UNIVERSITEIT GENT

FACULTEIT PSYCHOLOGIE EN PEDAGOGISCHE WETENSCHAPPEN

Auditory word recognition by bilinguals

Evelyne Lagrou

Promotor: Prof. Dr. Wouter Duyck

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Proefschrift ingediend tot het behalen van de academische graad
van Doctor in de Psychologie

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CONTENTS

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CHAPTER 1
INTRODUCTION

This doctoral dissertation is about bilingualism. But what exactly is required to be considered as being a bilingual? In contrast with common misconceptions about bilingualism, bilinguals are not rare, they do not necessarily have equal knowledge about both languages, and they are allowed to have an accent when speaking different languages. Instead, the more frequent adopted criterion adopted in the psycholinguistic literature for bilingualism is *"the regular use of both (or more) languages",* and bilinguals are *"those people who need and use two (or more) languages in their everyday lives"* (Grosjean, 1992, pp. 51). In this view, it has been estimated that more than half of the world's population is bilingual (Grosjean, 2010). Most often, these bilinguals are *unbalanced*, which means that they are more proficient in their dominant native language than in a second language. Exactly because (unbalanced) bilingualism is such a common phenomenon, it is important to understand the underlying mechanisms of bilingual word recognition. In psycholinguistics, a lot of studies have therefore now investigated how bilinguals represent their different languages. In defining such architecture, the first question that has posed itself is whether both languages rely on the same neural structures and cognitive processes, or alternatively whether they constitute independent systems so that it is even possible to completely "turn off" one language. Early theories on bilingualism tended towards the latter possibility, assuming that bilinguals have two lexicons (*mental dictionaries*) and only activate lexical candidates from the language in use. After all, most bilinguals can speak and read in each language without too many intrusions or errors (e.g., Poulisse & Bongaerts, 1994). However, especially in the visual domain, there is now a considerable amount of more recent evidence that bilinguals do not equal the sum of two monolinguals (Grosjean, 1989). These studies have demonstrated that a bilingual's languages are in constant interaction with each other, even though they are reading in a single language (e.g., Dijkstra & Van Heuven, 1998;

Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Van Assche, Duyck, Hartsuiker, & Diependaele, 2009; Van Assche, Drieghe, Duyck, Welvaert, & Hartsuiker, 2011). This evidence suggests that lexical candidates from both languages are initially activated and compete for recognition, even if only one language is relevant. Because there are so many visual word recognition studies, and because they have been an important inspiration for the work on auditory word recognition by bilinguals (e.g., in choosing markers of cross-lingual lexical interactions), we start the Introduction of this dissertation with a discussion of the literature on bilingual visual word recognition. Then we turn to the actual topic of the thesis, bilingual auditory word recognition. We will present an extensive overview of the studies that have been conducted in the bilingual auditory domain, both when listening to words out-of-context and in a sentence context. Next, we will provide a general theoretical framework for the studies on bilingual auditory word recognition that were carried out for this dissertation. In the final part of this Introduction, we give an overview of the studies presented in this thesis.

BILINGUAL VISUAL WORD RECOGNITION

Visual Word Recognition in Isolation

In the visual domain, numerous studies report findings in favor of a language-nonselective account of lexical access. Evidence for such an account has been reported for example using cognates (i.e., words that share not only orthography and phonology, but also semantics across languages). Typically, cognates (i.e., the Dutch-English cognate *ring*) are recognized faster than control words. This is called the cognate facilitation effect, and has been replicated several times in the literature (e.g., Caramazza & Brones, 1979; Dijkstra, Grainger, & Van Heuven, 1999; Duyck et al., 2007; Lemhöfer & Dijkstra, 2004; Libben & Titone, 2009; Van Assche et al., 2009; Van Hell & Dijkstra, 2002). Whereas this effect was initially only observed in second language (L2) word processing, there is now also evidence for cross-lingual lexical activation transfer (and hence language-nonselectivity) even in native language (L1) word processing. For example, Van Hell and Dijkstra tested Dutch-English-French trilinguals in a L1 lexical decision task. They observed that both L1-L2 cognates and L1-L3 cognates yielded faster reaction times than control words (although the L1-L3 cognate facilitation effect was only observed with high proficient L3 speakers).

Evidence for language-nonselectivity has also been found in a seminal study by Dijkstra, Timmermans, and Schriefers (2000). Dutch-English bilinguals responded more slowly to interlingual homographs (i.e., words that share orthography across languages, but not meaning, e.g., *room*, meaning *cream* in Dutch) than to matched control words in a language decision task (i.e., one button was pressed when an English word was presented and another button was pressed for a Dutch word). Similarly, reaction times were slower for interlingual homographs than for controls in an English or a Dutch go/no-go task (i.e., press a button only when the stimulus is a word in the target language). Further evidence was found by Dijkstra, Moscoso del Prado Martín, Schulpen, Schreuder, and Baayen (2005). They observed that Dutch-English bilinguals recognized interlingual homographs more slowly than control words in an English visual lexical decision task (i.e., requiring a yes-response when reading an English word) or a Dutch visual lexical decision task (i.e., requiring a yes-response when reading a Dutch word), but faster than control words when they had to complete a generalized visual lexical decision task (i.e., a yes-response was required for words from both languages).

Sentence Reading

Of course, in daily life people rarely read lists of isolated words; instead, words are embedded in sentences. Therefore, more recent studies investigated whether the assumption of language-nonselectivity is still valid when reading meaningful sentences in L2 (e.g., Elston-Güttler, Gunter, & Kotz, 2005; Duyck et al., 2007) and in L1 (Van Assche et al., 2009). In the study by Elston-Güttler et al. with German-English bilinguals, interlingual homographs were presented at the end of a relatively low-constraining sentence (e.g., *The woman gave her friend a pretty gift* [poison]). After participants read the sentence, a target word appeared on the screen. This target could be either related to the L1-meaning of the homograph (*poison*, which is the translation of the German meaning of *gift*) or unrelated to the control sentence not containing a homograph (e.g., *The woman gave her friend a pretty shell*). Targets were recognized faster after the related homograph sentence than after the unrelated control sentence, but only in the first block of the experiment, boosting the L1 activation. Moreover, in a study by Duyck et al., Dutch-English bilinguals completing a visual lexical decision task on the final word of low-constraining sentences responded faster to cognate words (i.e., *banana – banana*) than to control words. In this study, the effect was replicated for sentence-embedded target words using an eyetracking methodology. In this experiment, the authors also observed the cognate facilitation effect, but only for identical cognates (e.g., *ring*). This suggests that the presentation of a sentence context may influence, but does not annul cross-lingual interactions in the bilingual lexicon.

With respect to L1 recognition, the influence of a second language when reading sentences was investigated by Van Assche et al. (2009). In this eyetracking study, Dutch-English bilinguals read low-constraining sentences in which a cognate or a control word was embedded (e.g., *Bert heeft een oude OVEN/LADE gevonden tussen de rommel op zolder* [Bert has found an old OVEN/DRAWER among the rubbish in the attic]). Reading times demonstrated that cognates were read faster than control words, and that there was a continuous effect of phonological overlap (i.e., faster reading times for cognates with higher degrees of Dutch-English overlap). These results suggest that even when bilinguals are reading in their native language, they are still influenced by knowledge of a second language. It also clarifies the L2 results of Duyck et al. (2007), by showing that cross-lingual facilitation may still be observed for non-identical cognates if a sensitive (continuous) measure of interlingual overlap is used, instead of the dichotomous distinction by Duyck et al.

Semantic Constraint Effects

Further studies on bilingual visual word recognition investigated whether cross-lingual interactions might be modulated by the semantic constraint of the sentence. For example, in a L2 sentence reading study by Schwartz and Kroll (2006) cognate facilitation was observed when participants read low-constraining sentences (e.g., *When we entered the dining hall we saw the PIANO in the corner of the room*). However, when these targets were embedded in a sentence context that was very constraining toward the L2 target representation (e.g., *Before playing, the composer first wiped the keys of the PIANO at the beginning of the concert)*, the cognate facilitation effect disappeared. This effect was replicated by Van Hell and de Groot (2008). In that study, Dutch-English bilinguals completed a lexical decision task on the last word of low- and high-constraining sentences. There was cognate facilitation in the low-constraining sentences, but not in the high-constraining sentences.

In contrast, in a study in L2 by Libben and Titone (2009) and in L1 by Titone, Libben, Mercier, Whitford, and Pivneva (2011) and by Van Assche et al. (2011), cross-lingual interactions remained significant in the high-constraint sentences (although in the studies by Libben and Titone and Titone et al. only early eyetracking measures of reading were consistent with nonselective access). Taken together, these studies suggest that semantically rich sentences (i.e., high-constraining sentences) can modulate the degree of language-nonselectivity, although they do not necessarily annul cross-lingual interactions in the bilingual lexicon.

BILINGUAL AUDITORY WORD RECOGNITION

In contrast with bilingual visual word recognition, the number of studies that have investigated bilingual auditory word recognition is much more limited. Also, the results are not always consistent across studies, and many research questions that have been investigated in the visual domain remain unaddressed. This is remarkable, because social interactions and oral communication are part of daily life, and bilinguals do not only use their L2 when reading, but also very often when listening and speaking. Therefore, it is very important to investigate the underlying processes of bilingual auditory word recognition. This is especially interesting because there are compelling reasons why the results found in visual word recognition do not necessarily generalize to the auditory domain. First, auditory input is qualitatively completely different from visual input. In contrast to written words, after spoken words or sentences are pronounced, the signal disappears, and one cannot look back to verify the input. Second, speech is characterized by a large variability in the signal. Speakers differ for example significantly with respect to their pronunciation, there is often background noise which makes it more difficult to understand the speech, and speech varies as a function of the speaker's age, gender, social background, or the region the person comes from. Third, in written language there are punctuation marks to indicate the boundaries between words and sentences, whereas spoken language consists of a stream of speech, which makes it harder to position the boundaries, especially when listening in L2. Fourth, visual stimuli share the same or similar letters across languages so that the words do not necessarily contain information about their language membership, at least for languages that share the same alphabet (with a few exceptions, mainly with respect to the use of diacritics: <ç> occurs in French, but not in Dutch, English, or German; <ü> occurs in German, but not in Dutch, English, or French). In contrast, speech contains phonemic and sub-phonemic cues about the language in use. There are for example phonemes that occur in English but not in Dutch (e.g.,

/æ/) or vice versa (e.g., /y:/), and although some phonemes overlap between languages (e.g., /r/), they sound different because of allophonic variation. Evidence for the fact that the brain processes cues inherent to speech comes for example from Van Berkum, Van den Brink, Tesink, Kos, and Hagoort (2008). In their study, ERPs were measured while participants listened to sentences spoken by different individuals. Importantly, the semantic content of some of the sentences was incompatible with the information about that person that could be extracted from speech cues - for example when a male voice pronounced the sentence *“Before I leave I always check whether my make-up is still ok”*. In comparison with a control condition where the content was consistent with the inferred properties of the speaker, sentences with a mismatch between content and speaker elicited a difference in the ERP signal after about 200-300 ms. This indicates that listeners use cues in speech to make predictions about the meaning of upcoming words. Given that bilingual listeners are sensitive to these cues in speech, they might also use these speech cues to make predictions about the language of the words they hear, and thus restrict (or bias) lexical access to the language in use. This would actually be a very efficient strategy to speed up lexical search, because such a selection mechanism would considerably diminish the number of lexical candidates for recognition (a bit more or less than by half, depending on whether the target language is L2 or L1, assuming that the L1 lexicon is somewhat larger than the L2 lexicon). For all these reasons, research focusing specifically on bilingual auditory word recognition is necessary, similar to the monolingual domain where separate subdomains have evolved for visual versus auditory language processing.

Bilingual Auditory Word Recognition in L2

Research on bilingual auditory word recognition is much more scarce than research in the visual domain. However, there are still a few studies that have investigated whether lexical access is language-nonselective when listening in L2. The series of studies that actually started the interest for bilingual auditory word recognition was carried out by Marian and colleagues (e.g., Marian, Blumenfeld, & Boukrina, 2008; Marian & Spivey, 2003a, b; Marian, Spivey, & Hirsch, 2003; Spivey & Marian, 1999). These authors used the visual world paradigm in which highly proficient Russian-English bilinguals were instructed in their L2 (English) to pick up a real-life object (e.g., *"Pick up the marker"*). An eyetracking technique was applied to register eye movements, and the results showed that participants fixated more on competitor items with a name in the irrelevant L1 that was phonologically similar to the target (e.g., a stamp; *marka* in Russian), relative to distracter objects with a name in L1 that was phonologically unrelated to the L2 target. These results were replicated in an eyetracking study of Weber and Cutler (2004), in which less proficient Dutch-English bilinguals received the instruction to click on one of four pictures presented in a display and move it to another location on the computer screen (e.g., *"Pick up the desk and put it on the circle"*). Similar to the results of Marian and colleagues, the authors observed longer fixation durations on competitor objects with a phonologically similar L1 onset than to distracter objects (e.g., when participants were instructed to pick up the *desk*, they fixated longer on a picture of a *lid* than on distracter pictures, because *lid* is the translation equivalent of the Dutch word *deksel*, which overlaps phonologically with the L2 target *desk*). Additional evidence for language-nonselective lexical access when listening in L2 was reported by Schulpen, Dijkstra, Schriefers, and Hasper (2003). They administered a cross-modal priming task with auditory primes and visual targets to Dutch-English bilinguals. Visual lexical decision times were longer when the target was preceded by an interlingual homophone than when the target was preceded by a monolingual control. For instance, responses after the pair /li:s/ – LEASE were slower than after /freIm/ – FRAME (/li:s/ is the Dutch translation equivalent for *groin*). The observation of longer reaction times after interlingual homophone pairs suggests that bilinguals activated both the Dutch and the English meaning of the homophone, and hence supports language-nonselective lexical processing.

