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The importance of phonological coding in visual word recognition: Further evidence from second-language processing

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Abstract

Silent word reading does not rely exclusively on orthographic information but involves the activation of the phonology of words, as is revealed by the phonological priming effect in the masked priming paradigm. Thus far, the phonological priming effect has been documented mainly in monolinguals and bilinguals recognizing words in their first language. We provide evidence that the effect is equally strong in second language processing, even for bilinguals who acquired the second language at the age of 10-12 years in a school setting. This finding suggests that phonological coding is not a mere by-product of the fact that beginning readers try to map an orthographic representation to an already well-established phonological representation.

The importance of phonological coding in visual word recognition:

Further evidence from second-language processing

There is abundant evidence that visual word recognition in adults is not based on visual processing alone. When we read a text, many of us have the impression that we are using a kind of an inner voice (especially when the text is difficult), even when we are reading silently. In addition, historical documents suggest that silent reading is a recent phenomenon. Up to 100 years ago, reading aloud was the default option, just like children who begin to read need to say the words out loud. There is, however, more debate the extent to which the phonological code is accessed on the basis of lexical information or on the basis of prelexical letter-sound conversions. In the former case, the orthographic code of the visual word stimulus first activates a representation in the visual input lexicon, which then activates the phonological code. Coltheart and Patterson (1987) called this “addressed phonology”. In the latter case, in the very first stage of visual word recognition, the letters of the stimulus are converted into sounds, which then help in the process of word recognition. Coltheart and Patterson called this “assembled phonology”. In recent years, an increasing number of researchers has pointed out that the importance of assembled phonology may have been underestimated in many dominant models of visual word recognition.

Most of the evidence for assembled phonology comes from the masked priming paradigm. Humphreys, Evett, and Taylor (1982) reported that a tachistoscopically presented target word (e.g., *MADE*) has more chances of being recognised if it is preceded by a tachistoscopically presented homophonic prime word (*maid*) than when it is preceded by a graphemic control prime that has the same number of position-specific letters in common with the target word (*mark*). Perfetti and Bell (1991) subsequently showed that the phonological priming effect is not due to interactions within the lexicon, because it is also obtained with non-word primes (which do not have a lexical representation), provided the prime is presented for 40 ms or longer. In this study, the target word *CREEP* was identified more often when it followed the pseudohomophonic prime *creap* than when it followed the graphemic control prime *crelp*. The phonological priming effect is not limited to the English language, but has been obtained in a series of other languages including French, Dutch, Hebrew, and Serbo-Croatian (for reviews, see Brysbaert, 2001; Frost, 1998). In addition, the phonological priming effect is not reduced when filler items are added to the test stimuli so that phonological coding is effective in a small proportion of the trials only (Brysbaert, 2001; Xu & Perfetti, 1999), suggesting that the prelexical activation of phonological codes is not under strategic control (see also Van Orden, 1987).

Further evidence for the importance of phonological coding in visual word processing comes from associative priming (Drieghe & Brysbaert, 2002; Lesch & Pollatsek, 1993; Lukatela & Turvey, 1994). Again using the masked priming paradigm, it has been reported that a target word is processed faster not only when it is preceded by a true associate (e.g., *sand* preceded by *beach*) but also when it is preceded by a homophone of the associated word (*sand* preceded by *beech*) or a pseudohomophone of the associated word (*frog* preceded by *tode*). Drieghe and Brysbaert (2002, Experiment 4) even observed associative priming with pseudohomophones when participants had to make a lexical decision between real words (e.g., *NACHT* [night]) and pseudohomophonic non-words (e.g. *KAD*, which sounds like *kat* [cat]) . Although this word/pseudohomophone decision task strongly discouraged the use of phonology (because phonology did not enable participants to distinguish between word and non-word trials), reaction times to target words still were 26 ms faster when they were preceded by a pseudohomophone of an associated word (e.g., *dach – NACHT*) than when they were preceded by a control prime (*dap – NACHT*). This phonologically mediated priming effect was not significantly smaller than the 31 ms priming effect observed with the true associates (*dag – NACHT*) in the same word/pseudohomophone decision task.

