HOW MUCH CONTROL DO READERS HAVE OVER PHONOLOGICAL CODING IN VISUAL WORD RECOGNITION?

EVIDENCE FROM CROSS-LANGUAGE PRIMING IN FARSI-ENGLISH BILINGUALS

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ABSTRACT

Research with the masked priming paradigm has indicated that phonology contributes to visual word recognition and is activated automatically. The present study investigates whether this is also the case when prime and target have different orthographies. The existing evidence is reviewed and a new experiment is presented involving Farsi primes and English targets. On the basis of the findings it is concluded that a difference in script does not allow bilinguals to strategically control phonological coding of visual words in their languages. The phonological priming effect is of the same size across scripts as within scripts and within languages.

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There is ample evidence that phonology plays an important role in text reading (e.g., Brysbaert, Grondelaers, & Ratinckx, 2000; Inhoff, Connine, Eiter, Radach, & Heller, 2004; Ziegler, Tan, Perry, & Montant, 2000). In addition, it is well established that at least in alphabetical languages the phonological coding of written words starts before the words have been recognized. That is, some of the letter-sound conversions happen on the basis of letter information and not on the basis of word information (also called assembled phonology instead of addressed phonology). In the past there has been a fierce discussion about whether this implied that visual words first had to be translated into sounds before they could be identified (i.e., a strong phonological model; e.g., Frost, 1998; Lukatela & Turvey, 1994; Van Orden, Johnston, & Hale, 1988), but now consensus is growing that orthographic and phonological codes are involved simultaneously in visual word recognition (i.e., a weak phonological model; e.g., Ferrand, 1995; Grainger, Kiyonaga, & Holcomb, 2006; Perea & Carreiras, 2008; Rastle & Brysbaert, 2006).

The strongest evidence for the contribution of assembled phonology in visual word recognition comes from masked priming with homophones and pseudohomophones. In these experiments, target words (e.g., MADE, CONE) are preceded by briefly presented homophonic primes (e.g., MAID, KOAN) or orthographic controls that share the same number of letters with the target but not the same sounds (e.g., MOOD, VOAN). The usual finding is that target word recognition is faster after a homophonic prime than after a control prime. The fact that the effect is also obtained with nonword primes (which do not have lexical representations) is in line with the hypothesis that phonological coding occurs prelexically (Perfetti & Bell, 1991). Further research has suggested that the activation of phonology escapes strategic control (Brysbaert, 2001; Xu & Perfetti, 1999) and that unsupportive phonological information is not prevented from being activated but is pruned as part of the competition processes involved in lexical selection (Drieghe & Brysbaert, 2002).

Brysbaert, Van Dyck, and Van de Poel (1999) reasoned that the automatic activation of phonology should have implications for bilingual word recognition. If participants do not have control over the activation of phonology, then it should be possible to show that not only the phonology in the target language becomes activated as part of word recognition, but also the phonology of the other language mastered by the bilingual. Brysbaert et al. (1999) investigated this with Dutch-French bilinguals and showed that first language (L1) primes sounding like second language (L2) target words induced better target recognition than L1 orthographic controls. Dutch-English bilinguals recognized the target word *CONE* better after the prime *koon* (which is pronounced like *cone* in Dutch) than after the control prime *poin*. The finding was replicated by Duyck, Diependaele, Drieghe, and Brysbaert (2004) and extended to priming from L2 primes to L1 targets (Brysbaert & Van Wijnendaele, 2003; Van Wijnendaele & Brysbaert, 2002).

The finding that a written prime not only activates the phonology of the target language but also the phonology of another language mastered by the participants is in line with many recent demonstrations that bilinguals do not have selective access to one of their languages. When bilinguals are processing words in one language, they are influenced by their knowledge of the other language. Representative studies in this respect are Dijkstra, Grainger, and van Heuven (1999; Dutch-English bilinguals), Duyck (2005; Dutch-English bilinguals), Schwartz, Kroll, and Diaz (2007; English-Spanish bilinguals), Haigh and Jared (2007; French-English bilinguals), Knupsky and Amrhein (2007; English-Spanish bilinguals), and Marian, Blumenfeld, and Boukrina (2008; English-German bilinguals).

A limitation of the above evidence is that it is based on languages with the same orthography (the Roman alphabet). This raises the question whether bilinguals have more control over the access to their languages when these differ in orthography. Four studies are relevant with respect to the issue of phonological coding in visual word recognition.