Furthermore, the authors observed that the auditory presentation of the English pronunciation of the interlingual homophone led to faster decision times on the related English target word than the Dutch pronunciation of the interlingual homophone. This indicates that these subtle (sub-phonemic) differences between homophones may affect the degree of cross-lingual activation spreading. This confirms the basic rationale that cues in the speech signal may influence interactions between languages, relative to visual word processing, demonstrating the need for bilingual research in the auditory domain.

Bilingual Auditory Word Recognition in L1

Less consistent findings have been obtained for auditory word recognition in L1. On the one hand, Spivey and Marian (1999), Marian and Spivey (2003a, b), and Marian, Spivey, and Hirsch (2003) replicated the results from their L2 studies when listening in L1: when Russian-English bilinguals received the instruction: *"Podnimi marku"* ("Pick up the stamp"), interlingual competitor objects (*marker*) were fixated more often than distracter objects. Again, this can be explained because the English translation equivalent of *marka* (stamp) is more phonologically similar to the Russian target word *marku* than to the distracters. Similar results were observed in a study by Canseco-Gonzalez, Brehm, Brick, Brown-Schmidt, Fischer, and Wagner (2010). In this study, the same visual world paradigm was applied with English-Spanish bilinguals who received the instruction to pick up an object from a display (e.g., *"Pick up the beans"*). The results showed that participants fixated more on competitor items with a name in the irrelevant L2 that was phonologically similar to the target (e.g., *bigote*, which means "mustache" in English) than on distracter objects with a name in L2 that was phonologically unrelated to the L1 target. However, unlike the effect for L2 listening, this effect when listening in L1 was *not* replicated by Weber and Cutler (2004). They found evidence for language-nonselectivity when listening in L2, but when Dutch-English bilinguals were instructed in their L1, competitor pictures with a phonologically similar L2 onset (e.g., *desk*, given target *deksel*, which means “lid” in Dutch) were not fixated longer than distracter pictures. This suggests that non-target language representations in L2 are not activated strongly enough to influence L1 recognition. A possible explanation for this apparent contradiction between Marian and colleagues and Weber and Cutler might be the difference in L2 proficiency of the bilinguals in both studies. Whereas the Russian-English bilinguals in the studies of Marian and colleagues were high-proficient in their L2 and lived in a L2 dominant environment, the Dutch-English bilinguals of Weber and Cutler were unbalanced, and lived in a L1 dominant environment.

In another L1 study, Ju and Luce (2004) also found that Spanish-English bilinguals fixated interlingual L2 distracters (nontarget pictures whose English names shared a phonological similarity with the Spanish targets) more frequently than control distracters. However, this was only the case when the Spanish target words were altered to contain English-appropriate voice onset times, but not when the Spanish targets had Spanish voice onset times, even though the bilinguals in this study were very proficient in their L2 (they had been living in a L2 dominant environment since birth or a very young age). Such an interaction seems to suggest that bilingual listeners use fine-grained, sub-phonemic, acoustic information to regulate cross-lingual lexical activation, which is consistent with the L2 results of Schulpen et al. (2003), discussed above.

BILINGUAL AUDITORY WORD RECOGNITION IN SENTENCES

In the literature on monolingual visual word recognition, several studies have shown that contextual information is used to facilitate word recognition in the native language. As a consequence, a large literature has developed focusing on sentence processing, rather than isolated word processing. A typical finding here is that a top-down sentence context influences lexical access, such that ambiguous words are easier to interpret when there is a context that helps to select the correct interpretation (e.g., Binder & Rayner, 1998; Onifer & Swinney, 1981; Rayner & Frazier, 1989). Also, predictable words are processed faster than non-predictable words (e.g., Schwanenflugel & LaCount, 1988; Schwanenflugel & Shoben, 1985; Stanovich & West, 1983). This yields the plausible hypothesis that in the case of bilingual word recognition, the language context provided by the sentence might also be used as a cue for lexical search. However, given that bilingual auditory word recognition studies in itself are already quite rare, the number of studies investigating the influence of a L2 sentence context is very limited. And, to our knowledge, there are even no studies investigating this issue in L1 auditory sentence comprehension.

Auditory Sentence Processing in L2

In a visual world study, Chambers and Cooke (2009) investigated whether interlingual lexical competition is influenced by the prior sentence context. English-French bilinguals listened to L2 sentences and were instructed to click on the image that represented the last word of the spoken sentence. Each display contained an image of the final noun target (e.g., *poule*, meaning *chicken*), an interlingual near-homophone whose name in English is phonologically similar to the French target (e.g., *pool*), and two unrelated distracter items. When the sentence information was compatible with the competitor (i.e., both the French target and the interlingual near-homophone are plausible in the sentence context) (e.g., *Marie va décrire la poule* [Marie will describe the chicken]), interlingual competitors were fixated more than unrelated distracter images. However, this was not the case when sentence information was incompatible with the competitor (i.e., only the French target, but not the interlingual near-homophone is plausible in the sentence context) (e.g., *Marie va nourrir la poule* [Marie will feed the chicken]). The results of this study indicate that sentence context can constrain cross-lingual lexical interactions in L2 word recognition. The restriction here however was only of a semantic nature, the homophone effect survived the unilingual language context of the neutral sentence.

Language-nonselectivity when listening to sentences in L2 was investigated further in an EEG study by FitzPatrick and Indefrey (2010). Dutch-English bilinguals listened to sentences in L2 that could be (a) congruent (e.g., "The goods from Ikea arrived in a large cardboard *box*"), (b) incongruent (e.g., "He unpacked the computer, but the printer is still in the *towel*"), (c) initially congruent within L2 (e.g., "When we moved house, I had to put all my books in a bottle"), or (d) initially overlapping with a congruent L1 translation equivalent (e.g., "My Christmas present came in a bright-orange doughnut", which shares phonemes with the Dutch *doos* "box"). When listening to incongruent sentences, a N400 component was observed that was delayed to L2 words, but not to L1 translation equivalents. This indicates that these L1 competitors that were initially congruent with the sentence context were not activated when Dutch-English bilinguals listened to sentences in L2. These studies suggest that sentence context imposes strong constraints on, or even annuls, cross-lingual lexical interactions, even for L2 recognition, which shows consistent interference effects from L1 in isolated word recognition.

Vandeberg, Guadalupe, and Zwaan (2011) went a step further and investigated whether cross-lingual lexical competition may even be constrained by mere word class restrictions. While looking at a visual world display, Dutch-English bilinguals listened to L2 sentences containing interlingual homophones from different word classes (e.g., the English verbe *spoke*, which overlaps phonologically with the Dutch noun for ghost, *spook*). The eyetracking results demonstrated that interlingual competitors were fixated more than unrelated distracters, so that they concluded that word class restrictions do not annul language-nonselective lexical interactions in a sentence context.

In sum, whereas Chambers and Cooke (2009) and FitzPatrick and Indefrey (2010) demonstrated that the degree of language-nonselectivity when listening to sentences in L2 is restricted by the preceding (semantic) sentence context, Vandeberg et al. (2011) still found cross-lingual interactions despite the grammatical (word class) restrictions imposed by the sentence context.

THEORIES ON BILINGUAL AUDITORY WORD RECOGNITION

It is clear from the previous brief overview of all relevant studies that there are far fewer studies on bilingual auditory word recognition than on bilingual visual word recognition. A similar tendency can be seen in the development of theoretical models that have been used to explain the data patterns in auditory word recognition by bilinguals. This is unfortunate, because as the data from the visual domain do not necessarily generalize to the auditory domain, and given the distinct processes that these models should capture, it is evident that bilingual auditory word recognition requires distinct models, just as in the monolingual psycholinguistic literature.

A crucial difference between the monolingual models that have been proposed is related to the way information flows between the different components of the processing system. Whereas autonomous models only assume a bottom-up flow in one direction from lower to higher components, interactive models additionally allow a top-down flow from higher to lower components. In the following paragraphs we give an overview of the monolingual and bilingual models of auditory word recognition.

Monolingual Models of Auditory Word Recognition

Marslen-Wilson and colleagues (Marslen-Wilson, 1987, 1990; Marslen-Wilson & Tyler, 1980; Marslen-Wilson & Welsh, 1978) proposed the ***Cohort*** model, which is a parallel activation model that consists of three levels of word recognition. On the first level, there is contact between the word recognition system and the acoustic-phonetic representations of speech input. At this point, a set of candidate words (i.e., a cohort) is activated, and this activation occurs based on feature overlap. For example, when the /t/ enters the word recognition system, all words that are part of this cohort (e.g., table, tree, task, twins…) are activated in a strictly bottom-up manner. Then, as more acoustic information comes in, certain words will cease to be compatible with the input, and so their activation strength is reduced. This implies that once the uniqueness point of a word is reached, there is only one word candidate in the cohort, and word recognition is complete. On a second level, there is a selection process that chooses one item from the cohort. In contrast with the first level, this selection process is sensitive to syntactic and semantic constraints. At the third level, words are integrated with the syntactic and semantic discourse. In this model, the emphasis on word onset is potentially problematic, because this cannot explain how it is possible to recover from early errors in perception. Moreover, because the uniqueness point of many words is located at the last phoneme, this model cannot explain how to recognize the onset of a new word in a speech stream.

A highly interactive model for auditory word recognition is ***TRACE*** (Elman & McClelland, 1988; McClelland & Elman, 1986), which is the auditory equivalent of the Interactive Activation Model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982) for visual word recognition. TRACE is a fully implemented connectionist model with three levels of processing elements (nodes) with resting activation values: the feature level, the phoneme level, and the lexical level. When there is speech input, the activation level of relevant nodes increases until a threshold is reached. Then, activation spreads to connected nodes. Between levels there is bottom-up activation from the lower levels to the higher levels, which in turn use their increasing activation to exert top-down influences on the lower levels. Within levels, there is inhibition towards elements that are incompatible with those activated by the input. However, because there is constant feedback between adjacent levels, errors at the phoneme level will automatically be corrected by top-down feedback from the lexical level, which makes it impossible to identify the nature of mispronunciations.

In contrast with the Cohort model and TRACE, ***Shortlist*** (Norris, 1994; Norris, McQueen, Cutler, & Butterfield, 1997) is a strictly autonomous model of auditory word recognition, in which word recognition occurs in two distinct stages. First, bottom-up information determines a set of candidate words that can be considered as members of the shortlist. Second, only the shortlisted candidates enter into a small interactive activation network. The model is similar to TRACE, but there is no top-down influence from higher levels on lower levels, the activation only spreads from phoneme level to word level, and there are bidirectional connections between nodes within a level, but not between adjacent levels.

Although these models were developed to account for the data patterns in monolingual word recognition, they could be adapted so that they can also predict the earlier results for bilingual word recognition, indicating cross-lingual lexical interactions. Therefore, these models would have to be extended with the assumption that L2 representations are part of the same system, and interact with L1 representations. In that case, these models would have to allow lexical competition between languages, in order to explain the markers of cross-lingual interactions. The subtle interactions between sub-phonemic, language-specific input and cross-lingual competition (e.g., increased cross-lingual interactions with non-target language voice onset times, Ju & Luce, 2004) may then be implemented through different mechanisms: this could be obtained by means of a bottom-up mechanism in which speech activates sub-phonemic cues related to the spoken language. Alternatively, speech input could activate the corresponding language node, which uses top-down feedback to regulate activation in lexical representations from the spoken language, *tuning* or biasing the lexical system to one of the languages.

Bilingual Models of Auditory Word Recognition

Whereas there are several models that make precise predictions, and even allow computational simulations of monolingual auditory word recognition data, only the first steps have been taken to construct connectionist models for bilingual auditory word recognition. To date, there are only two models that have made an attempt in doing this. In the following paragraph, we describe them in more detail.

First, there is ***BIMOLA*** (Bilingual Interactive Activation Model of Lexical Access), developed by Léwy and Grosjean (1997). However, this model has not yet been implemented and is only descriptive. Also, its formulation is now already quite old, and its further development appears to have stopped. According to BIMOLA there are two independent, but interconnected language networks. These lexicons are completely separate, so there can only be within-language competition at the word level. Within the system, there is a feature level that is common to both languages, and a phoneme level and a word level with independent subsets for both languages. Between these three layers, both bottom-up and top-down activation spreading is assumed. There are no language nodes, but top-down activation is spreading as a function of the bilingual's language mode (meaning that cross-lingual interactions are more likely in a bilingual than in a monolingual context; for the present dissertation this also implies that a sentence context rather constitutes a monolingual mode than isolated speech), and of the higher order linguistic information of a syntactic or semantic nature. Cross-lingual interactions are modeled by means of inhibition of L2 lexical representations (and not because there is activation of L1 representations).

Recently however, Shook and Marian (in press) proposed a new connectionist interactive model on bilingual auditory word recognition. This model is called ***BLINCS*** (Bilingual Language Interaction Network for Comprehension of Speech). BLINCS consists of an interconnected network of self-organizing maps that is able to learn by means of an unsupervised learning algorithm. These maps create interconnected phonological, phono-lexical, ortho-lexical, and semantic processing levels. Within the system, bidirectional interaction within and between the levels is possible because there is both feed-forward activation and back-propagation. The model has been implemented, and simulations predict strong cross-lingual interactions between languages that are influenced for example by lexical frequency and neighborhoodsize. As such, the model accounts for the observed markers of cross-lingual lexical interactions. These models will provide the theoretical framework for the empirical findings in this dissertation.