On the basis of these (and other) findings, researchers have started to defend a strong phonological view of visual word recognition, according to which there is early, rapid, and mandatory prelexical phonological assembly (e.g., Lukatela & Turvey, 1994; Perfetti & Bell, 1991; Van Orden, 1987). However, Brysbaert, Van Dyck, and Van de Poel (1999) noted that all the evidence for this strong phonological view is based on native language (L1) processing. This raises the question of what happens in second language processing (L2). Is phonological coding limited to visual word recognition in L1, or is it also observed in L2? And if it does, to what extent is it involved? Is the phonological priming effect equally strong in L2 as in L1, or is it significantly weaker?

Van Wijnendaele and Brysbaert (2002) reported some evidence that the phonological priming effect in the masked priming paradigm is equally strong in L2 as in L1. They used the French stimuli of Grainger and Ferrand (1996) and compared the phonological priming effect for two groups of bilinguals in a perceptual identification task with tachistoscopically presented stimuli. The first group were French-Dutch bilinguals, and the second group Dutch-French bilinguals. The French-Dutch bilinguals saw the stimuli in their mother tongue and showed a priming effect of 7%. Thus, a tachistoscopically presented target word like *FAIM* [hunger] was 7% more likely to be identified after the homophonic non-word prime (*fain*; 55%) than after the graphic control non-word prime (*faic*; 48%). The Dutch-French bilinguals were given the same stimuli (which were part of their L2) and showed a similar priming effect of 8% (*fain-FAIM*: 53% target recognition; *faic-FAIM*: 45% target recognition). Unfortunately, the findings of Van Wijnendaele and Brysbaert (2002) were less clear-cut than hoped. The phonological priming effect failed to reach significance in the analysis over stimuli and it was considerably smaller in the two groups of bilinguals than in a control study with French monolinguals who showed a phonological priming effect of 16%. Van Wijnendaele and Brysbaert attributed the latter finding to the fact that the phonological overlap between *faic* and *faim* is larger for someone who masters Dutch than for someone who does not know Dutch (the end-letter *c* changes the pronunciation of the grapheme *ai* in French but not in Dutch).

To further examine the phonological priming effect in L2, we repeated the study of Van Wijnendaele and Brysbaert (2002) with Dutch stimuli. Brysbaert (2001) reported a significant phonological priming effect of 9% in the Dutch language with a set of carefully controlled and validated stimuli. He found that a target word like *FIJN [nice]* was 9% more likely to be recognised after a homophonic non-word prime (*fein*; 51%) than after a graphemic control prime (*foun*; 42%). This effect was obtained with native Dutch speakers identifying words in their mother tongue. However, because the participants were Belgian university students, they also had good knowledge of French and English, so that effectively they were Dutch-French bilinguals or even Dutch-French-English trilinguals rather than Dutch monolinguals (who are impossible to find at universities). In the experiment below, we repeated the study of Brysbaert (2001) with French-Dutch bilinguals recognising the same words in their second language. The prediction is very straightforward: If Van Wijnendaele and Brysbaert (2002) are right that the phonological priming effect is as strong in L2 as in L1, then we should obtain the same priming effect of 9% for French-Dutch bilinguals as the one reported by Brysbaert (2001) for Dutch-French bilinguals.

Method

Participants. Participants were 30 French-Dutch bilinguals. They were native French speakers who had acquired L2 at the age of 10-12 years in school, and who had attended French-speaking primary and secondary schools. At the moment of testing they were taking courses at the University of Leuven (given in the Dutch language). They rated themselves as being rather fluent in Dutch (around 7 on a scale of 10)[1].

Stimulus materials. The stimuli were the 42 test stimuli used by Brysbaert (2001, Experiment 3; see the Appendix). Each stimulus consisted of a target word (e.g., *FIJN* [nice]) with three accompanying primes: a homophonic non-word prime (*fein*), a graphemic control non-word prime that had the same orthographic overlap with the target word as the homophonic prime (*foun*), and an unrelated control prime that had no letters in common with the target word (*lous*). The primes were controlled on bigram frequency, number of neighbours, and had been validated in a naming and a lexical decision experiment (see Verstaen, Gielen, Brysbaert, & d'Ydewalle, 1993, for these data).

