Bilingual visual word recognition: Evidence from masked phonological priming[1]

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A number of recent developments in the research on bilingualism and visual word recognition have convinced me that the time is ripe to integrate both topics. As many of the developments were due to the use of the masked priming paradigm, the present book may indeed be the ideal outlet to summarise the main findings in these research areas and to discuss some of the ongoing integration work. First, I will review a number of recent trends in the research on bilingualism, then I will talk about the issue of phonological coding in visual word recognition, and finally I will discuss a few studies that examined the possibility of cross-fertilisation. The advantage of a book chapter is that one can be more outspoken than in a journal article, where one never knows who the reviewers will be and the review process itself usually ends in a much more toned-down version of the original submission. Unfortunately, “more outspoken” is rarely a synonym for “more correct” (which is why journal editors and reviewers rightly ask for all necessary qualifications and reservations). However, it makes clearer what an author really thinks at a certain moment in time, even though it entails the risk that the same author at some later point may be forced to backtrack and to acknowledge that he had it completely wrong after all. As such, the present chapter is better considered as a workshop talk (on which it is based) than as a balanced review of the literature.

Changing views about bilingualism

Two recent insights in the research on bilingualism are likely to put the issue of multiple language proficiency in the centre of written word recognition for the coming years. The first is that a bilingual person is not equipped with two independent visual word recognition systems. That is, a bilingual cannot be thought of as the equivalent of two monolingual word recognisers living within the same person. There are influences from the first language (L1) on word recognition in the second language (L2), but also from L2 on word recognition in L1, making an English-Dutch bilingual different from an English monolingual, even in the identification of English words. The second insight is that bilinguals are not a minority, so that a model of visual word processing that cannot account for second language processing is not a good model.

Bilinguals differ from monolinguals also in the processing of L1

Up to the late 1980s, the dominant view about word recognition in bilinguals was that bilinguals could control which part of their language processing brain was active. They were believed to have two separate lexicons that could be switched on and off by means of a selective access control mechanism (e.g. MacNamara & Kushnir, 1971; Scarborough, Gerard, & Cortese, 1984). Such an architecture of language selective access seemed ideal to explain why in general bilinguals do not experience interference

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problems from one language to the other. Gradually, however, it became clear that bilinguals cannot completely suppress the non-target language, be it their first or their second language. Here, I only discuss some of the most recent evidence. People interested in the older literature can choose from a selection of good review papers (Beauvillain, 1992; Brysbaert, 1998; de Groot & Kroll, 1997; Grainger, 1993; Kroll & Dijkstra, in press; Smith, 1997; Van Heuven, Dijkstra, & Grainger, 1998).

The clearest evidence for language non-selective lexical access comes from studies in which participants were asked to perform a task in one of their languages and in which knowledge of the other language did not seem to matter. Dijkstra, Timmermans, and Schriefers (2000, Experiment 2), for instance, asked Dutch-English bilinguals to press on a button only if an English word was presented. If the presented word belonged to the Dutch language the participants were instructed to wait for the next word to appear (i.e., a go / no-go paradigm). Dijkstra et al. were particularly interested in the comparison between words that only exist in English (e.g., *home*) and words that exist both in English and in Dutch but have a different meaning in both languages (the so-called homographs, such as *room*, which means *cream* in Dutch). The idea was that if participants only activated their English lexicon, they should not be influenced by whether or not the letter string formed a word with a different meaning in Dutch. Still, Dijkstra et al. obtained a reliable homograph effect: Participants needed more time to decide that a homograph was an English word (657 ms) than that a non-homograph was an English word (577 ms), even though the English reading of the word was much more frequent than the Dutch reading and even though all test words were readily recognised as valid English words (more than 97% correct responses).

Van Heuven et al. (1998, Experiment 4) asked English monolinguals and Dutch-English bilinguals to take part in an English lexical decision task. The variable they manipulated was the size of the orthographic neighbourhood of the target words both in the Dutch and the English language. Following Coltheart, Davelaar, Jonasson, & Besner (1977), an orthographic neighbour was defined as a word of the same length with one letter changed. An English word like *left*, for instance, has quite some English neighbours (e.g., *deft, heft, lift, loft, lent, lest*) but also many Dutch neighbours (e.g., *heft, lift, lest, leut*). In contrast, a word like *deny* has very few neighbours both in English and in Dutch. The word *keen* also has few neighbours in English but has a lot of Dutch neighbours (e.g., *been, teen, kien, koen, kern, keel, keer*), whereas the last type of words had many neighbours in English but few in Dutch (e.g., *coin*). With monolingual participants, Dijkstra et al. found the expected effect of the size of the English neighbourhood: RTs were faster to words with a large neighbourhood (486 ms) than to words with a small neighbourhood (505 ms). Also in line with the expectations, these participants did not show an effect of the Dutch neighbourhood size. In contrast, the Dutch-English bilinguals showed no effect of the English neighbourhood size, but a significant reverse effect of the Dutch neighbourhood size (large size = 584 ms, small size = 563 ms). Participants took longer to accept letter strings as English words if these letter strings had a lot of Dutch neighbours, even though the task was a pure English lexical decision task.