Gollan, Forster, and Frost (1997) presented Hebrew-English and English-Hebrew participants with masked primes in L1 and targets in L2 (prime presentation time was 50 ms). These authors observed a stronger translation priming effect for primes and targets that were cognates (i.e., had a large overlap in phonology) than for primes and targets that had no form overlap. They hypothesized that this difference was due to the fact that the participants activated the phonology of the primes and exploited the shared phonology of the cognates.

Kim and Davis (2003) also presented Korean-English bilinguals with a masked priming task, involving Korean L1 primes and English L2 targets (prime presentation time again was 50 ms). Primes either were translations of the targets or homophones of the targets.[1] Participants had to perform one of three different tasks on the targets: naming, lexical decision, or semantic categorization. Kim and Davis (2003) observed a significant phonological priming effect when the targets had to be named, but not when participants had to do a lexical decision or a semantic classification. In contrast, a significant translation priming effect was observed for lexical decision and semantic classification, but not for naming. Kim and Davis (2003) pointed out that the absence of phonological priming in lexical decision and semantic categorization was hard to reconcile with Brysbaert et al.'s (1999) claim of automatic phonological coding in L1 and L2. It seemed to suggest that participants had strategic control either over the phonological coding itself or over the use of the phonological code.

Lee, Nam, and Katz (2005) also investigated phonological priming in Korean-English bilinguals. Unlike Kim and Davis (2003), they reported significant phonological priming in lexical decision both from Korean L1 primes to English L2 targets (47 ms and 43 ms in two different experiments) and from English L2 primes to Korean L1 targets (19 ms and 36 ms). However, the prime durations used by Lee et al. (2005) were much longer than those of Kim and Davis: 140 ms (in Experiments 1a and 2a) and 250 ms (in Experiments 1b and 2b). Within the masked priming literature these are very long presentation times that are unlikely to reveal automatic processes in the early stages of word processing, given that prime and target are perceived as distinct events.

[1] There was also a condition in which primes and targets were cognates, so that they shared both form and meaning. The results of this condition were entirely consistent with those of the other conditions and will not be discussed here.

Finally, Voga and Grainger (2007) reported phonological priming for Greek L1 primes on French L2 targets in Greek-French bilinguals with a prime duration of 50 ms and lexical decision on the target. Unfortunately, the effect was only investigated for cognate target words (such as *metro* and *piano*). Given that cognates are processed differently than other words (De Groot & Nas, 1991), this entail the possibility that phonological priming may be limited to translation equivalents with a large phonological overlap.

All in all, the available data are not very clear. There is evidence for phonological interactions between primes and targets that differ in orthography, but there is also the tantalizing suggestion of strategic control in the only study that made use of a short prime duration and noncognate targets. To further address the issue, we decided to replicate the lexical decision experiment of Kim and Davis (2003). Is it true that phonological priming is less robust across scripts than within scripts and within languages? In addition, in line with previous research addressing the issue of ***automatic*** phonological coding (Brysbaert, 2001; Xu & Perfetti, 1999; Rastle & Brysbaert, 2006), we made sure that there was no inherent gain in using the phonological information of the prime. That is, participants were not encouraged to activate the phonological code because this was helpful for their performance (as in the naming task).

Method

Participants. Participants were 30 Farsi-English bilinguals, living in England. They had acquired Farsi first and started to study English after the age of 10 at school in Iran. All participants used English regularly and rated their proficiency as more than 6/10. As will be discussed further, they all knew the target words used in the experiment. Most of the participants were students; a few were family members of the students (the participants' age ranged from 18 to 56 years).

Stimulus materials. The stimuli consisted of 60 English target words and 60 target nonwords (see the Appendix). Both the word and the nonword targets had a Farsi homophone that did not overlap in meaning. For instance, the English word SHOE sounds the same as the Farsi word for "husband". Similarly, the nonword SEEB has a Farsi homophone meaning "apple". For each homophone a control word was selected that was matched on familiarity and length and that sounded differently (i.e., the Farsi word for "towards" as a control prime for SHOE and the Farsi word meaning "garlic" for SEEB).