Procedure. Participants were informed that the experiment was investigating processes in L2 visual word recognition. All instructions were given in Dutch. Each trial started with the presentation of a forward mask (#######) in the centre of the computer screen, followed by the prime in lowercase letters for 43 ms, the target in uppercase letters for 29 ms, and a backward mask (#######) until the end of the trial. Participants were asked to report the word in capital letters. None of the participants reported having seen the non-word primes. Each participant saw each target word once, preceded by one of the three possible primes according to a latin-square design.

Results

[1] Belgians tend to be rather modest in their appreciation of L2 fluency. Unpublished cross-national research by the authors suggests that people in other countries tend to rate themselves higher in L2 fluency, but do not score better on more objective tests such as word translation or picture naming.

Percentages target recognition as a function of prime type are shown in Table 1, together with the results of Brysbaert (2001, Experiment 3[2]). The phonological priming effect of 11% in L2 was significant (analysis over participants: $F1(2,58) = 15.46$, $MSE = .0120$; analysis over stimuli: $F2(1,41) = 9.00$, $MSE = .0265$) and did not differ reliably from the 9% effect reported by Brysbaert for L1 ($Fs < 1$).

Table 1: Percentage target word recognition as a function of prime type and first or second language.

	L1 (Brysbaert, Experiment 3)	L2 (present study)
Homophonic	52%	42%
Graphemic control	43%	31%
All-letters different	11%	13%
Phonological priming effect	9%	11%

Discussion

Previously, we have argued that it is important to determine whether the phonological priming effect is present in L2 visual word recognition, and whether it is of the same magnitude in this language as in the native language (Brysbaert, 1998, 2003; Brysbaert et al., 1999; Van Wijnendaele & Brysbaert, 2002). Finding a significant phonological priming effect in L2 not only has major implications for theories of visual word recognition in bilinguals, but is also important for theories of visual word recognition in general. If it were found that phonological recoding is absent or largely reduced in L2 word processing relative to L1 word processing, then it would be difficult to sustain that phonological coding is an *essential* element of visual word recognition. In contrast, if an equivalent phonological priming effect were found in L2 as in L1, this

[2] These results are averaged over the condition with homophonic filler primes and the condition with non-homophonic filler primes, because there was no difference between these two conditions (see the Introduction).

would be one more argument in favour of the strong phonological view of visual word recognition.

Some preliminary evidence for a similar phonological priming effect in L2 and L1 was reported by Van Wijnendaele and Brysbaert (2002). They found the same effect with French target words in Dutch-French bilinguals as in French-Dutch bilinguals. Unfortunately, their findings were not fully convincing because the phonological priming effect was not significant in the analysis over stimuli. The present study was a replication of the original finding with Dutch word stimuli. These stimuli have been used in L1 research before and are known to induce a reliable phonological priming effect of 9% (Brysbaert, 2001).

The results were very clear. Target words have more chances of being identified if they are preceded by a pseudohomophonic prime not only in L1 but also in L2. In addition, the magnitude of the phonological priming effect is the same in both languages (if anything, there was a trend towards a stronger effect in L2 than in L1, see Table 1). In combination with the data reported by Van Wijnendaele and Brysbaert (2002), this puts us in a strong position to conclude that the activation of phonology is as important in L2 visual word recognition as in L1 visual word recognition.

As far as we can see, there are three possible reasons why phonological coding is equally important in L2 and in L1. The first is that fluent visual word recognition critically depends on phonological mediation. This strong view would be in line with claims made by Lukatela and Turvey (1994; see also Frost, 1998) and would imply that there is no point in trying to acquire a new language on the basis of reading alone (see Atkins & Baddeley, 1998, and Ellis & Laporte, 1997, for evidence that second language acquisition largely depends on spoken word forms).

The second reason for an equivalent importance of phonology in L2 as in L1 word reading is that the activation of phonology, although not required, is equally helpful in both languages. One reason why this might be so, is that sentence and discourse processing heavily rely on phonological codes for the maintenance of information in working memory. Apparently, our verbal short-term memory relies more on phonological than on orthographic information (Levy, 1977; Sowiaczek & Clifton, 1980) and it has been claimed that people who cannot keep more than three spoken words in short term memory, have difficulties comprehending written text, certainly if the sentences are long (Baddeley, Vallar, & Wilson, 1987; but see Hanten & Martin, 2001). The fact that sentence understanding makes use of phonological information could be a strong incentive to recode visually presented words into phonology as rapidly as possible.