At this point, it might be objected that what has been shown thus far is that participants are not able to suppress their mother tongue when they are reading words in their second language. Although this finding is not in line with a strong model of language selective lexical access, it is in agreement with the more general – albeit often implicit – assumption that a person’s first language processing is not affected by knowledge of a second language. According to this view, it is possible to stop the machinery of the second language and to study L1 as if there were no L2, whereas it is not possible to completely switch off the first language. However, evidence is accumulating that this view too is incorrect.

Bijeljac-Babic, Biardeau, and Grainger (1997, Experiment 2) tested French-English bilinguals and looked at the influence of English L2 primes on the processing of French L1 targets. In particular, they were interested in the inhibitory effect caused by cross-language orthographic neighbour primes. Previous monolingual research (e.g., Segui & Grainger, 1990) had shown that low-frequency L1 target words are more difficult to recognise after tachistoscopic presentation of a high-frequency orthographic L1 neighbour, than after presentation of an orthographically dissimilar control prime (i.e., recognition of the word *BLUR* is slower when it is preceded by *blue* than when it is preceded by *pink*). This effect was predicted on the basis of the Interactive Activation Model (McClelland & Rumelhart, 1981), which sees word identification as involving a competition between orthographically similar words. Bijeljac et al. replicated this effect in the first language of their proficient French-English bilinguals: Participants took 28 ms longer to decide that *MIEL* [honey] was a French word if it had been preceded by the French prime *mien* [my] than if it had been preceded by the French prime *hier* [yesterday]. In addition, they showed that the inhibition effect was also present when the same L1 target word *MIEL* was preceded by the L2 primes *mile* or *meet* (lexical decision times of 792 en 749 ms respectively). In contrast, French monolinguals only showed the inhibition effect for the French primes, not for the English primes. Beginning French-English bilinguals showed an intermediate effect for the English primes.

Dijkstra et al. (2000, Experiment 3) repeated their go / no-go experiment with Dutch-English bilinguals, but this time they did not address word recognition in L2 but in L1. Participants were asked to press on a button when the letter string formed a word in Dutch and to refrain from responding when it was a word in English. As in their experiment on L2 word recognition, Dijkstra et al. obtained a reliable homograph effect: Participants took longer to accept a letter string as an existing Dutch word when it was an English homograph (*room*) than when it was not (e.g., *nis* [niche]). The effect was particularly strong (over 200 ms) when the English reading of the homograph was more frequent than the Dutch reading (as is the case for *room*), but still amounted to 31 ms for homographs that had a higher frequency in Dutch than in English (e.g. *hoop* [hope] vs. *mond* [mouth]).

Finally, van Hell and Dijkstra (in press) asked Dutch-English-French trilinguals to take part in a lexical decision task in L1 (Dutch). The basic manipulation in this experiment involved a comparison of Dutch-English cognates and Dutch noncognates. Dutch-English cognates are translation-equivalent words in Dutch and English that have a large orthographic and phonological overlap (e.g., the word pair *bakker-baker*). Even though participants were not told about the fact that some words had cognates in their L2, they responded more than 30 ms faster to these words than to the noncognates that had been matched for length, frequency, and Dutch neighbourhood size.

The above evidence shows mutual influences between L1 and L2 in the early stages of visual word processing (see Grosjean (1988) and Li (1996) for evidence in auditory word processing). This is not to say that there are no inhibitory links between the languages mastered by an individual (which would be hard to defend given the ease with which bilinguals can protect themselves from cross-language interferences during text reading), but these links appear to be situated later in the word processing chain than generally assumed. Unless there are clear orthographic cues as to which language a word belongs (e.g., the first letters *wh*), language selection seems to be achieved in the process of lexical activation itself, probably as a result of the competition between overlapping word candidates in the different languages (Grainger, 1993; van Heuven et al., 1998). This view agrees with recent interpretations of selective language loss after brain damage. Although such selective loss is rather common (Fabbro, 1998), it is no longer believed to be caused by a selective loss of an entire lexicon, but rather by a shift in the activation thresholds of the different languages (Gollan & Kroll, 2001; Paradis, 1997). Such a view also agrees with the increasing number of imaging studies that report very similar activation patterns for L1 and L2 word processing (e.g., Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001; Nakada, Fuji, & Kwee, 2001; Pu et al., 2001).

Bilinguals are not a minority

The fact that L1 processing is influenced by L2 knowledge would not be a big issue if the interaction were limited to those few individuals that are equally proficient in both languages and that acquired the languages simultaneously because they grew up in a bilingual environment (either because the parents spoke different languages, or because the language at school was different from the language at home). Research on bilingualism has indeed too long been confined to these very few, so-called “balanced” bilinguals. However, in the last years it is becoming increasingly clear that interactions between the different languages mastered by an individual extend across a wide range of proficiency levels in L2. All research of Dijkstra and colleagues, discussed above, was based on native Dutch-speaking students who learned English around the age of 10. Although most of them were rather fluent in English and, of course, understood the words presented, they were by no means balanced, with a similar proficiency level in L2 as in L1. Furthermore, in one of the experiments (van Heuven et al., 1998, Experiment 1), the proficiency level of the participants was manipulated, but this did not have a large effect on the findings. The proficient bilinguals of Bijeljac-Babic et al. (1997) were more towards the balanced end of the continuum, but for this particular effect (inhibition by orthographic neighbours) it was pivotal that the L2 primes had a higher frequency than the L1 targets (Segui & Grainger, 1990).