THE PRESENT DISSERTATION

The overview of the literature on bilingual auditory word recognition indicates that the number of studies investigating language-nonselectivity when listening in the native or a nonnative language is relatively limited. Additionally, the results of the different studies are not always consistent. Moreover, important research questions remain unaddressed, for example with respect to the influence of several constraints on the degree of language-nonselective lexical access. In this dissertation we investigated whether cross-lingual interactions are influenced by sub-phonemic cues inherent in the speech signal when listening to isolated words (Chapter 2) and to sentences (Chapters 3, 4, and 5). Importantly, we investigated this when listening in L2 *and* in L1. Second, we also tested whether sub-phonemic cues related to the native accent of the speaker (Chapters 2 and 4) and phonological differences between languages (Chapter 3) are used to restrict lexical access to the currently relevant lexicon. Finally, the influence of semantic constraint on cross-lingual lexical interactions was examined (Chapters 4 and 5).

Isolated Word Processing in L2 and L1

In ***Chapter 2***, we first investigated whether listening to isolated words in L2 is influenced by knowledge of L1, and crucially, whether listening to the L1 is also influenced by knowledge of a L2. With this aim, Dutch-English bilinguals completed an English (Experiment 1) or a Dutch (Experiment 3) auditory lexical decision task. As a control, the English auditory lexical decision task was also completed by English monolingual control participants (Experiment 2). Similar to several studies on bilingual visual word recognition, we used the homophone interference effect (i.e., slower reaction times on interlingual homophones like *lief* (sweet) – *leaf* /li:f/ than on matched control words) as a marker of lexical interactions in the bilingual lexicon. In the present study, we used a lexical decision paradigm, which is also often used in the literature on bilingual visual word recognition (e.g., Duyck et al., 2007). In this way, we also wanted to generalize the earlier findings on bilingual auditory word recognition which were almost exclusively based on the visual world paradigm, to a different task. In the visual word paradigm, one can not exclude with absolute certainty that the nontarget lexical representation is activated, not by lexical activation transfer from the target word, but directly by its visual depiction (although one would have to assume that this only occurs after target onset, given that such studies always include pre-target baseline eye movement controls). The homophone interference effect in the lexical decision paradigm excludes this possibility.

We expected to find an interlingual homophone interference effect in the bilingual group, but not in the monolingual group of participants. This would be in line with the work by Marian and colleagues (e.g., Marian & Spivey, 2003a, b; Spivey and Marian, 1999), and by Weber and Cutler (2004), although the latter only found evidence for cross-lingual interactions when listening in L2. A possible explanation for the absence of the effect in L1 in the Weber and Cutler study may be that the degree of cross-lingual overlap of the stimuli is quite limited. If this is the case, it is more likely to observe cross-lingual interactions in L1 in the present study because we used interlingual homophones with almost complete phonological overlap.

Second, we also tested whether the language-nonselective nature of lexical access is influenced by sub-phonemic cues provided by the speaker's native language, and thus his/her accent. Therefore targets were pronounced by a native Dutch speaker with English as the L2, or by a native English speaker with Dutch as the L2. Schulpen et al. (2003) already demonstrated that the degree of cross-lingual activation spreading is affected because bilinguals can exploit sub-phonemic cues when listening in L2. Additionally, Ju and Luce (2004) found evidence for the fact that sub-phonemic cues can influence the degree of language-nonselectivity when listening in L1. If bilingual listeners actually use these fine-grained sub-phonemic cues to regulate cross-lingual lexical activation spreading, we expected a larger homophone interference effect when targets were pronounced by the nonnative speaker (i.e., for L2 recognition, we expected larger cross-lingual interactions when targets are pronounced by the native Dutch speaker, while for L1 recognition we expected larger interactions when targets were pronounced by the native English speaker). We expected this because the nonnative speaker might introduce, for example, allophonic variation indicative of the nontarget language, and this variation may trigger the lexical system of the listener to also consider lexical candidates from the nontarget language.

Sentence Processing in L2 and L1

In Chapter 2 we investigated whether isolated auditory word recognition is influenced by knowledge of another language. However, rather than listening to isolated words, bilinguals use their languages often when having a conversation with other individuals. This is important because, in contrast with isolated words, full sentences contain many more sub-phonemic cues referring to the target language. And because sentences rarely contain language switches, the language of a sentence is also in itself a strong cue for lexical search: using the language of the sentence as a cue to restrict lexical search to only the representations belonging to the target language would be a very efficient strategy. Therefore, in ***Chapter 3*** we tested whether there are still cross-lingual interactions when the target word is embedded in a meaningful sentence. Dutch-English bilinguals participated in a visual world study in which eye movements were measured while they were listening to low-constraining sentences in L2 (Experiment 1) or in L1 (Experiment 2). If cross-lingual interactions can survive the constraints by embedding the target word in a sentence, we predicted that bilinguals will fixate more on interlingual competitor pictures with a name in the irrelevant language that is phonologically related to the target than to unrelated distracter pictures (e.g., *fles*, (bottle), given target *flower* for the L2 experiment, and *flower*, given target *fles* (bottle) for the L1 experiment). Additionally, we also investigated whether sub-phonemic cues influence cross-lingual interactions. Therefore, based on similarity judgments of an independent group of bilinguals, stimuli were subdivided in two groups: a group in which the overlapping part of target and competitor can be considered as phonologically very similar (e.g., *fles* (bottle) – *flower*), and a group in which the overlapping part of target and competitor is phonologically less similar (because of sub-phonemic differences, e.g., *koffer* (suitcase) – *comb*). This allows us to test whether phonological similarity is a constraining factor that can restrict lexical access to the currently relevant lexicon. If this is the case, we expected more cross-lingual interaction for items that were phonologically very similar than for items that were phonologically less similar. This would be compatible with computational models that predict more lexical competition between languages as a function of the overlap between representations.

Semantic Constraint Effects in L2

Because there are now several L2 studies demonstrating that lexical access is language-nonselective, we investigated in ***Chapter 4*** whether there are factors that can modulate this language-nonselectivity when listening in L2. In this chapter, three possible constraints were tested. First, we wanted to replicate the finding from Chapter 3 that the mere presentation of words in a sentence context is not sufficient to restrict lexical access. Second, we now additionally manipulated the semantic constraint of the sentences, in order to investigate whether the degree of cross-lingual interactions is reduced or annulled when listening to sentences that are highly constraining towards the target. Third, we also tested again whether sub-phonemic cues inherent to the native accent of the speaker, influence language-nonselectivity. With this aim, Dutch-English bilinguals completed an auditory lexical decision task on the last word of low- and high-constraining sentences. To test for sub-phonemic influences, sentences were again pronounced by a native Dutch or by a native English speaker. Because sentences contain more sub-phonemic cues referring to the target language than isolated speech, we expected that the homophone interference effect would be reduced in comparison with the effect in isolation, especially when the sentences were pronounced by the native English speaker (similar to the effects obserbed by Ju & Luce, 2004). However, because cues based on speaker accent are not always valid indicators of the language for recognition, it is possible that listeners still do not exploit them to regulate the degree of language-selectivity. Additionally, if the semantic constraint of the sentence is used as a cue to restrict lexical access to the currently relevant lexicon, we predicted a reduced (or maybe even annulled) homophone effect for the high-constraining sentences.

Semantic Constraint Effects in L1

There are currently no previous studies investigating language-nonselectivity when listening to sentences in L1. Therefore, we addressed this issue in ***Chapter 5***. Additionally, we also manipulated the semantic constraint of the sentences to test whether the presentation of words in high-constraining sentences can restrict cross-lingual interactions when listening in L1. Because there is evidence from previous studies that the effects from L2 on native language listening might be less robust, it could be that the presentation of a highly constraining sentence context in L1 results in a situation where multiple factors coincide to make lexical access language-selective. If this is the case, we predicted a reduced or annulled homophone interference effect when listening to high-constraining sentences in L1.

To summarize, in the present dissertation we investigated whether lexical access is language-nonselective when listening to words in isolation and in a sentence context, both in L2 and in L1. Additionally we tested whether this language-nonselectivity is influenced by sub-phonemic cues provided by the native accent of the speaker or phonological similarity between languages. Finally, we investigated the influence of the semantic constraint of the sentence on the degree of language-nonselective lexical access.

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CHAPTER 2
KNOWLEDGE OF A SECOND LANGUAGE INFLUENCES AUDITORY WORD RECOGNITION IN THE NATIVE LANGUGE[1]

Many studies in bilingual visual word recognition have demonstrated that lexical access is not language-selective. However, research on bilingual word recognition in the auditory modality has been scarce, and it yielded mixed results with regard to the degree of this language-nonselectivity. In the present study, we investigated whether listening to a second language (L2) is influenced by knowledge of the native language (L1) and, more importantly, whether listening to the L1 is also influenced by knowledge of a L2. Additionally, we investigated whether the listener's selectivity of lexical access is influenced by the speaker's L1 (and thus his/her accent). With this aim, Dutch-English bilinguals completed an English (Experiment 1) and a Dutch (Experiment 3) auditory lexical decision task. As a control, the English auditory lexical decision task was also completed by English monolinguals (Experiment 2). Targets were pronounced by a native Dutch speaker with English as the L2 (Experiment 1A, 2A, and 3A) or by a native English speaker with Dutch as the L2 (Experiment 1B, 2B, and 3B). In all experiments, Dutch-English bilinguals recognized interlingual homophones (e.g., lief (sweet) – leaf /li:f/) significantly slower than matched control words, whereas the English monolinguals showed no effect. These results indicate that (a) lexical access in bilingual auditory word recognition is not language-selective in L2, nor in L1, and (b) language-specific sub-phonological cues do not annul cross-lingual interactions.

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INTRODUCTION

Research on bilingual word recognition has mainly focused on the visual modality. However, bilinguals of course do not only use their second language (L2) when reading, but also when listening to speech in that L2. Moreover, bilinguals often need to recognize spoken words in L2 not only when these words are spoken by a native language (L1) speaker, but also when these words are spoken by someone who is also using a L2 (e.g., when Dutch-English bilinguals have a conversation with for instance a Hebrew-English bilingual). These issues raise the question of whether bilinguals represent their languages in functionally/structurally independent systems when listening to speech. Perhaps the simplest point of view is that bilinguals have two separate language systems and lexicons, so that a bilingual only accesses words of the currently relevant lexicon (e.g., Gerard & Scarborough, 1989). However, in the bilingual visual word recognition literature, there is now ample evidence supporting a language-nonselective account of lexical access, with bilinguals activating both language systems and lexicons in parallel (e.g., Dijkstra & Van Heuven, 1998; Duyck, 2005; Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Van Assche, Duyck, Hartsuiker, & Diependaele, 2009; Van Assche, Drieghe, Duyck, Welvaert, & Hartsuiker, 2011). According to this account, lexical representations from both languages always get activated to a certain degree, even if only one language is task-relevant.

In visual word recognition, the assumption of language-nonselectivity has been studied in several ways, for example by investigating the recognition of homographs (e.g., the Dutch-English homograph *room*, which means *cream* in Dutch). Dijkstra, Timmermans, and Schriefers (2000) for instance, observed longer reaction times (RTs) when reading homographs in a language decision task (i.e., one button was pressed when an English word was presented and another button was pressed for a Dutch word) as well as in a go/no-go task (i.e., participants responded only when they identified either an English word (English go/no-go) or a Dutch word (Dutch go/no-go)). Similarly, in a study by Dijkstra, Moscoso del Prado Martín, Schulpen, Schreuder, and Baayen (2005), Dutch-English bilinguals completed (a) an English visual lexical decision task, (b) a Dutch visual lexical decision task, and (c) a generalized visual lexical decision task (requiring yes-responses for words from both languages). Interlingual homographs were recognized slower than control words when participants completed the English (L2) or the Dutch (L1) visual lexical decision task, but faster than control words in the generalized visual lexical decision task. This implies that lexical access is language-nonselective, but that the direction of the homograph effect is task-dependent. When interlingual homographs are presented in a monolingual context (English or Dutch visual lexical decision task), activation of the language-irrelevant phonological representation should yield a no-response for the language-relevant lexical decision, and will therefore compete with the yes-response triggered by the activation of the language-relevant phonological representation of the homophone. This competition causes a delay in responding to homographs. However, when interlingual homographs are presented in a bilingual context (generalized visual lexical decision task), the activation of the Dutch and English phonological representation both activate the yes-response, which causes facilitation.

Second, many recent studies used cognate words (e.g., the Dutch-English cognate *tomato*) to investigate lexical access in bilinguals. A recurring observation is that participants respond faster to cognates than control words in a lexical decision task; this is called the *cognate (facilitation) effect* (e.g., Caramazza & Brones, 1979; Dijkstra, Grainger, & Van Heuven, 1999; Duyck et al., 2007; Lemhöfer & Dijkstra, 2004; Libben & Titone, 2009; Van Assche et al., 2009; Van Hell & Dijkstra, 2002). This effect is considered as a reliable marker for language-nonselective lexical activation, and is commonly explained by convergent activation spreading from the cognate's similar semantic, orthographic, and phonological representations across languages. In the study of Dijkstra et al. (1999), cross-lingual overlap with respect to semantics (S), orthography (O), and phonology (P) was systematically manipulated. They observed that orthographic and semantic overlap (SOP and SO items), as in cognates, resulted in response facilitation, whereas the recognition of words that only shared phonology (P) across languages (interlingual homophones) resulted in response inhibition. Initially, the cognate facilitation effect was only found in L2 word processing (e.g., Caramazza & Brones, 1979). However, recent evidence does support language-nonselectivity in L1 by demonstrating a bidirectional L1-L2 cognate facilitation effect. Van Hell and Dijkstra (2002) tested Dutch-English-French trilinguals in a Dutch lexical decision task. Both L1-L2 cognates and L1-L3 cognates yielded faster reaction times than control words. However, the L1-L3 cognate facilitation effect was only observed with high proficient L3 speakers. This is in line with an account of language-nonselective lexical access, but highlights the importance of language proficiency before cognate effects become noticeable in L1 processing. More recently, Van Assche et al. (2009) demonstrated in an eyetracking study that even in a L1 sentence context Dutch-English bilinguals read cognates faster than control words.