Finally, another reason why the phonological priming effect is equally strong in L2 as in L1 may simply be that learning to read in L2 happens in very much the same way as learning to read in L1: through a continuous, interleaved exposure to auditory and visual language. We deliberately chose bilinguals who acquired their second language relatively late, at the age of 10-12 in the final years of primary school or in the beginning of secondary school, because we hypothesised that these bilinguals might have acquired their second language more on the basis of visually presented stimuli (words of a second language are often learned by studying them in textbooks, where they are listed together with their translation). However, in all likelihood, these same words had been used over and over again in the oral lectures that accompanied the textbook.

Whatever the exact reason for the equivalent phonological priming effect in L2 and in L1 in late learners, this finding allows us to rule out one explanation of the origin of the recoding, namely that the coding is a simple by-product of the fact that children have an extensive knowledge of spoken language when they start to read. Given that primary school children have a good command of spoken language when they receive their first reading lessons, it could be hypothesised that the acquisition of the new skill sponges on the existing knowledge, because it is easier to map the orthographic symbols on the existing spoken language than to build a completely new orthographic word recognition system from scratch. There is indeed evidence that children have less difficulties learning to read in languages with a transparent orthography like German or Italian than in languages with many inconsistencies in the grapheme-phoneme mappings like English (Landerl, Wimmer, & Frith, 1997; Lindgren, De Renzi, & Richman, 1985). In addition, it is known that children who cannot properly segment spoken words into phonemes are likely to experience reading difficulties (e.g., Rayner, Foorman, Perfetti, Pesetksy, & Seidenberg, 2001). On the basis of these findings, it could be argued that phonological coding in visual word recognition is simply a residual of the way in which printed words were read originally. However, such a view would seem more in line with the finding of a reduced phonological priming effect in late L2 acquirers, than with the data we report in Table 1 and the ones we reported before in

Van Wijnendaele and Brysbaert (2002). As such, our data are a strong indication that phonological coding in visual word processing happens for a more fundamental reason than the fact that we originally learned to read words by mapping letters to well-known patterns of sounds.

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Appendix

Stimuli used in the experiment

Target	homof	graph.	all letters diff.
FIJN	fein	foun	lous
HUIS	huys	huus	daur
FOUT	faut	feut	leil
HAREM	harum	harom	lisos
HYMNE	himne	humne	bucra
RADIJS	radeis	raduis	votuin
GRAUW	grouw	greuw	nilst
GALERIJ	galerei	galeroi	potomoe
NIVEAU	nivo	nivy	cazy
EERLIJK	eerluk	eerlik	aandit
RUW	ruuw	reuw	vein
TEAM	tiem	toem	koes
ZWIJN	zwein	zwaun	craus
BOUW	bauw	beuw	keem
IDEE	iedee	odee	olou
FRAME	freem	froem	knuis
SOLDIJ	soldei	soldoi	vakkou
TONUS	toonus	tanus	hazem
BOEZEM	boezum	boezom	kaaron
SNEEUW	sneew	snoow	mulda
HUMAAN	huumaan	homaan	doreer
BASE	baze	bave	hovo
NAAKT	naact	naant	rienk
ASIEL	aziel	aviel	ovouk
VIGNET	vinjet	vipnet	sopral
AFVAL	affal	afral	etrot
FEEKS	feex	feem	doom
PORTIE	porsie	pordie	gandau
LIK	lick	limk	frug
CELLO	sjello	nello	nuffa
PANEEL	panneel	pameel	gimoot
BELEG	belech	belemd	katomd
JUIST	yuist	guist	geenk
VERBOD	verbot	verbol	wankil
ACTIE	aksie	amdie	omduo
TAXI	taksi	tanni	bredu
VISUM	vizum	virum	worex
AMBT	amt	ankt	enks
NEON	nejon	nepon	wipum
HERT	herd	herk	dink
GOD	got	gof	jaf
OPTIE	obsie	okrie	akrua