If the proficiency level of L2 need not be perfect for it to have an effect on L1 word processing, then suddenly a lot more people become bilingual (see, e.g., de Groot & Kroll, 1997). As a matter of fact, if for the present purposes bilingualism is loosely defined as being able to understand a text written in a non-native language, it can be estimated that more than half of the literate world population is bilingual. Consequently, a model of visual word recognition that only applies to those people who read but one language may be so limited in its application that it becomes next to pointless (even if L1 is English). This, I think, is the second main message from current psycholinguistic research on bilingualism.

Below, I illustrate my point by focussing on the topic of phonological coding in visual word processing. I will show how strong theories about this issue not only have important implications for bilingual word recognition but also lead to a number of very counter-intuitive predictions that can be tested. First, I describe why I believe phonological mediation is pivotal in visual word recognition (as some people still seem to require a bit of extra persuasion in this matter) and then I will discuss some of my recent work on phonological coding in bilinguals.

Changing views about phonology in visual word recognition

As discussed in several other chapters of this book, there is now quite some evidence that visually presented words are not recognised on a visual basis alone. Readers rely on the spoken – phonological – information enclosed in the orthographic stimulus when they identify written words, and researchers no longer quarrel about *whether* phonology is involved in visual word recognition but *to what extent* it is involved. Interestingly, this debate on the automaticity of phonological coding in visual word recognition has followed a similar line of development as the debate on strategic lexical access in bilingual word processing. Just like researchers of bilingualism in the 1970-1980s assumed that knowledge of a language could be switched on and off on command, so did researchers of phonology believe that reliance on phonology in visual word recognition could be controlled as a function of task demands. For instance, in the 1978 version of the dual-route theory, Coltheart explicitly postulated the existence of strategic control over the use of the information produced by the non-lexical grapheme-phoneme conversion system. He wrote: “Consequently in this section I would like to discuss evidence, as yet rather fragmentary since this is a fairly novel area of research, concerning the extent to which the various procedures which can be involved in lexical access are strategic procedures – that is, procedures whose adoption are under the subject’s control, rather than being automatic.” (Coltheart, 1978, p. 199), Not much of this strategic aspect of processing remained in the 1993 and the 2001 versions of the dual-route model (Coltheart et al., 1993, 2001), largely due to the introduction of cascaded processing (McClelland, 1979) in computational models of word recognition.

Coltheart is not the only one to accept an unconditional contribution of phonology to visual word recognition nowadays. Other authors have even started to question whether there still is enough evidence to postulate a direct pathway from visual input to meaning in word recognition. I will not reiterate their arguments here (see Brysbaert, 2001; and Frost, 1998, this volume). Instead, I will give a more personal account of what made me change my mind on the issue, in the hope that others may recognise some of their own situation in these experiences.

I became involved in the issue when I was a PhD-student in Leuven, because my office neighbour at the time, Caroline Praet, was running into problems. She tried to replicate Perfetti et al. ’s (1988) pseudohomophone effect in the Dutch language. Perfetti, Bell, and Delaney (1988) had shown that in a backward masking paradigm a tachistoscopically presented target word like *blue* had more chances of being recognised if it was followed by a homophonic mask (*BLOO*) than if it was followed by a graphemic control mask (*BLOS*) that shared the same number of letters with the target as the homophonic mask, but not the same number of phonemes. Unfortunately, Caroline Praet was not able to replicate the effect in Dutch, even though she fiddled around with different presentation times of targets and masks and with different kinds of stimuli (a few of these efforts can be found in Brysbaert & Praet, 1992, Experiments 1 and 2). Remembering some of Coltheart’s (1978) writings, I advised her to look at what would happen if the use of phonological information was made more useful for good performance in the task. Because of all the controls Caroline Praet thought necessary for a correct interpretation of her results, only a few trials contained targets with homophonic masks. In all other cases, there was but a small overlap between the phonemic codes of the targets and the masks. If the word recognition system to some extent was capable of adapting its reliance on phonological information as a function of the usefulness of this information, then it was no wonder that the homophone effect did not show up in her results. By using filler items, we constructed a condition in which it was useful to rely on phonological information (as 78% of the trials were of the type target – homophonic mask) and another condition in which it was not useful to rely on phonological information (because only 6% of the trials were of the homophonic type). As expected (hoped?), we found the homophone effect in the former condition but not in the latter, leading us to conclude that reliance on phonological information in visual word recognition was not automatic but strategic (Brysbaert & Praet, 1992). Shortly afterwards Alexander Verstaen, a student from the Leuven lab who went to do research at the University of Birmingham, obtained a similar strategic effect in the use of phonology in the English language (Verstaen, Humphreys, Olson, & d'Ydewalle, 1995), reassuring us about the correctness of our conclusion.