Third, Duyck (2005) demonstrated that recognition of L2 target words (e.g., *corner*) can be facilitated by L2 primes which are phonologically equivalent to L1 words (e.g., *hook*, a homophone of the L1 word *hoek*, which means *corner*). This implies that the phonological representation of the L2 prime /huk/ activates both its L1 (*corner*) and L2 (*hook*) meaning. But when the language of primes and targets was switched, the phonological representation accessed by a L1 prime did not activate both its L1 and L2 meaning.

Interestingly, it is less clear whether lexical access in the auditory modality is also language-nonselective (see below). Indeed, there are good reasons why the degree of language-selectivity during bilingual lexical access might differ across (visual vs. auditory) modalities: whereas visual stimuli in the languages typically tested use the same or similar letters (so that the words do not contain information about their language membership), speech contains phonemic and sub-phonemic cues about the language in use: there are many phonemes that occur in English but not Dutch (e.g., /æ/) or vice versa (e.g., /y:/); and while some phonemes overlap between the two languages (e.g., /r/), many of them sound different because of allophonic variation. Indeed, Grosjean (1988) showed that bilinguals are able to judge language membership of so-called guest words pronounced as either code-switches or borrowings, solely on the basis of the words' initial phonemes. Given that bilingual listeners are sensitive to these cues, they might use them to restrict lexical access to the language in use. This would actually be a very efficient strategy to speed up lexical search, because such a selection mechanism would considerably diminish the number of lexical candidates for recognition. Before we turn to the present study, we will first provide an overview of the few studies that have been conducted in the auditory domain.

Auditory Word Recognition by Bilinguals

In contrast to the large body of research in bilingual visual word recognition, evidence in favor of a language-nonselective account of lexical access in auditory word recognition has been relatively scarce. One interesting series of studies that reported evidence for a language-nonselective view of auditory word recognition was carried out by Marian and colleagues (e.g., Marian, Blumenfeld, & Boukrina, 2008; Marian & Spivey, 2003; Marian, Spivey, & Hirsch, 2003; Spivey & Marian, 1999). These authors used an eyetracking technique in which participants were instructed in their L2 (English) to pick up a real-life object (e.g., "*Pick up the marker*"). These participants were late Russian-English bilinguals with high L2 proficiency, living in a L2 dominant environment.[2] There were more fixations on competitor objects with a name in the irrelevant L1 that was phonologically similar to the target (e.g., a stamp; *marka* in Russian) than on distracter objects with a name in L1 that was phonologically unrelated to the L2 target.

Additionally, in a study by Schulpen, Dijkstra, Schriefers, and Hasper (2003) Dutch-English bilinguals completed a cross-modal priming task in which primes were presented auditorily and in which targets were presented visually. Visual lexical decision times were longer when the target was preceded by an interlingual homophone than when the target was preceded by a monolingual control (e.g., responses after the pair /li:s/ – LEASE were slower than after /freIm/ – FRAME; /li:s/ is the Dutch translation equivalent for *groin*). The observation of longer reaction times after interlingual homophone pairs suggested that bilinguals activated both the Dutch and the English meaning of the homophone. Furthermore, the authors observed that the auditory presentation of the English pronunciation of the interlingual homophone led to faster decision times on the related English target word than the Dutch version of the interlingual homophone. This indicates that sub-phonemic differences between homophones affect the degree of cross-lingual activation spreading, which is also relevant for the present study (see further).

Further evidence for nonselective lexical access was provided by Weber and Cutler (2004). In that study, Dutch-English bilinguals were instructed to click on one of four pictures presented in a display, and move it to another location on the computer screen (e.g., "*Pick up the desk and put it*

[2] These participants grew up in the former Soviet Union, but immigrated to the United States in their early teens, and were students at a top-tier American University at the time of testing. Only two of the participants stated that Russian was their preferred language at the time of testing, five stated that English was their preferred language, and five had no preference between Russian and English.

on the circle"). The authors observed longer fixation durations on competitor objects with a phonemically similar L1 onset than to distracter objects (e.g., when instructed to pick up the *desk*, participants fixated longer on a picture of a *lid* than on control pictures, because *lid* is the translation equivalent of the Dutch word *deksel*, phonologically overlapping with the L2 target *desk*). Moreover, these authors demonstrated a L1-L2 phonetic similarity effect: Dutch listeners hearing English speech fixated longer on competitor items with names containing vowels that are phonologically confusable with the vowels in the target item (e.g., *pencil*, given target *panda*); Dutch does not have the vowel contrast /ɛ/ - /æ/).

However, when we consider the few studies investigating whether knowledge of a L2 also interferes when bilinguals are listening in L1, the results are less clear. Evidence in favor of language-nonselectivity in L1 processing comes from studies by Spivey and Marian (1999) and by Marian et al. (2003). When Russian-English bilinguals received the instruction: *"Podnimi marku"* ("Pick up the stamp"), they looked more often to interlingual competitor objects *(marker)* than to distracter objects. Analogous to the findings with the English instructions, this can be explained because the English translation equivalent of *marka (stamp)* is more phonemically similar to the Russian target word *marku* than to the distracters.[3]

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[3] Note that the most straightforward evidence for both L1-L2 and L2-L1 interference was observed in the study by Marian et al. (2003). In this study the size of the interference effect was equivalent in both L2 and L1. Although the fixation time difference between targets and interlingual distracters was also the same in both L2 and L1 in the study by Spivey and Marian (1999), the L2 results demonstrated that participants fixated as much on interlingual distracter items as on unrelated distracter items. According to the authors this asymmetry across the two languages reflects a general tendency to scan the entire display before fixating on the target when instructions are presented in L2.

However, this effect has not been consistently replicated by other authors. Although Weber and Cutler (2004) observed longer fixation times on competitor pictures with a phonemically similar L1 onset than to dissimilar distracter pictures when listening in L2, they did not find an analogous effect when these Dutch-English bilinguals were instructed in their L1. Distracters that were phonologically related to English targets were fixated longer than phonologically unrelated distracters (*deksel*, given target *desk*), but when stimuli were translated into Dutch (*desk*, given target *deksel*), the cross-lingual interference effect disappeared. To complicate things further, Ju and Luce (2004) found that Spanish-English bilinguals fixated interlingual distracters (nontarget pictures whose English names shared a phonological similarity with the Spanish targets) more frequently than control distracters, but only when the Spanish target words were altered to contain English-appropriate voice onset times. This is very interesting for the present study because such an interaction indeed seems to suggest that bilingual listeners use fine-grained, sub-phonemic, acoustic information to regulate cross-lingual lexical activation. The latter finding is also interesting because Ju and Luce did not observe the L1 interference effect (as observed by Marian and colleagues) when Spanish targets had Spanish voice onset times, even though these bilinguals had been living in a L2 dominant environment since birth or a very young age.

Another factor that seems to constrain parallel language activation is language proficiency. For example, in an eyetracking study using the visual world paradigm, Blumenfeld and Marian (2007) tested German-native and English-native bilingual speakers of German and English when listening in English. On each trial, both groups of participants were instructed to click on a target. Each display contained (a) a target, that could either be a German-English cognate or an English-specific target, (b) a German competitor with phonologically similar word-onsets, and (c) two filler items. The results demonstrated that both bilingual groups fixated more on the German competitor item than on the filler items while processing cognate words, but that only German-native bilinguals, and not the English native bilinguals, coactivated German competitors while processing English-specific words. This demonstrates that parallel language activation is boosted for high-proficient bilinguals. However, in a study by Chambers and Cooke (2009) interlingual competition did not vary according to participant's proficiency, but was instead influenced by the prior sentence context. In this study, using the visual world paradigm, English-French bilinguals with varying proficiency levels listened to L2 sentences, and were instructed to click on the display that represented the last word of the sentence. Each display contained an image of the final noun target (e.g., *chicken*), and an interlingual near-homophone (e.g., *pool*) whose name in English was phonologically similar to the French target (e.g., *poule*). The results demonstrated that interlingual competitors were fixated more than unrelated distracter items when the prior sentence information was compatible (i.e., both the French target and the interlingual near-homophone are plausible in the sentence context) with the competitor (e.g., *Marie va décrire la poule* [Marie will describe the chicken]), but not when this sentence information was incompatible (i.e., only the French target, but not the interlingual near-homophone is plausible in the sentence context) with the competitor (e.g., *Marie va nourrir la poule* [Marie will feed the chicken]). Taken together, even although research on bilingual auditory word recognition is relatively scarce, the evidence in favor of a language-nonselective account of lexical access is mixed, and needs further exploration.

The Present Study

The present study was set up to investigate whether lexical access in auditory word recognition by bilinguals is language specific or not. This is especially important for L1 word recognition, given the inconsistent previous findings on this issue, discussed above. As a conservative test of this language-nonselectivity hypothesis, we tested this with a sample of proficient, but unbalanced bilinguals, who live in a L1 dominant environment. This contrasts with the work of Marian and colleagues (Marian et al., 2003; Spivey & Marian, 1999), who found interference from L2 to L1 processing with bilinguals living in a L2 dominant setting (but see Ju & Luce, 2004). Our Dutch-English bilinguals completed an English (Experiment 1) and a Dutch (Experiment 3) lexical decision task in which the same Dutch-English homophones (e.g., *lief* (sweet) – *leaf* /li:f/) were presented. The English lexical decision task was also completed by a group of monolingual English participants (Experiment 2). Our first question was whether Dutch-English bilinguals use sub-phonemic cues inherent to speech to decide which lexicon has to be activated and accessed. It seems plausible that bilinguals can exploit such cues, given that Grosjean (1988) showed that bilinguals can accurately judge language membership of words based on just the initial phonemes, and given that Ju and Luce (2004) found that fine-grained acoustic information such as non-target language (English) voice onset times inserted in auditorily presented target language (Spanish) words affect cross-lingual lexical activation.

Most (monolingual) models of native spoken word recognition seem to be compatible with effects of sub-phonemic information on the activation of language-specific lexical items; these models include the Distributed Model of Speech Perception, Shortlist, NAM, and TRACE. According to the Distributed Model of Speech Perception (Gaskell & Marslen-Wilson, 1997), which is the successor of the Cohort model (Marslen-Wilson, 1987; 1990; Marslen-Wilson & Tyler, 1980; Marslen-Wilson & Welsh, 1978), there are no discrete units for each lexical entry to represent lexical knowledge, as was the case in the original Cohort model, but there are distributed representations that use the same nodes for all lexical entries. This implies that lexical selection is influenced by the pattern and the amount of activation across a lexical representation. The Neighborhood Activation Model (NAM) of Luce and Pisoni (1998) is similar to the Distributed Model of Speech Perception (Gaskell & Marslen-Wilson, 1997), but also accounts for the influence of frequency of occurrence on processing. In contrast with these bidirectional models of spoken word recognition, the strictly bottom-up model Shortlist (Norris, 1994; Norris, McQueen, Cutler, & Butterfield, 1997) assumes that bottom-up information first determines a set of candidate words before the short-listed candidates compete with each other for recognition. However, there are no bidirectional connections between nodes at adjacent levels. For the case of bilingualism, these models would predict that sub-phonemic (e.g., allophonic variations) information (or even the activation of language-specific phonemes) related to the native accent of the speaker leads to larger activation in the lexical representations of the target language (*bottom-up*), resulting in smaller cross-lingual interactions. For instance, hearing an allophonic variation of /r/ by a native speaker, could provide sufficient bottom-up information to further activate only English lexical candidates during lexical search.

Alternatively, it could be the case that such information activates language nodes that then regulate activation in lexical representations belonging to a given language through *top-down* facilitation or inhibition, which is what would be predicted by the fully interactive TRACE model (Elman & McClelland, 1988; McClelland & Elman, 1986). This is a connectionist model with bidirectional connections between the feature level, the phoneme level, and the word level. This model is similar to the Shortlist model, but does assume influence from higher levels onto lower levels, which implies that activation does not only spread from the phoneme level to the word level, but also vice versa. According to TRACE, the presence of sub-phonemic information would result in lexical search processes that appear to be language-specific to a larger extent. Finally, a verbal model that is much less known than the computational models we mentioned above, but that is specifically designed to account for auditory word recognition in bilinguals, is Léwy and Grosjean's (1997) Bilingual Interactive Activation Model of Lexical Access (BIMOLA). This model assumes both bottom-up and top-down activation spreading between the different layers of the model. In contrast to the assumptions of the BIA+ model of bilingual visual word recognition, top-down activation is spreading as a function of the bilingual listener's language mode, and of the higher order linguistic information of a syntactic or semantic nature. Hence, if lexical access in L1 auditory word recognition would be language-selective, this could be modeled in BIMOLA by means of top-down inhibition of L2 lexical representations, following activation in language-specific (L1) phoneme representations.