The Farsi language is used in Iran and was previously known as Persian (see Baluch & Besner, 1991, for more information). Although it is written in a modified version of the Arabic script, it belongs to the Indo-European family of languages (unlike Arabic which is a member of the Semitic family). Farsi is written from right to left and is alphabetical using 32 letters. The writing is transparent (i.e., the relationship between letters and sounds is quite consistent), except for the fact that the vowels indicated by small marks above or below the consonants are omitted in everyday usage such as in newspapers and books (as in Hebrew). They are only included in children's and beginner's teachings or when explicit disambiguation is needed.

The familiarity of the Farsi words was determined on the basis of frequency ratings given by 10 Farsi-English bilinguals of the same population as the participants [2], who indicated on a 1-5 scale how often they used the word (1 = never come across the word before; 2 = heard of the word but do not know its meaning; 3 = know the meaning of this word but have never or rarely used it; 4 = this word is familiar and used often; 5 = this word is very commonly used in all aspects of communication). Only words that were given the category 5 by at least 8/10 people were used (as in Baluch & Besner, 1991).

Because the nonword targets also had a Farsi homophone, the similarity in sound between prime and target could not be used to help the participants reach a "word" decision (Rastle & Brysbaert, 2006). In this way, there was no incentive for participants to activate the Farsi phonology of the primes.

Procedure. Testing happened individually in a quiet room. A trial consisted of (1) the presentation for 200 ms of a fixation stimulus at the center of the screen consisting of a vertical line above and below the text line where the stimulus would be presented (participants were asked to look at the gap between the lines), (2) a forward mask consisting of 8 hash marks (########) presented for 300 ms, (3) the Farsi prime presented for 50 ms, and (4) the English target presented until a decision was reached. All stimuli were centered on the fixation location. Stimuli were divided over two lists according to a Latin-square, so that target stimuli were included only once per list, half preceded by their phonological prime and half by their unrelated control prime. Each participant

[2] We originally tried to use website counts to determine the frequencies of the words (Blair, Urland, & Ma, 2002), but decided against this because the counts did not agree well with HB's intuitions. In particular words related to trade were overrepresented. For instance, the word "steel" came up with a higher number of hits than the word "friend".

received a different permutation of the list. The test list of 60 word and 60 nonword trials was preceded by a practice list of 10 trials, which was repeated if after the initial presentation the participant did not feel confident or did not achieve a reaction speed expected in lexical decision tasks.

After the experiment, participants were given a list with the 60 English target words and asked to write their translation. The percentage of correct translations was 95%.

Results

Table 1 lists the reaction times (RTs) of the correct trials and the percentages of error (PEs) for the different conditions. For the RTs, values higher than 2000 ms (2.8% of the data) were excluded.

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Insert Table 1 about here

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Reaction times to the English target words were 29 ms faster when they were preceded by Farsi homophones than when they were preceded by unrelated Farsi words ($F1(1,29) = 8.79$, $MSE = 1502$, $p < .01$; $F2(1,59) = 36.49$, $MSE = 563$, $p < .01$). In contrast, RTs to the English nonwords was 19 ms ***slower*** when they were preceded by Farsi homophones ($F1(1,29) = 19.91$, $MSE = 291$, $p < .01$; $F2(1,59) = 40.24$, $MSE = 334$, $p < .01$). The percentages of error were in line with the RTs, so that there was no problem of a speed-accuracy trade-off.

Discussion

In the past decades evidence has been accumulating that phonology contributes to visual word recognition. In addition, whereas in the beginning it was believed that the phonological coding was under strategic control (Brysbaert & Praet, 1992; Verstaen, Humphreys, Olson, & d'Ydewalle, 1995), further investigation has shown that such coding is likely to happen automatically (Brysbaert, 2001; Brysbaert et al., 1999; Drieghe & Brysbaert, 2002; Rastle & Brysbaert, 2006; Xu & Perfetti, 1999). Phonological priming is observed also under conditions where the phonological code is of no use or even detrimental to good performance.

Brysbaert et al. (1999) argued that the automatic activation of phonology had implications for bilingual word recognition, because it implied that participants could not selectively deactivate the non-target language when reading words in one language. All subsequent masked priming studies, except for one, were in line with this prediction. The exception (Kim & Davis, 2003) was a study involving primes and targets based on a different script (Korean vs. English). This raised the possibility that more control is possible when the orthography of the stimulus unambiguously points to one or the other language.

To further address the question, we ran a new study with Farsi-English bilinguals in which (1) we had English target words preceded by Farsi homophones or unrelated controls, (2) we used a prime duration of 50 ms, and (3) we made sure that the use of phonology was not helpful to make a lexical decision. The latter was achieved by using English nonwords that had Farsi homophones and were primed by these words or unrelated controls.