By the time the Verstaen et al. paper got published, however, things had taken a bad turn in Leuven. After Caroline Praet quit research (fed up with the homophone effect), Alexander Verstaen and I, with the help of Ingrid Gielen, tried to replicate the strategic effect with better controlled stimuli. To do so, we devised a list of 100 Dutch target words with accompanying masks carefully controlled for confounding variables and validated in a naming task and a lexical decision task (Verstaen, Gielen, Brysbaert, & d'Ydewalle, 1993). However, when we tested this list of stimuli with a large group of students, we failed to obtain a reliable homophone effect, even in the phonology encouraging condition with lots of filler stimuli of the type target – homophonic mask (see Brysbaert, 2001, Experiment 1). At that time, we all decided to cut our losses and to quit the subject (for some of us even to quit scientific research altogether), convinced that the topic of phonological coding in visual word recognition was a dead end.

In the mean time, however, corroborative evidence for the homophonic masking effect kept on being reported in English, both by Perfetti and colleagues (e.g., Berent & Perfetti, 1995) and Lukatela and Turvey (1994). Intrigued by this, I asked a colleague in the Leuven lab, Ubolwana Pavakanun, whether she wanted to repeat our backward masking experiment with English stimuli, to see whether the results of Perfetti were due to a lack of some of the controls we thought were necessary (see Brysbaert, 2001, Experiment 1, for more details about the procedure). As there are many native English speaking students in Belgium, running the experiment turned out not to be a big problem. Basically, we used the Perfetti et al. (1988) stimuli as test items (for a total of 50), completed with 100 filler items which we took from appendices of various articles. A total of 40 students participated, half in the phonology encouraging condition (with 110/150 target words followed by a pseudohomophonic mask), half in the phonology discouraging condition (with 10/150 target words followed by a pseudohomophonic mask). The most important finding was that we obtained a reliable 6% homophone effect, both in the phonology encouraging condition (homophonic masks: 80% target recognition, graphemic control masks: 75% target recognition) *and* in the phonology discouraging condition (homophonic masks: 69% target recognition, graphemic control masks: 62% target recognition). Similar results for English were shortly afterwards reported by Xu and Perfetti at the 1996 Annual Meeting of the Psychonomic Society and eventually published in Xu and Perfetti (1999).

Intrigued by the language difference, I started to wonder what could be its origin, hoping that an answer to this question would give me a clue about what was really going on. The first bit of the answer came from Jonathan Grainger, who told me that he had given up the backward masking paradigm, because he got much clearer results with the masked priming paradigm (e.g., Ferrand & Grainger, 1994; Grainger & Ferrand, 1996). As indicated before, in the backward masking paradigm, the target word is presented first, followed by the homophonic or the graphemic non-word. Both are shown for a very short period of time and followed by a pattern mask consisting of a row of Xs. So, a typical trial in a backward masking experiment would consist of the presentation of the target word *blue* for 35 ms, followed by the non-word mask *BLOO* (or *BLOS*) for 30 ms and the pattern mask *XXXXXXX* until the participant wrote the target word and pressed a button to initiate the next trial. In the masked priming paradigm, the non-word does not follow the target but precedes it (e.g. *bloo* is presented first for 43 ms, followed by *BLUE* for 29 ms, and the pattern mask #######; the participant is asked to report the target word). Perfetti and Bell (1991) were the first to show a pseudohomophone effect with this paradigm, provided the prime was presented for more than 40 ms.

The second bit of the answer to my problem came from Ram Frost, who at an ESCOP conference told about his problems of finding the homophone effect in Hebrew. After obtaining several null-effects, he discovered that many of Perfetti's stimuli introduced a big change in phonology between the homophonic masks and the graphemic control masks. For instance, a typical item of Xu and Perfetti (1999) was BITE – bight / bisht. In this example, not only the final consonants of the masks differ but also the phonology of the vowel. The same was true for most of Ferrand and Grainger's stimuli. When Frost introduced larger changes in phonology between the homophonic and the graphemic control masks, he managed to replicate the homophonic effect in Hebrew (Gronau & Frost, 1997; also see his chapter in this book), whereas other people who tried to replicate Perfetti et al. (1988) in English with stimuli that induced a smaller change in phonology between the different types of masks, in general failed (e.g. Davis, Castle, & Iakovidis, 1998, Experiment 1 and Experiment 3 high overlap condition). So, the difference was not so much a language difference as a difference in the amount of phonological overlap between the different types of primes and masks.

Finally, Xu and Perfetti (1999) added the final piece of the puzzle: There is a ceiling level around 60-70% at which the phonological effect no longer is observed. To ensure that participants would not see the masks, I usually made the targets rather visible, so that they would be recognised over half of the time. Apparently, this seems to reduce the phonology effect.

Armed with this knowledge, it turned out that I could rather easily produce a homophonic effect (Brysbaert, 2001, Experiment 2; see Table 2 below). The only considerations to take into account were: (a) to use the masked priming technique instead of the backward masking technique, (b) to ensure that there is a big difference in the phonology of the homophonic masks and the graphemic controls, and (c) to make sure that target recognition is not too easy if a perceptual identification task is used. Under these conditions, the homophonic effect is readily obtained even when the use of phonology is detrimental in more than 80% of the trials (Brysbaert, 2001, Experiment 3; also see Xu & Perfetti, 1999; and the study of Ubolwana Pavakanun reported above), suggesting that – contrary to my previous belief – reliance on phonological information is not strategic in visual word recognition.

I have reported these experiences at a rather great length, not because I had an urgent need to write my memoirs, but because over the years I have found out that research labs accumulate a lot of informal knowledge about how to run particular experiments, which is rarely published and, if it is, usually well after the original discoveries (also because of the publication lag that currently plagues many major psychology journals).