Secondly, while our first question is concerned with the effects of target language cues, inherently present in spoken words, our second question is about sub-phonemic information conveyed by particular speakers. Languages differ of course in their phonological systems and only very few bilinguals manage to speak a second language without a persistent accent that provides many sub-phonemic (and sometimes even phonemic) cues about the speaker's first language. Previous work has demonstrated that listeners have some difficulty processing speech with a non-native accent (Adank, Evans, Stuart-Smith, & Scott, 2009) but it is not clear whether such an accent cues an irrelevant language that subsequently affects the degree to which lexical representations of that irrelevant language become active during lexical search. Our second question was therefore whether the accent of the speaker (i.e., Dutch or English), could influence the degree of language-selective lexical access. With this aim, the native accent of the speaker was systematically manipulated with the same set of stimuli and both in L1 and L2.

Again, there are at least two ways in which the sub-phonemic cues in (accented) speech of non-native speakers, now referring to a non-target language, could influence the selectivity of lexical access. The sub-phonemic information, referring to the non-target language, could trigger bottom-up activation in the lexical representations of that language, resulting in larger cross-lingual interaction effects. For instance, if a Dutch native speaker produces a more Dutch-like /r/ than a native speaker of English producing the correct allophonic variation, the system might also consider Dutch lexical candidates. This would be predicted by bottom-up models of spoken word recognition such as the Cohort model, the Distributed Model of Speech Perception, NAM, and especially Shortlist. The second possibility is that activation of irrelevant language representations lead to larger activation of the corresponding "language node" (see for instance TRACE, BIMOLA, or the early BIA model in visual word recognition). This would imply smaller non-target language inhibition than when listening to a native speaker, implying larger cross-lingual effects.

EXPERIMENT 1

ENGLISH LEXICAL DECISION TASK WITH DUTCH-ENGLISH BILINGUALS

In Experiment 1 we investigated whether L1 knowledge affects lexical access when listening to L2. With this aim, Dutch-English bilinguals completed an English lexical decision task in which interlingual homophones were presented auditorily. To answer the question whether this effect is sensitive to sub-phonemic/allophonic differences between native and nonnative speakers, targets were pronounced by a native Dutch speaker (Experiment 1A) or by a native English speaker (Experiment 1B).

Method

Participants

Thirty-four students from Ghent University participated in Experiment 1A for course credits or a monetary fee. All were native Dutch speakers and reported English as their L2.[4] They started to learn English

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[4] Although French is in fact the second language of children raised in Flanders, we consider it here as the third language because our participants are much more proficient in English.

around age 14 at secondary school, and because they were regularly exposed to their L2 through popular media, entertainment, and English university textbooks, they were all quite proficient in their L2. After the experiment, participants were asked to rate their L1 (Dutch) and L2 (English) proficiency with respect to several skills (reading, writing, speaking, understanding, general proficiency) on a 7-point Likert scale ranging from “very bad” to “very good”. We also assessed general L3 (French) proficiency. Means are reported in Table 1. Mean self-reported L1 (M = 5.94), L2 (M = 4.91), and L3 (M = 4.03) general proficiency differed significantly (dependent samples t-tests yielded ps < .001).

Table 1. Self-reported rating (7-point Likert Scale) of L1, L2, and L3 Proficiency (Experiments 1A, 1B, 3A, and 3B).

Language	Skill	Exp. 1A	Exp. 1B	Exp. 3A	Exp. 3B
	Writing	5.85 (0.74)	6.31 (0.58)	5.97 (0.93)	6.31 (0.60)
	Speaking	6.00 (0.70)	6.46 (0.61)	6.03 (0.97)	6.38 (0.82)
L1 (Dutch)	Reading	6.00 (0.89)	6.57 (0.56)	6.44 (0.56)	6.55 (0.57)
	Understanding	6.85 (0.36)	6.54 (0.56)	6.38 (0.58)	6.55 (0.51)
	General Proficiency	5.94 (0.55)	6.37 (0.55)	6.28 (0.58)	6.45 (0.63)
	Writing	4.65 (0.98)	4.89 (0.80)	4.97 (0.78)	5.00 (0.93)
	Speaking	4.74 (0.98)	5.14 (0.91)	5.38 (0.75)	5.38 (0.86)
L2 (English)	Reading	5.09 (0.97)	5.71 (0.83)	5.72 (0.85)	5.59 (0.98)
	Understanding	5.38 (0.78)	5.57 (0.78)	5.69 (0.90)	5.66 (0.77)
	General Proficiency	4.91 (0.79)	5.20 (0.83)	5.34 (0.70)	5.34 (0.72)
L3 (French)	General Proficiency	4.03 (1.14)	4.29 (1.10)	4.06 (1.05)	4.48 (0.99)

Participants were not informed that their L1 knowledge would be of any relevance to the experiment. Two participants made more than 20 % errors in the L2 lexical decision task, and were excluded from all analyses. In Experiment 1B there were 35 new participants. They met the same criteria as the participants in Experiment 1A, and were also asked to rate their L1, L2, and L3 proficiency. Means are reported in Table 1. Mean self-reported L1 (M = 6.37), L2 (M = 5.20), and L3 (M = 4.29) general proficiency differed significantly (dependent samples t-tests yielded ps < .001). One participant made more than 20 % errors and was excluded from all analyses.

Stimulus materials

The target stimuli consisted of 440 items: 44 interlingual Dutch-English homophones (e.g., *lief* (sweet) – *leaf* /li:f/), 44 matched English control words, 132 English fillerwords, and 220 nonwords. All targets were three to seven phonemes long. Interlingual homophones were selected from the stimulus lists of Dijkstra et al. (1999, 2005), Schulpen et al. (2003), or were selected from the CELEX lexical database (Baayen, Piepenbrock, & Van Rijn, 1993). Using the WordGen stimulus generation program (Duyck, Desmet, Verbeke, & Brysbaert, 2004), a control word was generated for each interlingual homophone, matched with respect to number of phonemes and L2 word frequency. The selected homophones and their matched control words are included in the Appendix. WordGen also generated the fillerwords and nonwords. Fillerwords did not differ from homophones and control words with respect to the matching criteria mentioned above. Nonwords were phoneme strings with no Dutch or English meaning, but with a legal English phonology. These were also matched with homophones and control words with respect to word length. In Experiment 1A each target was pronounced by a native Dutch speaker who was also a high-proficient English speaker, and in Experiment 1B each target was pronounced by a native English speaker who was also a high-proficient Dutch speaker. Fourteen targets (seven homophones, one control word, and six fillerwords) were translated incorrectly in a backward translation test following the experiment by more than 30 % of the participants; together with their matched stimuli these were removed from further analyses. Using WaveLab software, stimulus materials were recorded in a sound-attenuated booth by means of a SE Electronics USB1000A microphone on a sampling rate of 44.1 kHz and a 16-bit sample size. Target durations were measured with WaveLab software.

Speakers

The speaker in Experiment 1A was a 25 year old female with Dutch as L1 and English as L2. She had 12 years of experience with her L2. Her English was very fluent but characterized by a clear Dutch accent. The speaker in Experiment 1B was a 45 year old female with English as L1 and Dutch as L2. She had experience with her L2 since she moved to the Dutch-speaking part of Belgium 15 years ago. Her Dutch was very fluent but characterized by a clear English accent. Audio excerpts of both speakers are provided on http://expsy.ugent.be/research/Rdocuments.

Procedure

Participants received written instructions in L2 to perform a L2 lexical decision task. They were instructed to put on a headphone through which targets would be presented auditorily. Before the experiment, a practice session of 24 trials was completed. Each trial started with a 500 ms presentation of a fixation cross in the center of the screen. After another 200 ms the target was presented auditorily. Then participants had to decide whether they heard an English word or a nonword. When a word (nonword) was presented, participants used their right (left) index finger to press the right (left) button of a response box. Visual feedback (i.e., when an error was made the screen turned red, when the response was correct “OK!” appeared on the screen) was always presented on the screen during 200 ms. The next trial started 500 ms later. After the experiment, participants completed a questionnaire assessing self-ratings of L1 and L2 proficiency (reading, speaking, writing, understanding, and general proficiency), and general L3 proficiency on a 7-point Likert scale, and a backward translation test to verify that they knew the L2 words.

Results

Results Experiment 1A: native Dutch speaker

On average participants made 10.64 % errors (*SD* = 2.71). Errors, trials with RTs faster than 300 ms after target onset, and trials with RTs more than 2.5 standard deviations above the participant’s mean RT after target offset for word targets were excluded from the analyses. As a result, 12.91 % of the data were excluded from the analyses.

Latencies. In all experiments, reported latency analyses are based on reaction times measured from (auditory) target offset.[5] An ANOVA with target type (interlingual homophone vs. control) as the independent variable and RTs as the dependent variable demonstrated that homophones were

[5] We reported these measures because the native and non-native speaker differed in pronunciation duration (see further). When latency analyses were based on reaction times measured from (auditory) target onset, the same pattern of results was obtained.

recognized significantly slower than control words[6], *F1*(1,31) = 24.23, $p < .001$; *F2*(1,36) = 7.64, $p < .01$ (see Table 2).

Table 2. Mean RTs and Effect (in Milliseconds), and Accuracy (% Errors) as a function of word type (both RT and Accuracy) for Experiment 1A and 1B.

	Controls		Homophones		Effect	
Speaker	RT	% Errors	RT	% Errors	RT	% Errors
Experiment 1A: Native Dutch speaker	372	11.15	417	20.95	45	9.80
Experiment 1B: Native English speaker	290	10.57	331	15.10	41	4.53

Accuracy. An ANOVA with target type (interlingual homophone vs. control) as the independent variable and error percentage as the dependent variable mirrored RT analyses by revealing that participants made more errors on homophones than on control words, *F1*(1,31) = 71.82, $p < .001$; *F2*(1,36) = 5.40, $p < .05$ (see Table 2).

[6] To investigate the effect of word frequency on the homophone effect, we ran an ANOVA (including the data of Experiments 1A and 1B) with target type (interlingual homophone vs. control) and word frequency (low vs. high) as the independent variables and RTs as the dependent variable. This analysis revealed a significant interaction between target type and word frequency *F1*(1,64) = 28.54, $p < .001$; *F2*(1,72) = 15.57, $p < .001$, indicating that the homophone effect was larger for homophones with a low frequent English meaning.

Results Experiment 1B: native English speaker

On average, participants made 9.53 % errors (*SD* = 3.95). Errors, trials with RTs faster than 300 ms after target onset, and trials with RTs more than 2.5 standard deviations above the participant's mean RT after target offset for word targets were excluded from the analyses. As a result, 11.39 % of the data were excluded from the analyses.

Latencies. An ANOVA with target type (interlingual homophone vs. control) as the independent variable and RTs as the dependent variable demonstrated that homophones were recognized significantly slower than control words, $F1(1,33) = 25.48$, $p < .001$; $F2(1,36) = 5.93$, $p < .05$ (see Table 2).

Accuracy. An ANOVA with target type (interlingual homophone vs. control) as the independent variable and error percentage as the dependent variable mirrored RT analyses by revealing that participants made more errors on homophones than on control words, $F1(1,33) = 9.81$, $p < .01$; $F2(1,36) = 5.19$, $p < .05$ (see Table 2).

Comparison Experiment 1A-1B

We also compared the results of Experiment 1A, in which targets were pronounced by a native Dutch speaker, and the results of Experiment 1B, in which targets were pronounced by a native English speaker (see Figure 1).

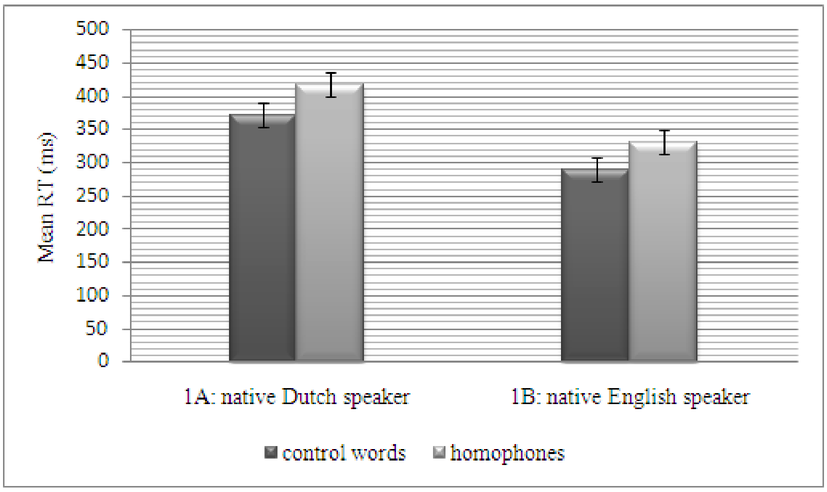

Figure 1. Graphical presentation of RTs on homophones and matched control words in Experiment 1, when targets were pronounced by a native Dutch speaker (1A) and a native English speaker (1B). The vertical bars represent the 95 % confidence interval.

An ANOVA with target type (interlingual homophone vs. control) as the independent within-subjects variable, speaker (native Dutch vs. native English) as the independent between-subjects variable, and RTs as the dependent variable demonstrated a main effect of speaker, $F1(1,64) = 14.76$, $p < .001$; $F2(1,72) = 23.89$, $p < .001$, which showed that RTs were slower when targets were pronounced by the native Dutch speaker than when they were pronounced by the native English speaker. The main effect of target type was also significant, $F1(1,64) = 55.65$, $p < .001$; $F2(1,72) = 13.39$, $p < .001$, indicating that participants recognized homophones slower than control words. More importantly, the interaction between target type and the L1 of the speaker was not significant, $F1 < 1$ and $F2 < 1$.