The results were exceptionally clear. There was a significant 29 ms advantage to indicate that a letter string was an English word when it was preceded by a Farsi homophone than when it was preceded by an unrelated Farsi word. At the same time, there was a 19 ms time cost to decide that a letter string was not an English word when it was preceded by a Farsi homophone than when it was preceded by an unrelated Farsi word. Apparently, the overlap in phonology between prime and target made it difficult to initiate a "no" response.

A closer look at Kim and Davis (2003) further indicated that their findings were not really in contradiction with ours. Although they did not find a significant priming effect in the lexical decision task, they found a healthy trend in the expected direction. Only in the semantic categorization task was there a complete absence of phonological priming. One reason for the latter may be that all critical trials involved a "no" response (i.e., the word was not an exemplar of the semantic category shown previously). For instance, participants were first shown the category "fruit", then the target "BEE", and they had to indicate that the target was not part of the category. The trials with "yes" responses were all filler items. Given our observation of a time cost for "no" responses when there is a phonological overlap between prime and target, it is possible that this time cost offset the phonological priming effect. [3]

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[3] A problem with this alternative explanation is that Kim and Davis (2003) did find a translation effect in the very same semantic decision task with "no" responses. This can only be accounted for by assuming that the translation priming effect in semantic decision was much larger than the time cost of the bias towards a "yes"

Looking at the wider literature, Kim and Davis's (2003) suggestion of strategic control in phonological coding was rather isolated as well. There were the three studies of phonological priming across languages with different scripts (Gollan et al., 1997; Lee et al., 2005; Voga & Grainger, 2007). In addition, Hoshino and Kroll (2008) found that bilinguals are faster to name a picture in one language if it has the same name in the other language, not only when both languages share the same script (English and Spanish), but also when they differ in script (English and Japanese). They too interpreted this as evidence for the automatic activation of the picture name in both languages.

In conclusion, we are adamant that both the existing evidence and the new evidence we present are more in line with automatic activation of phonology in visual word recognition than with controlled activation. Even when there is a difference in script between the two languages, bilinguals cannot prevent the activation of assembled phonology. This finding has important implications for models of bilingual visual word recognition, as thus far only the BIA+ model of Dijkstra and Van Heuven (2002) explicitly includes phonology. All other models still assume a strict distinction between visual word processing and auditory word processing.

response. A test of the alternative interpretation would be an experiment in which the homophone stimuli of Kim and Davis are presented in "yes" trials (e.g., is a BEE an animal?). Then a strong phonological priming effect should be found, as for the homophone trials there would be both a bias towards a "yes" response due to the sound overlap and the phonological priming, whereas in the unrelated trials there would be a bias against a "yes" response and no phonological priming.

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Table 1 : Reaction times and percentages of error in an English (L2) lexical decision task when the target words are preceded by masked Farsi (L1) primes that are either homophonic or not. Standard deviations are given between brackets.

	RT		PE	
	Homophonic prime	Unrelated prime	Homophonic prime	Unrelated prime
word targets	928 (188)	957 (177)	5.1 (4.9)	7.7 (6.3)
priming effect		29 ms		2.6%
nonword targets	1068 (233)	1049 (228)	9.2 (4.5)	5.8 (4.4)
priming effect		-19 ms		-3.4%

Appendix

Stimuli used in the experiment

Target words: no, shoe, two, band, seem, bar, tar, luck, dame, geese, beam, lease, chin, must, door, tan, man, narrow, as, bee, sang, pool, aid, his, pass, tell, on, arm, chop, tip, run, jam, soot, car, foot, could, dumb, read, gum, peach, axe, left, rang, bead, deed, sea, cheese, loose, sad, feel, rude, shall, male, sale, mess, calm, palm, poor, keep, sue

Target nonwords: soor, noor, shoore, mord, sard, tond, tord, fard, seeb, jeeb, mizz, liss, shepesh, lizz, tizz, dast, kam, doost, gome, kond, keef, teer, leef, boose, toop, shen, gardan, sen, kesh, aks, rish, rast, yad, shoud, mordan, bordan, ketri, saf, garm, dood, tooty, recab, roban, engar, sorang, gand, biny, pelle, choub, pish, killid, patoo, lak, nish, gorm, shast, nakon, rafte, bakon, sangin