At the same time, however, the automatic activation of phonology by visual word stimuli poses a real challenge to researchers who are aware of the facts that many people have knowledge of more than one language and that the first stages of word recognition are language independent. Already in 1993, Grainger hypothesised that the above premises force one to conclude that it must be possible to prime a target word in L2 by a homophonic stimulus of L1. As will be shown below, the reality is even stronger than this.

Masked phonological priming in L2 and across languages

In the preceding sections I have first shown that visual word recognition in a bilingual person is influenced by the knowledge of the other language. This is true not only for word recognition in L2 but also for word recognition in L1. Second, I have shown that a visual word in L1 automatically activates its phonological code. This representation cannot be suppressed, even not when it is detrimental for good task performance.

Three questions follow from these observations, all with the potential of a large impact on how we think about bilingualism and phonological coding in visual word recognition. The first question is whether visual word recognition in L2 makes use of phonological information as well? The second question is whether it is possible to phonologically prime an L2 word with a homophonic stimulus from L1? Obviously, the answer to this question partly depends on the answer to the first question: If L2 word recognition does not involve phonology then it is impossible to prime an L2 word with any kind of phonologically related stimulus. Finally, the third question is: Given that the first two questions have been answered positively, is it then possible to phonologically prime an L1 word with a homophonic stimulus from L2? I will deal with these three questions successively.

Is visual word recognition in L2 phonologically mediated?

When asked why visual word recognition would be phonologically mediated, researchers sometimes refer to the fact that children starting to read already have an extended knowledge of auditory word recognition. Therefore, it seems more parsimonious to graft the new skill onto the existing intelligence. If this argument is the main reason of phonological coding, then one would expect that phonological information is less important when people start to learn a second language at the age of 10, largely through formal school instruction and on the basis of written texts. According to this hypothesis, one would expect a smaller phonological priming effect in L2 than in L1 (although it need not be completely absent).

Another reason why one might expect less phonological mediation in visual L2 word recognition is that this is in line with some of the current models of word recognition. For instance, in the DRC-model (Coltheart et al., 1993, 2001) the grapheme-phoneme conversion (GPC) is based on rules that apply to L1. Unless one accepts that there is a second GPC system that can be switched on and off as a function of the language input (given the evidence summarised above, a very unlikely assumption), the rule-based nature of the GPC system prevents it from incorporating L2 grapheme-phoneme conversions that contradict L1 rules. So, the GPC system of an English-Dutch bilingual cannot simultaneously translate the grapheme *ee* into the

"English" phoneme /i:/ and the "Dutch" phoneme /e:/, meaning that for this individual the orthographic prime *keed* (/ki:d/) would not be a pseudohomophone of the Dutch word *keet* [shed, racket] which is pronounced as /ke:t/. Only when there is no contradiction between the L2 GPC and the L1 GPC is it possible to use the L2 phonology. For instance, the non-word *nijt* could be a pseudohomophone of the Dutch word *nijd* [envy, malice] for an English-Dutch bilingual, because there is no English rule that excludes the Dutch conversion of the grapheme *ij* into the phoneme /Ei/.

The existence of conflicting GPCs in L1 and L2 would also lead to the prediction of smaller phonological priming effects in bilinguals than in monolinguals according to the distributed models of letter-sound conversions (Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989; Van Orden, Pennington, & Stone, 1990). These models can handle inconsistencies in the spelling-sound relationships, but predict that the time to recover the phonology from a printed word depends on (a) the frequency of the word, (b) the frequency of words with the same letter-sound mapping (so-called friends), and (c) the frequency of words with an incompatible letter-sound mapping (enemies). In these models, consistent letter-sound mappings in L1 and L2 will have the same effect as friends, whereas inconsistent mappings will act as enemies against one another. Contrary to DRC, however, these models predict that the effect will be present for L1 processing as well as for L2 processing. This is because the phonology of the English word *meet* will be "clouded" for an English-Dutch bilingual because the Dutch phonology of the word /me:t/ will compete with the English phonology /mi:t/ (see Dijkstra, Grainger, & Van Heuven, 1998, for some empirical evidence concerning this particular prediction).

To examine the issue of phonological coding in visual L2 word recognition, I made use of the fact that in Belgium quite some people are Dutch-French bilingual and French-Dutch bilingual (Brysbaert, Van Dyck, Van de Poel, 1999; Van Wijnendaele & Brysbaert, in press; Brysbaert & Van Wijnendaele, in preparation). In a first series of experiments, I repeated the research of Grainger and Ferrand (1996) with various types of bilinguals. Following Perfetti and Bell (1991), Grainger and Ferrand asked participants to identify tachistoscopically presented French target words. These words were preceded by a masked prime that either was a pseudohomophone of the target word and had a large orthographic overlap with the word (e.g. the non-word *fain* for the target word *FAIM* [hunger]), a pseudohomophone with a small orthographic overlap (*fint - FAIM*), or a graphemic control that had a large orthographic overlap with the target but only a small phonological overlap (*faic – FAIM*; In French, the letters *ai* are pronounced differently in *faic* than in *faim*). This allowed Grainger and Ferrand to investigate the effects of phonological and orthographic similarity among prime and target by comparing the *fain* and *faic* conditions, and the *fain* and *fint* conditions respectively. The first column of Table 1 displays their results, together with a replication done by Brysbaert et al. (1999) with the same population of Parisian monolingual participants (second column). As can be seen, the effects were quite stable and revealed a robust effect of both phonological and orthographic priming.

