non-cognate	chairs	6	23	sillas	5	NA	NA
Non-cognate	cotton	6	36	algodón	7	NA	NA
Non-cognate	danger	6	86	peligro	7	NA	NA
Non-cognate	daughter	8	79	hija	4	NA	NA
Non-cognate	desk	4	65	escritorio	10	NA	NA
Non-cognate	devil	5	32	diablo	6	NA	NA
Non-cognate	dinner	6	9	cena	4	NA	NA
Non-cognate	dress	5	63	vestido	7	NA	NA
Non-cognate	elevator	8	12	ascensor	8	NA	NA
Non-cognate	factory	7	32	fábrica	7	NA	NA
Non-cognate	farmer	6	43	granjero	8	NA	NA
Non-cognate	flower	6	64	flor	4	NA	NA
Non-cognate	forest	6	88	bosque	6	NA	NA

	English			*Spanish*		*Similarity ratings*	
Condition	*Word*	*Length*[a]	*Frequency*[b]	*Word*	*Length*	*O*[c]	p[d]
Non-cognate	fun	3	44	diversión	9	NA	NA
Non-cognate	furniture	9	39	muebles	7	NA	NA
Non-cognate	gathering	9	28	reunión	7	NA	NA
Non-cognate	grass	5	55	hierba	6	NA	NA
Non-cognate	guess	5	77	adivina	7	NA	NA
Non-cognate	hat	3	71	sombrero	8	NA	NA
Non-cognate	hatred	6	20	odio	4	NA	NA
Non-cognate	health	6	105	salud	5	NA	NA
Non-cognate	heaven	6	53	cielo	5	NA	NA
Non-cognate	highway	7	56	carretera	8	NA	NA
Non-cognate	horses	6	68	caballos	7	NA	NA
Non-cognate	hunger	6	17	hambre	6	NA	NA
Non-cognate	inside	6	67	adentro	7	NA	NA
Non-cognate	insight	7	68	entendimiento	13	NA	NA
Non-cognate	kitchen	7	95	cocina	6	NA	NA
Non-cognate	lady	4	64	señora	6	NA	NA
Non-cognate	lawyer	6	43	abogado	7	NA	NA
Non-cognate	loan	4	78	préstamo	8	NA	NA
Non-cognate	lock	4	75	cerradura	8	NA	NA
Non-cognate	loyalty	7	25	lealtad	7	NA	NA
Non-cognate	madness	7	2	locura	7	NA	NA
Non-cognate	mayor	5	47	alcalde	7	NA	NA
Non-cognate	mercy	5	20	piedad	6	NA	NA
Non-cognate	middle	6	47	medio	5	NA	NA
Non-cognate	miracle	7	26	milagro	7	NA	NA
Non-cognate	mirror	6	27	espejo	6	NA	NA
Non-cognate	missile	7	28	proyectil	9	NA	NA
Non-cognate	mistakes	8	16	errores	6	NA	NA
Non-cognate	mouse	5	10	ratón	5	NA	NA
Non-cognate	movie	5	60	película	8	NA	NA
Non-cognate	neddle	6	21	aguja	5	NA	NA
Non-cognate	noise	5	43	ruido	5	NA	NA
Non-cognate	nonsense	8	13	tonterías	9	NA	NA
Non-cognate	pencil	6	38	lápiz	5	NA	NA
Non-cognate	plane	5	138	avión	5	NA	NA
Non-cognate	pride	5	45	orgullo	6	NA	NA
Non-cognate	prize	5	34	premio	6	NA	NA
Non-cognate	pumpkins	8	2	calabazas	9	NA	NA
Non-cognate	rabbit	6	16	conejo	6	NA	NA
Non-cognate	remnant	7	58	resto	5	NA	NA
Non-cognate	repair	6	23	arreglo	7	NA	NA
Non-cognate	school	6	175	escuela	7	NA	NA
Non-cognate	scissors	8	1	tijeras	7	NA	NA
Non-cognate	shame	5	21	vergüenza	9	NA	NA

	English			Spanish		Similarity ratings	
Condition	*Word*	*Length*[a]	*Frequency*[b]	*Word*	*Length*	*O*[c]	p[d]
Non-cognate	sheep	5	24	oveja	5	NA	NA
Non-cognate	shirt	5	29	camisa	6	NA	NA
Non-cognate	shoulder	8	64	hombro	6	NA	NA
Non-cognate	sidewalk	8	26	acera	5	NA	NA
Non-cognate	skirt	5	21	falda	5	NA	NA
Non-cognate	song	4	129	canción	7	NA	NA
Non-cognate	south	6	54	sur	3	NA	NA
Non-cognate	spider	6	2	araña	5	NA	NA
Non-cognate	square	6	143	cuadrado	8	NA	NA
Non-cognate	stone	5	66	piedra	6	NA	NA
Non-cognate	struggle	8	57	lucha	4	NA	NA
Non-cognate	sugar	5	34	azúcar	6	NA	NA
Non-cognate	summer	6	151	verano	6	NA	NA
Non-cognate	supper	6	38	cena	4	NA	NA
Non-cognate	support	7	47	apoyo	5	NA	NA
Non-cognate	sweat	5	22	sudor	5	NA	NA
Non-cognate	thread	6	16	hilo	4	NA	NA
Non-cognate	threat	6	56	amenaza	7	NA	NA
Non-cognate	throat	6	63	garganta	8	NA	NA
Non-cognate	truck	5	80	camión	6	NA	NA
Non-cognate	umbrella	8	11	paraguas	8	NA	NA
Non-cognate	vegetable	9	26	legumbre	8	NA	NA
Non-cognate	village	7	84	aldea	5	NA	NA
Non-cognate	warmth	6	28	calor	5	NA	NA
Non-cognate	watch	5	31	reloj	5	NA	NA
Non-cognate	weakness	8	52	debilidad	9	NA	NA
Non-cognate	welfare	7	53	bienestar	9	NA	NA
Non-cognate	window	6	172	ventana	7	NA	NA
Non-cognate	windows	7	53	ventanas	8	NA	NA
Non-cognate	wrinkle	7	8	arruga	5	NA	NA
Non-cognate	youth	5	71	juventud	8	NA	NA

[a]Based on number of letters
[b]Based on Francis & Kučera, 1982.
[c]Based on Van Orden's (1987) measure of graphemic similarity.
[d]Based on perceived phonological similarity ratings.