Discussion

The results of the L2 lexical decision task were very straightforward: auditorily presented homophones were recognized more slowly than matched control words. This provides evidence that lexical representations of more than one lexicon are activated during monolingual L2 auditory word recognition. This implies that bilingual listeners do not use sub-phonemic cues inherent to speech as a cue to restrict lexical search to a single language.

In our comparison of the results of Experiments 1A and 1B there was a main effect of speaker: reaction times were slower when targets were pronounced by the native Dutch speaker. There are two possible explanations for this effect. First, because the native English speaker did not have a Dutch accent, her pronunciation may provide a closer match to the listener's stored lexical representations, so that the threshold for word recognition was exceeded faster, yielding faster word/nonword decisions. This explanation is also compatible with the results of Adank et al. (2009), who observed longer RTs when participants listened to a speaker with a nonnative accent. Second, we noted that the English speaker tended to stretch the pronunciations (particularly the final phonemes) more than the Dutch speaker; indeed, target word durations were significantly longer when spoken by the English speaker (a dependent samples t-test yielded $p < .001$) (see Table 3). Because of the longer word duration, lexical activation has more time to accumulate as speech unfolds, so that participants can respond more quickly at speech offset. However, if we analyzed the RTs from target onset, the main effect of speaker remained significant, which makes this explanation less plausible.

Table 3. Mean target durations (in ms) in Experiment 1 and 3 when targets were pronounced by the Dutch or the English native speaker as a function of word type. Standard deviations are presented between brackets.

	Native Dutch speaker		Native English speaker	
	Controls	Homophones	Controls	Homophones
Exp. 1: L2 lexical decision task	437 (80)	449 (70)	606 (94)	599 (100)
Exp. 2: L1 lexical decision task	435 (73)	406 (68)	604 (130)	567 (115)

Finally, if sub-phonemic cues can influence the degree of language-selectivity, one would expect an interaction between target type and speaker. Because the L2 and L1 pronunciations of the targets differ at the sub-phonemic level, we assumed that participants could use this information as a cue to indicate which language is in use. Considering that the nonnative target pronunciation contains sub-phonemic cues of both languages, one may predict that the homophone effect should be larger when targets were pronounced by the nonnative speaker. However, there was no trace of an interaction between target type and speaker, demonstrating that bilinguals do not use these sub-phonemic differences between languages as a strict cue for language selection.

In Experiment 2, the same set of stimuli was tested with a group of English monolinguals. Because these participants do not have any knowledge of Dutch, we expected no difference between reaction times on homophones and on control words.

EXPERIMENT 2

ENGLISH LEXICAL DECISION TASK WITH ENGLISH MONOLINGUALS

Although the stimulus materials used in Experiment 1 were carefully controlled item by item, it is not impossible that certain stimulus characteristics that were not taken into account could have influenced the results. In order to ensure that the observed homophone effect in Experiment 1 is indeed due to L1 activation during L2 listening, a control experiment with English monolinguals was carried out.[7] In this experiment the same stimulus materials as in Experiment 1 were presented to these monolingual participants. If the homophone effect in Experiment 1 is caused by cross-lingual interactions when listening to L2, this effect should disappear for English monolinguals.

Method

Participants

Thirty students from the University of Southampton participated in Experiment 2A and received course credit or a monetary fee. They were all

[7] We opted for a control experiment in another country because a control experiment with these homophones in Dutch monolinguals is by definition not possible. According to Graddol (2004) in the Netherlands nearly 80 % of the population claims fluency in English. We suspect that this number is comparable in the Dutch-speaking community of Belgium. For our study, this implies that the entire population has at least some knowledge of English, except specific groups that would also differ on several other related variables.

native speakers of English and had no knowledge of Dutch. Two participants made more than 20 % errors and were excluded from all analyses. In Experiment 2B, 30 further students took part in the experiment. They met the same criteria as the participants in Experiment 2A. One participant made more than 20 % errors and was excluded from all analyses.

Stimulus Materials, Speakers, and Procedure

Stimulus materials, speakers, and procedure were identical to Experiment 1, except that the participants did not complete a questionnaire assessing self-ratings of L1 and L2 proficiency, and a backward translation test after the experiment.

Results

Results Experiment 2A: native Dutch speaker

On average participants made 13.90 % errors (SD = 2.62). Errors, trials with RTs faster than 300 ms after target onset, and trials with RTs more than 2.5 standard deviations above the participant's mean RT after target offset for word targets were excluded from the analyses. As a result, 16.21 % of the data were excluded from the analyses.

Latencies. An ANOVA with target type (interlingual homophone vs. control) as the independent variable and RTs as the dependent variable demonstrated that homophones were not recognized significantly slower than control words, $F1 < 1$ and $F2 < 1$ (see Table 4).

Table 4. Mean RTs and Effect (in Milliseconds), and Accuracy (% Errors) as a function of word type (both RT and Accuracy) for Experiment 2A and 2B.

	Controls		Homophones		Effect	
Speaker	RT	% Errors	RT	% Errors	RT	% Errors
Experiment 2A: Native Dutch speaker	399	14.12	402	15.69	3	1.57
Experiment 2B: Native English speaker	218	6.58	223	5.87	5	-0.71

Accuracy. An ANOVA with target type (interlingual homophone vs. control) as the independent variable and error percentage as the dependent variable mirrored RT analyses by revealing that participants did not make more errors on homophones than on control words, $F1(1,27) = 2.65$, $p > .05$; $F2(1,43) = 1.44$, $p > .05$ (see Table 4).

Results Experiment 2B: native English speaker

On average, participants made 7.41 % errors ($SD = 2.56$). Errors, trials with RTs faster than 300 ms after target onset, and trials with RTs more than 2.5 standard deviations above the participant's mean RT after target offset for word targets were excluded from the analyses. As a result, 9.30 % of the data were excluded from the analyses.

Latencies. An ANOVA with target type (interlingual homophone vs. control) as the independent variable and RTs as the dependent variable demonstrated that homophones were not recognized significantly slower than control words, *F1* < 1 and *F2* < 1 (see Table 4).

Accuracy. An ANOVA with target type (interlingual homophone vs. control) as the independent variable and error percentage as the dependent variable mirrored RT analyses by revealing that participants did not make more errors on homophones than on control words, *F1* < 1 and *F2* < 1 (see Table 4).

Comparison Experiment 2A-2B

We also compared the results of Experiment 2A, in which targets were pronounced by a native Dutch speaker, and the results of Experiment 2B, in which targets were pronounced by a native English speaker (see Figure 2).

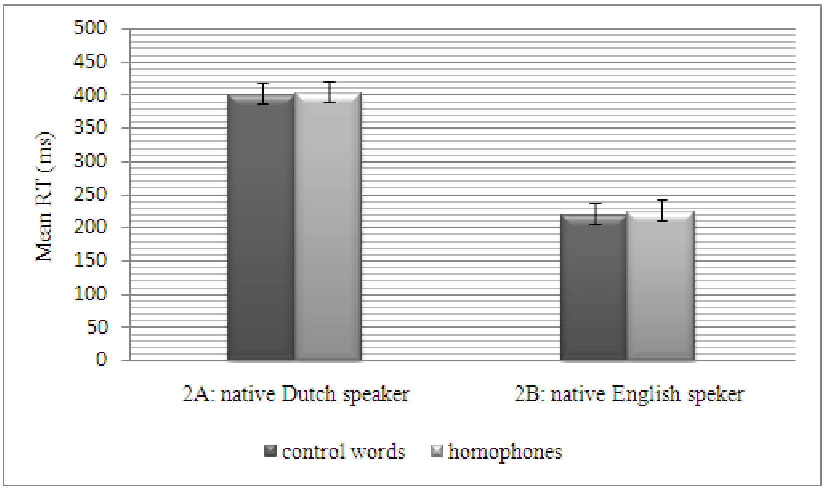

Figure 2. Graphical presentation of RTs on homophones and matched control words in Experiment 2, when targets were pronounced by a native Dutch speaker (2A) and a native English speaker (2B). The vertical bars represent the 95 % confidence interval.

An ANOVA with target type (interlingual homophone vs. control) as the independent within-subjects variable, speaker (native Dutch vs. native English) as the independent between-subjects variable, and RTs as the dependent variable demonstrated a main effect of speaker, $F1(1,55) = 66.77$, $p < .001$; $F2(1,86) = 293.89$, $p < .001$, which showed that RTs were slower when targets were pronounced by the native Dutch speaker than when they were pronounced by the native English speaker. The main effect of target type was not significant, $F1 < 1$ and $F2 < 1$. More importantly, the interaction between target type and the L1 of the speaker was not significant, $F1 < 1$ and $F2 < 1$.

Comparison Bilinguals – Monolinguals

Next, we compared the results of our Dutch-English bilinguals with the results of our English monolinguals. When targets were pronounced by the native Dutch speaker, an ANOVA with target type (interlingual homophone vs. control) as the independent within-subjects variable, speaker (native Dutch speaker vs. native English speaker) and sample (bilinguals – monolinguals) as the independent between-subjects variables, and RTs as the dependent variable demonstrated a significant interaction between target type and the sample, $F1(1,119) = 22.03$, $p < .001$; $F2(1,158) = 13.27$, $p < .001$. The interaction between speaker and sample was also significant, $F1(1,119) = 9.98$, $p < .001$; $F2(1,158) = 30.16$, $p < .001$, indicating a larger speaker effect for our monolinguals than for our bilinguals (i.e., our English monolinguals responded faster than our bilinguals when targets were pronounced by the native English speaker).

Discussion

In this control experiment, English monolinguals completed the same English auditory lexical decision task as the Dutch-English bilinguals in Experiment 1. The results showed that these monolingual participants recognized homophones equally fast as control words. In line with the results of Experiment 1 we also observed a main effect of speaker, with faster reaction times when targets were pronounced by the native English speaker. This effect was even larger in our monolingual than in our bilingual group of participants, which can be explained by the fact that monolingual speakers of English are less familiar with the Dutch pronunciation of English than our bilinguals. As in Experiment 1, the main effect of speaker is probably due to the fact that the native speaker provides speech input that matches the listener's stored lexical representation more closely. The absence of the homophone effect in this group of participants, together with the significant interaction between target type and the sample, ensures that the observed homophone effect in Experiment 1 indeed resulted from their bilingual knowledge, and more specifically from the cross-lingual activation of L1 when listening in L2.

In the next experiment, we investigated whether we could also provide evidence for a view of language-nonselective lexical access in auditory word recognition when listening in the native language. In line with the results of Experiment 1, we expected an equivalent homophone effect with both L1 and L2 speakers. The next experiment using Dutch targets also allows dissociating between two possible explanations for the observation that RTs are faster when targets are pronounced by the native English speaker: if the effect depends on the articulation times of the particular speaker, one would predict that RTs are again faster for the English speaker. Instead, if the effect originates from the speaker's accent (non-native speech that mismatches stored lexical representations somewhat), we would predict slower RTs for the English speaker.

EXPERIMENT 3

DUTCH LEXICAL DECISION TASK WITH DUTCH-ENGLISH BILINGUALS

Experiment 3 tested whether L2 knowledge affects lexical access when listening to L1. With this aim, Dutch-English bilinguals completed a Dutch auditory lexical decision task in which interlingual homophones were again the crucial targets. To answer the question of whether the homophone effect is sensitive to sub-phonemic differences between native and nonnative speakers, targets were again pronounced by a native Dutch speaker (Experiment 3A) or by a native English speaker (Experiment 3B).

Method

Participants

Thirty-two students from Ghent University participated in Experiment 2A for a monetary fee. All of them met the same criteria as the participants of Experiment 1. Mean proficiency ratings are reported in Table 1. Mean self-reported L1 (M = 6.28), L2 (M = 5.34), and L3 (M = 4.06) general proficiency differed significantly (dependent samples t-tests yielded ps < .001). Participants were not informed that their L2 knowledge would be of any relevance to the experiment. Because virtually all university students in Ghent are sufficiently L2 proficient to participate, knowledge of English was not mentioned as a participation criterion in recruitment. In Experiment 3B there were 29 further participants. They met the same criteria as the participants in Experiment 3A and they were also asked to rate their L1, L2, and L3 proficiency. Means are reported in Table 1. Mean self-reported L1 (*M* = 6.45), L2 (*M* = 5.34), and L3 (*M* = 4.48) general proficiency differed significantly (dependent samples t-tests yielded *p*s < .001). Two participants made more than 20 % errors and were excluded from all analyses. None of the participants participated in Experiment 1.

Stimulus materials

The target stimuli consisted of 440 items: 44 interlingual Dutch-English homophones which were phonologically equivalent to the homophones in Experiment 1, 44 matched Dutch control words, 132 Dutch fillerwords, and 220 nonwords. Nonwords were phoneme strings with no Dutch or English meaning, but with a legal Dutch phonology. All targets met the same selection criteria as in Experiment 1. The selected homophones and their matched control words are included in the Appendix. The same native Dutch (Experiment 3A) and native English (Experiment 3B) speakers as in Experiments 1 and 2 pronounced all targets for the Dutch lexical decision task. Six homophones were translated incorrectly in the forward translation test following the experiment by more than 30 % of the participants; together with their matched stimulus these were removed from further analyses. The same procedure as in Experiment 1 was followed for material recording and processing.

Procedure

The procedure was identical to Experiments 1 and 2, except that participants now received written instructions in Dutch and that they had to decide whether they heard a Dutch word or a nonword.

Results

Results Experiment 3A: native Dutch speaker

On average participants made 6.48 % errors (*SD* = 2.69). Errors, trials with RTs faster than 300 ms after target onset, and trials with RTs more than 2.5 standard deviations above the participant's mean RT after target offset for word targets were excluded from the analyses. As a result, 8.34 % of the data were excluded from the analyses.