Table 1 : Percentage correct target identification as a function of language group and stimulus type (French words preceded by French non-word primes; presentation times of 42 and 28 ms for prime and target, respectively)

Stimulus Type	Monol. French GF, 96	Monol. French BVV, 99	D-F bil. BVV, 99	F-D bil. VB, i.p.
fain-FAIM	72	44	53	55
faic-FAIM	55	28	45	48
fint-FAIM	50	16	25	32
phon. priming	17	16	8	7
orth. priming	22	28	28	23

Colums 3 and 4 of Table 1 display the data of Dutch-French bilinguals (Brysbaert et al., 1999) and French-Dutch bilinguals (Van Wijnendaele & Brysbaert, in press). All bilinguals were relatively proficient in L2, but had not started to acquire L2 before the age of 10 and were not proficient enough to be qualified as balanced. As shown in Table 1, whereas the orthographic priming effect remained the same, the phonological priming effect was halved. Interestingly, this was true both for the participants who tried to recognise words in L2 *and* for the participants who tried to recognise words in L1. That is, the difference was not so much between L1 and L2 word recognition, but between monolinguals and bilinguals, as predicted by the connectionist type of models for letter-sound translations. Also, the reduced phonological priming effect did not seem to result from worse target recognition after homophonic primes (stimulus type *fain-FAIM*) but from better performance after the graphemic control primes (*faic-FAIM*). As discussed by Van Wijnendaele & Brysbaert (in press), this could be due to the fact that the phonological overlap between *faic* and *FAIM* is smaller in French (where the vowels are pronounced differently) than in Dutch (where the vowels elicit the same phonology in both stimuli), so that the overall phonological similarity of *faic* and *FAIM* was larger for a bilingual than for a monolingual.

Unfortunately, because the phonological priming effect in the bilinguals was seriously reduced (it was only significant in a one-tailed test), one cannot easily refute the objection that the data are more in line with a dual-route model of visual word recognition that primarily relies on the orthographic pathway and treats the phonological route as a minor, secondary source of information (certainly in bilinguals with conflicting GPCs). Therefore, Ilse Van Wijnendaele and I recently decided to repeat my Dutch masked priming experiment (Brysbaert, 2001, Experiment 3; see above) with French-Dutch bilingual participants. In this experiment, I had found a reliable phonological priming effect in L1 independent of whether the use of phonology helped for good task performance or not. Although this study did not address the issue of bilingualism, all my native Dutch-speaking participants were quite proficient in French because Dutch-speaking pupils in Belgium start to learn French in school at the age of 10 (and subsequently also get English and German courses when they are 13 and 15 years old). If the data of Table 1 are trustworthy with respect to the phonological priming effect, then we should be able to replicate the phonological priming effect with French-Dutch bilinguals probed for L2 knowledge. In addition, the effect should be of more or less the same magnitude. Table 2 shows the results of the original experiment (Brysbaert, 2001, Experiment 3) together with those of the replication (Brysbaert & Van Wijnendaele, in preparation).

Table 2 : Percentage correct target identification as a function of language group and stimulus type (Dutch words preceded by Dutch non-word primes; presentation times of 42 and 28 ms for prime and target, respectively)

Stimulus type	example	D-F biling. B, 2001 encourag.	D-F biling. B, 2001 discourag.	F-D bilinguals unpublished
homophonic	aut - OUD	51	52	41
graph. control	zum - OUD	42	43	31
unrel. control	zim - OUD	10	11	11
phon. priming		9	9	10

As can be seen in Table 2, the results were entirely compatible with the hypothesis that phonological coding is as important for visual word recognition in L2 as it is in L1. They also add further credit to the idea that phonological coding in L1 is influenced by the knowledge of L2 (see Table 1). Unfortunately, we cannot directly test this latter idea with Dutch stimuli because there are no native Dutch-speaking university students who do not have some understanding of French. So, we cannot investigate whether the phonological priming effect for monolingual individuals would differ from the ones reported in Table 2. Such a comparison can only be made with respect to dominant languages.

Although much more refined research is needed to examine the precise reciprocal influences of L1 and L2, the results thus far show that phonological coding is equally important in L2 and L1 visual word recognition. In my view, this suggests that the reliance on phonology in word reading is not simply a consequence of the fact that L1 reading sponges on the existing database of spoken word recognition. Rather, it would seem that phonological coding is necessary for some other, more basic reason, possibly because phonological information can better be retained in working memory than visual information. Such an interpretation also agrees with the finding that word learning in L2 is hampered if students are prevented from sounding out the words (Ellis & Laporte, 1997, p. 75).

The equivalent phonological priming effect in L1 and L2 also questions a rule-based GPC system as currently implemented in the DRC model (Coltheart et al., 1993, 2001). This model would have been more at ease if it was not possible to prime L2 words with GPCs that contradict the L1 GPCs (although in all fairness, the empirical evidence against the model would be stronger if it was based on a comparison of English monolinguals vs. Dutch-English and English-Dutch bilinguals, and if the stimuli were specifically designed so that for half of the stimuli the Dutch GPCs were incompatible with the English and for the other half they were not - I indeed hope to set up such a study in the not too distant future).