Latencies. An ANOVA with target type (interlingual homophone vs. control) as the independent variable and RTs as the dependent variable demonstrated that homophones were recognized significantly slower than control words[8], $F1(1,31) = 72.21$, $p < .001$; $F2(1,37) = 18.07$, $p < .001$ (see Table 5).

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[8] To investigate the effect of word frequency on the homophone effect, we ran an ANOVA (including the data of Experiments 3A and 3B) with target type (interlingual homophone vs. control) and word frequency (low vs. high) as the independent variables and RTs as the dependent variable. This analysis revealed a significant interaction between target type and word frequency $F1(1,57) = 4.88$, $p < .05$; $F2(1,74) = 7.63$, $p < .01$, indicating that the homophone effect was larger for homophones with a low frequent Dutch meaning.

Table 5. Mean RTs and Effect (in Milliseconds), and Accuracy (% Errors) as a function of word type (both RT and Accuracy) for Experiment 3A and 3B.

	Controls		Homophones		Effect	
Speaker	RT	% Errors	RT	% Errors	RT	% Errors
Experiment 3A: Native Dutch speaker	289	5.51	354	13.98	65	8.47
Experiment 3B: Native English speaker	352	10.43	404	21.05	52	10.62

Accuracy. An ANOVA with target type (interlingual homophone vs. control) as the independent variable and error percentage as the dependent variable mirrored RT analyses by revealing that participants made more errors on homophones than on control words, $F1(1,31) = 45.99$, $p < .001$; $F2(1,37) = 12.16$, $p < .01$ (see Table 5).

Results Experiment 3B: native English speaker

On average, participants made 11.34 % errors ($SD = 2.39$). Errors, trials with RTs faster than 300 ms after target onset, and trials with RTs more than 2.5 standard deviations above the participant's mean RT after target offset for word targets were excluded from the analyses. As a result, 13.70 % of the data were excluded from the analyses.

Latencies. An ANOVA with target type (interlingual homophone vs. control) as the independent variable and RTs as the dependent variable demonstrated that homophones were recognized significantly slower than control words, $F1(1,26) = 18.24$, $p < .001$; $F2(1,37) = 7.68$, $p < .01$ (see Table 5).

Accuracy. An ANOVA with target type (interlingual homophone vs. control) as the independent variable and error percentage as the dependent variable mirrored RT analyses by revealing that participants made more errors on homophones than on control words, $F1(1,26) = 31.18$, $p < .001$; $F2(1,37) = 8.77$, $p < .01$ (see Table 5).

Comparison Experiment 3A-3B

We also compared the results of Experiment 3A, in which targets were pronounced by a native Dutch speaker, and the results of Experiment 3B, in which targets were pronounced by a native English speaker (see Figure 3).

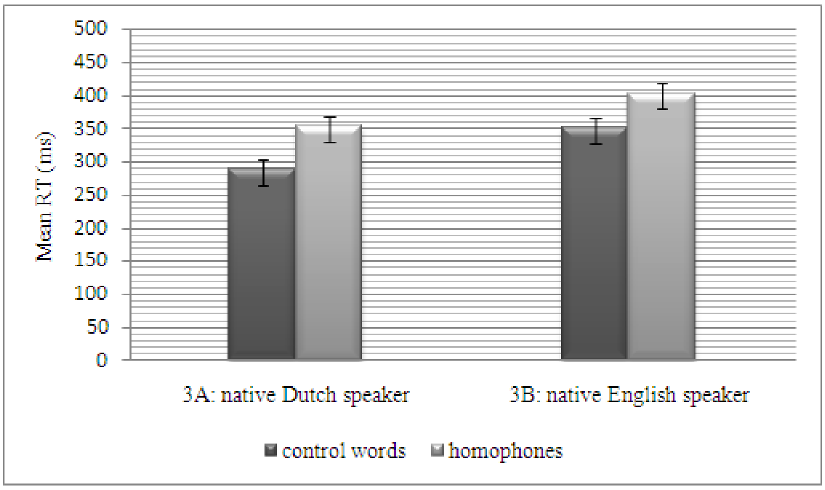

Figure 3. Graphical presentation of RTs on homophones and matched control words in Experiment 3, when targets were pronounced by a native Dutch speaker (3A) and a native English speaker (3B). The vertical bars represent the 95 % confidence interval.

An ANOVA with target type (interlingual homophone vs. control) as the independent within-subjects variable, speaker (native Dutch vs. native English) as the independent between-subjects variable, and RTs as the dependent variable demonstrated there was a significant main effect of speaker, $F1(1,57) = 4.03$, $p < .05$; $F2(1,74) = 16.64$, $p < .001$, indicating that RTs were slower when targets were pronounced by the native English speaker than when they were pronounced by the native Dutch speaker. The main effect of target type was also significant, $F1(1,57) = 78.44$, $p < .001$; $F2(1,74) = 22.56$, $p < .001$, indicating that participants recognized homophones slower than control words. As in Experiment 1, there was no interaction between target type and the L1 of the speaker, $F1 < 1$ and $F2 < 1$.

Discussion

The goal of this experiment was to provide further evidence for a language-nonselective account of lexical access in auditory word recognition, demonstrating that bilinguals are not only influenced by their L1 when listening to their L2, but also that a weaker L2 can influence the dominant, native L1. The results were straightforward: interlingual homophones were recognized slower than control words, both when targets were pronounced by a native Dutch speaker and when they were pronounced by a nonnative Dutch speaker. This is an important addition to the literature, especially because this cross-lingual lexical interaction effect in auditory word recognition was observed using unbalanced, late bilinguals living in a L1 dominant environment. It therefore extends previous work of Spivey and Marian (1999) and of Marian et al. (2003), who reported phonological similarity effects in the visual world paradigm with bilinguals immersed in a L2 setting. Moreover, this study demonstrated that this cross-lingual effect in L1 is equally large with L2 speakers as with L1 speakers. The present findings (at least those for L1 recognition) are inconsistent with Weber and Cutler (2004), who only reported cross-lingual effects during L2 listening, using the same eyetracking paradigm as Marian and colleagues.

This experiment also allows dissociating between two possible explanations for the main effect of speaker (i.e., faster RTs when targets were pronounced by a native English speaker) that we observed in Experiment 1. If this effect would have originated from the articulation times of the particular speaker, one would again have predicted faster recognition when listening to the native English speaker. Instead, if recognition was slower because a foreign accent yields speech that matched stored lexical representation less closely, one would now predict slower RTs for the English speaker (speaking Dutch). Comparing the results of Experiment 3A and Experiment 3B, we again observed a main effect of speaker, but now recognition was faster overall when targets were pronounced by the native Dutch speaker, in contrast with Experiments 1 and 2. These results support the suggestion that non-accented speech results in a better match with lexical representations than accented speech, and therefore speeds up word recognition. As in Experiment 1, there was no interaction between target type and the speaker, indicating that bilingual listeners do not use cues provided by sub-phonemic differences or allophonic variations between languages to restrict lexical search to a single language when listening in L1.

GENERAL DISCUSSION

The goal of this study was to answer two major questions: First, we wanted to investigate whether access to lexical representations in auditory word recognition is nonselective with respect to language. We examined homophone interference effects from L2 to L1 and vice versa, using unbalanced, late Dutch-English bilinguals, living in a L1 dominant environment. Our second research question concerned whether bilingual listeners are sensitive to sub-phonemic differences (e.g., allophonic variations) between the pronunciation of words by native and nonnative speakers, and whether they use these differences as a restrictive cue to limit lexical search to a single language. With this aim, we constructed a L2 and L1 lexical decision experiment in which targets were pronounced by a native Dutch or by a native English speaker. The results were clear-cut: We found that homophones were recognized slower than control words when participants were listening in L2 (Experiment 1), but also when they were listening in their dominant/native L1 (Experiment 3). Furthermore, this homophone effect was independent of the speaker's native language. In a control experiment with English monolinguals (Experiment 2) we did not find slower RTs for homophones than for control words. Therefore, we can safely conclude that the observed homophone effects with Dutch-English bilinguals are indeed due to lexical interactions in the bilingual lexicon, and not as a consequence of some confounded variable between homophone and control conditions. Moreover, to avoid the possibility that language-ambiguous stimuli may boost dual-language activation (Blumenfeld & Marian, 2007; Elston-Güttler, Gunter, & Kotz, 2005) in this study, only 10 % of the trials were interlingual homophones. Because this small percentage would probably not be much higher than the proportion of language-ambiguous stimuli in natural language use, we believe the experimental setting does not constitute an artificial bilingual context, and is not perceived as such by the participants. We will discuss the theoretical implications of these findings in the next paragraphs.

First of all, the fact that we do not only observe a homophone effect when listening in L2, but also in L1, provides convincing evidence for language-nonselective lexical access. It also shows that such interactions are quite robust, given that activation in lexical representations from a weaker language is strong enough to influence word recognition in the dominant language. Previously, a few studies in bilingual auditory word recognition have shown that L1 knowledge influences recognition of words in L2 (e.g., Schulpen et al., 2003; Weber & Cutler, 2004), but only two studies revealed some effects of L2 knowledge on the auditory recognition of words in L1, both using bilinguals that were immersed in a L2 speaking environment and/or started learning L2 at a young age (Marian et al., 2003; Spivey & Marian, 1999). This study demonstrated the effect of L2 knowledge on L1 auditory word recognition in a population of unbalanced, late bilinguals, living in a L1 dominant environment. Moreover, we investigated L2-L1 and L1-L2 effects in two samples of a very homogeneous population, using the same homophones, which allows a quite direct comparison of the effects. These findings are inconsistent with Weber and Cutler (2004), who only observed cross-lingual lexical interactions during L2 recognition, but not in L1 recognition. The crucial difference between that study and the present one may lie in the strength of the cross-lingual phonological overlap manipulation. Whereas the present study used interlingual homophones with almost complete overlap across languages, the eyetracking paradigm used by Weber and Cutler (and by Marian and colleagues) used items that shared only a few phonemes (the onset) across languages. This may explain why the cross-lingual phonological interference effects of Weber and Cutler are absent in L1 recognition.

The main finding of the present study, the interlingual homophone effect, can be explained within the Distributed Model of Speech Perception (Gaskell & Marslen-Wilson, 1997), NAM (Luce & Pisoni, 1998) and Shortlist (Norris, 1994; Norris, McQueen, Cutler, & Butterfield, 1997), if these models are extended with the assumption that L2 representations are part of the same system as, and interact with, L1 representations. These models predict competition, and therefore slower recognition of interlingual homophones, under the above assumption. In general, the cross-lingual interactions observed here are also in line with the core assumption of BIMOLA (Léwy & Grosjean, 1997) that the auditory presentation of a homophone activates phoneme representations, and then lexical representations in both languages. When words from two languages are activated, the bilingual listener needs additional information (and hence more time) to make a final decision about which word is selected. This assumption was confirmed by the results of both experiments. These findings imply that sub-phonemic information referring to the target language does not imply selective bottom-up activation of lexical representations belonging to (only) that language, nor top-down regulation of target language (facilitation) or non-target language (inhibition) lexical representations. This also implies that there is no need for an additional mechanism that uses language nodes (e.g., as in the visual BIA model (Dijkstra & Van Heuven, 1998)) or language schemes (e.g., as in BIA+ (Dijkstra & Van Heuven, 2002)) to inhibit the non-relevant language, because the same mechanisms for within-language competition may be used to account for between-language competition. Thus, at a theoretical level, the results of the present study are compatible with models of auditory word recognition that support language-nonselective bottom-up activation with a very limited role for top-down connections.

Second, the present findings offer a clear answer to the question of whether bilinguals are sensitive to sub-phonemic differences or allophonic variations between the pronunciation of words by native or nonnative speakers, and whether they use these differences to modulate activation of lexical representation belonging to a single language. Such modulation of cross-lingual effects may also have at least two different origins: it may be the case that sub-phonemic cues from a non-target language trigger activation in lexical representations belonging to that language (*bottom-up*), so that a foreign accent yields larger homophone effects. On the other hand, such modulation may also occur through a different mechanism, by which hearing sub-phonemic cues of an irrelevant language causes a 'dual-language mode' (in BIMOLA's terms), triggering *top-down* activation of all representations belonging to that language, again yielding larger homophone effects. However, our results demonstrated that the size of the homophone effect was equivalent when targets were pronounced by a L1 or a L2 speaker. This suggests that bottom-up activation in sub-phonemic, non-target language representations does not spread strongly enough to influence target language recognition, and also that there is a very limited role for top-down connections of language nodes with lexical representations within that language. It may therefore be concluded that such information is not strong enough to modulate cross-lingual interactions (bottom-up) and that listeners do not use this information as a cue to activate a non-target language (top-down). The fact that salient language cues (such as information about the native accent of the speaker) do not influence lexical access may be a surprising conclusion. However, this is exactly what has been found in the visual domain, as the recent BIA+ model (Dijkstra & Van Heuven, 2002) does no longer contain such top-down connections, in contrast to its precursor, the BIA model (Dijkstra & Van Heuven, 1998). As such, our results seem to be inconsistent with Ju and Luce (2004). These authors found that Spanish-English bilinguals fixated pictures whose English names were phonologically similar to Spanish auditory targets more frequently than control distracters, but only when the Spanish target words were altered to contain English-appropriate voice onset times. Taken together, it appears that at least this acoustic feature influences cross-lingual lexical activation in bilinguals, although the sub-phonemic differences between the utterances in the different languages of the present study do not. Note that Ju and Luce's findings for Spanish (L1) targets that were not altered with L2 voice onset times are also inconsistent with the interference effects of Marian and colleagues, even though both used bilinguals that had been living in a L2 dominant environment. Ju and Luce argued that this discrepancy might originate from the fact that the stimuli of Marian and colleagues (just as those of the present study, and just as in natural word recognition) contained words starting with a variety of sounds, including nasals (e.g., *marker*) and fricatives (e.g., *fish*), whereas all of the Ju and Luce stimuli began with voiceless stops. Hence, the present findings are only consistent with Ju and Luce's when we reduce the claim that a strong acoustic cue (e.g., voicing, as present in their stimulus manipulation) might inhibit cross-lexicon activation, unlike recognition of materials that diverge on a wider range of acoustic parameters, and are not artificially manipulated on a single language-specific contrast (cfr. Marian and colleagues and the present study).