Is it possible to prime an L2 word with an L1 homophone?

Now that we have shown that phonological coding is as important in L2 as in L1, we must predict that an L2 word can be primed by an L1 homophone. If L1 phonology is automatically activated and if L2 visual word recognition is (partly) based on phonology, then failing to find a phonological priming effect from L1 on L2 would seriously undermine the validity of the claims I've been making thus far. Thus, for a Dutch-French bilingual it must be possible to prime the French word *oui* [yes] with the Dutch word *wie* [who], because the Dutch word *wie* (/wi/) is pronounced the same as the French word oui (/wi/). A comparable example for a Dutch-English bilingual would be the word pair *mee - may*: *Mee* is a Dutch word [with, along] with the same pronunciation as the English word *may*.

Table 3 shows the results of a study reported by Brysbaert et al. (1999, Experiment 1). As in the experiments listed in Table 2, there were three types of primes: homophonic primes, graphemic control primes, and unrelated primes. All primes were Dutch words of comparable frequency, but in the case of graphemic controls they had very little phonological overlap with the French target words even though they shared the same number of letters with them as the homophonic primes. The unrelated primes had no letters or sounds in common with the targets. Important for a correct interpretation of the results is that the homophonic primes were not homophonic to the target words according to the L2 GPC rules. So, we did not use stimulus pairs like *kus-CUSS* with Dutch-English bilinguals, because the letter string *kus* has the same pronunciation in both languages even though it is a word in one language [meaning kiss] but not in the other). To check for this possible confound, the stimuli were presented to French monolinguals (from Paris) as well as to Dutch-French bilinguals.

Table 3 : Percentage correct target identification as a function of language group and stimulus type (French words preceded by Dutch word primes; presentation times of 42 and 28 ms for prime and target, respectively)

Stimulus type	example	F monoling. BVV, 99	D-F biling. BVV, 99
homophonic	wie-OUI	35	30
graphemic	jij-OUI	36	23
unrelated	dag-OUI	26	17
phon. priming		-1	7

The phonological priming effect was significant for the bilingual group and completely absent for the monolingual group. This was predicted by the hypothesis that a word in L1 automatically activates its phonological code, which in turn is used in the process of L2 word recognition. A criticism against the finding of Table 3, however, might be that the primes for the bilingual participants were words whereas they were non-words for the monolinguals (see Perfetti & Bell, 1991, for a difference in the speed of phonological activation between words and non-words). Therefore, Brysbaert et al. (1999, Experiment 2) repeated the above experiment with non-words as primes. An example of such a stimulus for Dutch-English bilinguals is the prime-target couple *bleem-BLAME*; *bleem* is not a word in Dutch or English, but in Dutch it is pronounced the same as the English word *blame*. Brysbaert et al. (1999) used Dutch-French equivalents of these stimuli and presented them again to French monolinguals and Dutch-French bilinguals. The results are shown in Table 4.

Table 4 : Percentage correct target identification as a function of language group and stimulus type (French words preceded by Dutch non-word primes; presentation times of 42 and 28 ms for prime and target, respectively)

Stimulus type	example	F monoling. BVV, 99	D-F biling. BVV, 99
homophonic	soer-SOURD	24	41
graphemic	siard-SOURD	33	34
unrelated	chane-SOURD	9	16
phon. priming		-9	7

Whereas the monolinguals had more chances of recognising the target word after the graphemic control prime than after the homophonic prime (probably because the orthographic overlap between prime and target was larger for the graphemic primes than for the homophonic primes), the bilinguals showed a reliable – opposite – phonological priming effect. So, the effects reported in Table 4 were not due to the fact that the primes were words for the bilinguals but not for the monolinguals; they were due to the fact that for the bilinguals (but not for the monolinguals) the cross-language homophonic primes had phonological overlap with the targets. This shows that Grainger (1993) was correct when he hypothesised that it must be possible to prime an L2 word with an L1 homophone (either word or non-word). It raises, however, the question whether this priming effect is unidirectional from L1 to L2, or whether it can be observed the other way around as well, as suggested by the data of Tables 1 and 2. This issue is addressed in the next section.

Is it possible to prime an L1 word with an L2 homophone?

In the preceding sections I have shown that research on bilingual word recognition looks much more productive within the framework of a strong phonological model of visual word recognition than within a framework that denies an important role of phonology. This brings me to the final, quite contra-intuitive question: Is it possible to prime an L1 word with an L2 homophone? Notice that to answer this question positively, one has to assume not only that phonological coding is an essential part of visual word recognition, but also that within a bilingual the phonology on the basis of the L2 correspondences as well as that on the basis of the L1 correspondences is activated prelexically. In addition, the activation of the L2 sounds must be strong enough to influence the identification process of an L1 target word. Tables 1 and 2 provided some circumstantial evidence for this possibility, but to be really sure, we had to repeat the experiments of Table 5 with French-Dutch bilinguals. For these individuals the experimental task simply was to recognise words in their mother tongue. They were not told about the presence of primes, let alone about the fact that some of the primes were homophonic to the target words if coded according to the letter-sound correspondences of their second language. So, there was nothing in the experiment that encouraged the participants to use the L2 phonology (quite on the contrary), meaning that if we found an effect of L2 phonology it could only be due to a mandatory, unavoidable activation of this information.

Table 5 repeats the findings of Table 4 together with new data from a recent study we did with French-Dutch bilinguals (Van Wijnendaele & Brysbaert, in press). These bilinguals were rather proficient in Dutch (they attended courses in a Dutch-speaking university and rated themselves with a minimum of 7 on a scale of 1–10 for their proficiency in the second language), but had virtually all been educated in French before coming to the university and had not started to learn Dutch before the age of 10. Still, as Table 6 shows, their results were much more in line with those of the Dutch-French bilinguals than with those of the French monolinguals. Again, the difference was not so much between L1 and L2, but between bilinguals and monolinguals. This finding adds to the growing body of literature showing that bilinguals process their mother tongue differently than monolinguals.

Table 5 : Percentage correct target identification as a function of language group and stimulus type (French words preceded by Dutch non-word primes; presentation times of 42 and 28 ms for prime and target, respectively)

Stimulus type	example	F monoling. BVV, 99	D-F biling. BVV, 99	F-D biling. VB, i.p.
homophonic	soer-SOURD	24	41	48
graphemic	siard-SOURD	33	34	42
unrelated	chane-SOURD	9	16	20
phon. priming		-9	7	6

General Discussion

The evidence presented in the preceding sections strongly suggests that visual word recognition is phonologically mediated to a large extent, not only in L1 but also in L2. In addition, the phonological representations of both languages seem to be activated in parallel and to interact, even when there is an inconsistency between the letters-sound correspondences in L1 and in L2 (otherwise, it is impossible to explain why the non-word prime *bleem* can prime the target word *BLAME* in English-Dutch bilinguals). Our results also suggest that the mutual interactions of L1 and L2 phonology are already present for proficiency levels well below balanced bilingualism, although it seems logical to accept that the letter-sound correspondences in L2 must have been encountered frequently enough to interfere with the inconsistent L1 correspondences.

Phonological coding of visual words has been suggested before as a reason to explain some unexpected findings in bilingual word recognition (e.g., Dijkstra et al., 1998; Doctor & Klein, 1992; Gollan, Forster, & Frost, 1997). However, it was not until we directly looked at cross-language phonological priming effects that we discovered how important it really was. Needless to say, none of this research would have been possible if first we had not understood the intricacies of how to run this type of phonological priming experiments.

Looking at the broader picture, one cannot help but feel that the evidence presented in this chapter is more easily incorporated in some models of bilingual word recognition than in others. For instance, our findings can be plugged directly into MacWhinney and Bates's competition model of second language acquisition (e.g., MacWhinney, 1997). This connectionist model holds that four properties of neural networks are important in second language acquisition: competition, gradience, emergence, and transfer. Because in the connectionist tradition all mental processing is assumed to make use of a common, interconnected set of cognitive structures, the first thing an individual will experience when learning a new language is a massive transfer (and interference) from L1 to L2. The amount of transfer will only be limited to the extent that L2 characteristics are not present in L1. For the rest, all aspects of the first language that can possibly transfer to L2 will transfer, meaning that the second language learner begins learning with a parasitic lexicon, a parasitic phonology, and a parasitic set of grammatical constructs. Applied to the issue of prelexical phonological coding, this implies that if L1 and L2 are written in the same alphabet, all L1 grapheme-phoneme conversions that can be used for the new language, will be used. In general, this will also be of profit to the learner, as it is rarely the case that languages with the same alphabet have a completely incompatible letter-sound mapping. Many letters have a similar pronunciation (e.g., the "b" is pronounced the same in English, Dutch, and French). This information is of immediate use to the beginning language learner. Other letter combinations (graphemes) only exist in L2 and can easily be added to the stored information because they do not contradict existing knowledge. This means that already from the beginning of the language acquisition process, a great deal of the phonology of the new language is available to the reader. The most difficult parts of the new phonology to acquire are those letter-sound correspondences that contradict existing ones (just like the most difficult aspects of a new language to master are those that go against the characteristics of the own mother tongue). In the beginning, these conflicting correspondences are likely to give rise to L1 generalisation errors, but gradually they become incorporated in the network, just like inconsistencies within a language become incorporated, until in the end the letter-sound mappings of the new language are not only mastered but also start to have an influence on the letter-sound conversions of the native language (because of the competition process).

In contrast, our data are much more difficult to integrate in models that capitalise on differences between L1 and L2 processing, either because L1 is assumed to be based on an innate language acquisition device whereas L2 is not (or less), or because the model assumes that the L2 word processing system is completely independent from the L1 word processing system.

Our data also pose difficulties for models of monolingual word recognition that deny a strong role of phonology in visual word processing and/or limit the phonology to the grapheme-phoneme rules of the first acquired language. In this respect, the bilingual data are a perfect illustration of how models that are not based on general learning principles, may be capable of accounting for the empirical findings when the scope is artificially restricted, but are prone to failure as soon as the full width of reality is faced. They certainly remind us that it may be dangerous to forget that probably more than half of the English speakers have knowledge of at least one other language.

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