Note however that we did observe faster word recognition for words spoken by a speaker in her native language than spoken by a speaker in her L2, suggesting that sub-phonemic activation in a non-target language does have *some* influence on recognition, even if it does not annul cross-lingual interactions. At first sight, this observation is inconsistent with the work of Bradlow and Bent (2008). These authors demonstrated that non-native listeners are faster to recognize speech from other non-native speakers with the same L1. A possible explanation for these different results is the fact that the task participants had to perform was different in the Bradlow and Bent (2008) study and the present study. Whereas Bradlow and Bent (2008) investigated accuracy scores on a sentence recognition task, our participants were instructed to make lexical decisions on isolated words. As a consequence, a direct comparison of the results of both studies is not feasible. A plausible explanation for the results of the present study is that the native speaker's pronunciation of the targets provides a better match with stored lexical representations than the utterances of L2 speakers. This way, the threshold for recognition is exceeded faster. Another possibility is that the non-accented speech represents a less noisy signal than the accented speech, and that the accented speech either requires the extra step of talker normalization, or that the accented speech represents a poorer signal-to-noise ratio. At least, this interaction effect between the target listening language and the speaker's native language proves that the different types of speaker utterances indeed contained language-specific acoustic information. As such, this constitutes a successful manipulation check of sub-phonemic differences between languages.

At a theoretical level, the present L1 and L2 effects show great similarity with the findings in the bilingual visual word recognition literature. In that domain, it has also recently been shown that participants do not use language cues to decide which lexicon to access. For example, when reading words in a sentence context, this context is not used as a cue to restrict lexical access (Duyck et al., 2007; Libben & Titone, 2009; Schwartz & Kroll, 2006; Van Assche et al., 2009; Van Assche et al., 2011; Van Hell & de Groot, 2008). Additionally, Thierry and Wu (2007) investigated whether differences in script between the Chinese and English language can restrict lexical access. These authors demonstrated by means of brain potentials that English words were automatically and unconsciously translated into their Chinese counterpart when Chinese-English bilinguals made semantic relatedness decisions about English words, indicating that even script is not used as a cue to guide lexical access. However, the current findings are more surprising than the analogues in the visual domain, given that auditory, but not visual word presentation contains information about the language to which the word belongs, and given the fact that bilinguals are able to determine a word's language membership on the basis of just the initial phonemes (Grosjean, 1988).

Taken together, this study supports a view of bilingual lexical access that is highly nonselective. Whereas the results in bilingual visual word recognition have demonstrated that L1 or L2 readers do not restrict lexical access to one lexicon by using cues such as sentence context (e.g., Van Assche et al., 2009), or even script (Thierry & Wu, 2007), the results of the present study extend these findings to the auditory domain in bilingual word recognition. Apparently, bilinguals do not use speech-specific cues or sub-phonemic differences between speakers to restrict lexical access to the currently relevant lexicon when listening in L2, nor in L1.

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APPENDIX

Interlingual homophones and matched control words in Experiments 1 and 3. Asterisks indicate targets and control words excluded from the analysis for eliciting errors in a translation test by more than 30 % of participants.

L2 HOMOPHONE	phonology	CONTROL	L1 HOMOPHONE	phonology	CONTROL
BAY	[beI]	hug	BIJ	[bEI]	vol
BEAT	[bi:t]	nose	BIET	[bi:t]	kras
BILL	[bIl]	skin	BIL	[bIl]	lap
BONE	[b@Un]	lion	BOON	[bo:n]	kooi
BOSS	[bOs]	rush	BOS	[bOs]	hek
BRIEF	[bri:f]	nerve	BRIEF	[bri:f]	roman
BULL	[bUl]	page	BOEL	[bu:l]	boer
COOK	[kUk]	fast	KOEK	[ku:k]	zeef
COW	[kaU]	bag	KOU	[kAU]	lui
CRATE*	[kreIt]	mouse	KRIJT	[krEIt]	lepel
DAY	[deI]	boy	DIJ	[dEI]	mus
DOLL	[dOl]	moon	DOL	[dOl]	kam
FATE	[feIt]	pope	FEIT	[fEIt]	trap
HAY*	[heI]	bug	HEI	[hEI]	das
HEAL	[hi:l]	duck	HIEL	[hi:l]	kous
HOOK	[hUk]	farm	HOEK	[hu:k]	rook
KNOCK	[nOk]	chief	NOK	[nOk]	pit
LAKE	[leIk]	soft	LIJK	[lEIk]	kast

LANE	[leIn]	king	LIJN	[lEIn]	maag
LEAD	[li:d]	risk	LIED	[li:t]	lift
LEAF	[li:f]	wine	LIEF	[li:f]	buik
LEASE*	[li:s]	scarf*	LIES	[li:s]	saai
LIST	[lIst]	wing	LIST	[lIst]	slak
LOOP*	[lu:p]	fist	LOEP	[lu:p]	zoen
MAIL	[meIl]	fork	MIJL	[mEIl]	vork
MESS	[mEs]	safe	MES	[mEs]	aap
MOOD	[mu:d]	silk	MOED	[mu:t]	zout
PALE	[peIl]	twin	PIJL	[pEIl]	wolk
PET	[pEt]	fox	PET	[pEt]	put
PLANE	[pleIn]	towel	PLEIN	[plEIn]	plooi
PRAISE	[preIz]	poison	PRIJS	[prEIs]	straf
PRAY	[preI]	claw	PREI	[prEI]	wilg
PROOF	[pru:f]	widow	PROEF	[pru:f]	draad
QUICK	[kwIk]	chair	KWIK	[kwIk]	klad
RAISE	[reIz]	elbow	REIS	[rEIs]	dame
RAY*	[reI]	jar	RIJ	[rEI]	jas
ROOM	[ru:m]	wife	ROEM	[ru:m]	mand
SLIM	[slIm]	deaf	SLIM	[slIm]	spin
STREAM	[stri:m]	pillow	STRIEM	[stri:m]	fazant
TAIL	[teIl]	meat	TEIL	[tEIl]	deeg
THIGH*	[taI]	devil	TAAI	[ta:I]	tang
TRACK	[tr&k]	taste	TREK	[trEk]	muur
VET	[vEt]	spy	VET	[vEt]	kip
WAY	[weI]	old	WEI	[wEI]	mop

CHAPTER 3
INTERLINGUAL COMPETITION IN A SPOKEN SENTENCE CONTEXT: EVIDENCE FROM THE VISUAL WORLD PARADIGM[1]

We used the visual world paradigm to examine interlingual lexical competition when listening to low-constraining sentences in the nonnative (L2, Experiment 1) and native (L1, Experiment 2) language of Dutch-English bilinguals. Additionally, we also investigated the influence of the degree of cross-lingual phonological similarity. When listening in L2, participants fixated more on competitor pictures with phonologically related onsets in the non-target language (e.g., fles, 'bottle', given target flower) than on phonologically unrelated distracter pictures. Even when listening in L1, this effect was also observed when the onset of the target picture (in L1) and the competitor picture (in L2) was phonologically very similar. These findings provide evidence for interlingual competition during the comprehension of spoken sentences, both in L2 and in the dominant native language.

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[1] Lagrou, E., Hartsuiker, R. J., & Duyck, W. (revised manuscript submitted for publication). Interlingual lexical competition in a spoken sentence context: Evidence from the visual world paradigm.

INTRODUCTION

Many studies on visual word recognition by bilinguals have pointed out that a bilingual is not merely the sum of two monolinguals. Instead, learning a second language changes the cognitive system in several ways. For instance, bilinguals are not able to 'turn off' the irrelevant language when reading, and so a bilingual's native language (L1) and second language (L2) constantly compete for recognition with each other, both when reading in L2 *and* L1 (e.g., Dijkstra & Van Heuven, 1998; Duyck, 2005; Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Van Assche, Duyck, Hartsuiker, & Diependaele, 2009). However, the story may be different for auditory word recognition: In contrast to written language, speech contains subsegmental and suprasegmental cues that are highly indicative of the (target) language in use; this information may be used to optimize lexical search (e.g., by limiting search to the lexical representations of the target language). In line with this, evidence for non-target language activation in the auditory domain is more mixed. There is consistent evidence in favor of language-nonselectivity when listening to isolated words in L2 (e.g., Marian & Spivey, 2003; Schulpen, Dijkstra, Schriefers, & Hasper, 2003). But in L1 auditory word recognition in isolation, evidence for cross-lingual lexical interactions is inconsistent, without a clear explanation. Moreover, although some data exist for L2 word recognition in a meaningful spoken sentence context, such data is lacking for L1, so that it also remains unclear whether top-down factors may modulate such influences. The present study addresses both issues. We tested whether there is evidence for a language-nonselective account of lexical access in which lexical items from L1 and L2 compete with each other for activation when listening to semantically coherent (but low-constraining) sentences in L2 (Experiment 1) and in L1 (Experiment 2). Additionally, we investigated the role of cross-lingual phonological similarity and asked whether this might explain the divergent L1 findings reported in earlier isolated word recognition work.

A method very well suited to examine lexical competitor activation in auditory word recognition is the registration of eye movements in the visual world paradigm (e.g., Altmann, 2004; Huettig, Rommers, & Meyer, 2011; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). In this paradigm, location and duration of eye movements to objects in a scene are continuously recorded, so that target word recognition may be monitored as speech unfolds over time. In a seminal study, Tanenhaus et al. (1995) investigated within-language lexical competition using this paradigm. Each critical display contained four objects, two of which had phonologically similar beginnings (e.g., *candy* and *candle*). Tanenhaus et al. found that it took longer to initiate eye movements to the correct object when an object with a phonologically similar name was presented.

Visual-world studies on isolated L2 word recognition have yielded consistent cross-lingual lexical competition effects. For instance, in the studies of Marian and Spivey (2003) and Weber and Cutler (2004) bilinguals fixated more on competitor pictures with a phonologically related onset in the non-target language (e.g., *marka*, 'stamp', given target *marker*) than on unrelated distracter pictures. Importantly, studies that embedded target words in spoken sentences found that such cross-lingual interactions are influenced by the sentence context (Chambers & Cooke, 2009; FitzPatrick & Indefrey, 2010). When sentence information was compatible with both the target (e.g., *poule*) and the interlingual competitor (e.g., *pool*), Chambers and Cooke found that competitors were fixated more during L2 recognition than unrelated distracter items (i.e., both the French target and the interlingual near-homophone are plausible; e.g., *Marie va <u>decrire</u> la poule* [Marie will describe the chicken]). This was not the case when prior sentence information was incompatible with the competitor (i.e., only the French target, but not the interlingual near-homophone is plausible; e.g., *Marie va <u>nourrir</u> la poule* [Marie will feed the chicken]). In an EEG study by FitzPatrick and Indefrey, sentences could be (a) congruent (e.g., "The goods from Ikea arrived in a large cardboard *box*"), (b) incongruent (e.g., "He unpacked the computer, but the printer is still in the *towel*"), (c) initially congruent within L2 (e.g., "When we moved house, I had to put all my books in a bottle”), or (d) initially overlapping with a congruent L1 translation equivalent (e.g., My Christmas present came in a bright-orange doughnut”, which shares phonemes with the Dutch *doos* “box”). The EEG results demonstrated a N400 component on all incongruent sentences that was delayed to L2 words, but not to L1 translation equivalents. This indicates that these L1 competitors that were initially congruent with the sentence context were not activated when Dutch-English bilinguals listened to sentences in L2. Hence, these studies seem to suggest that sentence context imposes strong constraints on, or even annuls, cross-lingual lexical interactions, even for L2 recognition, which shows consistent interference effects from L1 in isolated word recognition.

For L1 word recognition, the evidence for language-nonselectivity is mixed and the question of whether any such language-nonselectivity can be affected by top-down factors remains unaddressed. Whereas Spivey and Marian (1999) observed lexical competition from L2 during L1 recognition, Weber and Cutler (2004) did not replicate this finding. Because bilinguals in the former study were immersed in a L2 dominant setting, whereas the latter bilinguals were not, this suggests that between-language lexical competition may depend on language profile factors such as the amount of daily use of each language and L2 proficiency. When it comes to L1 auditory word recognition in a meaningful sentence context, there are currently even *no* studies investigating cross-lingual interactions. Table 1 gives an overview of the different studies on L2 and L1 word recognition in isolation and in a sentence context.

Table 1. Overview of the different studies on auditory L2 and L1 word recognition in isolation and in a sentence context.

	ISOLATION	SENTENCE
L2	Marian and Spivey (2003)	Chambers and Cooke (2009)
	Schulpen et al. (2003)	FitzPatrick and Indefrey (2010)
	Weber and Cutler (2004)	
L1	Ju and Luce (2004)	
	Spivey and Marian (1999)	The present study
	Weber and Cutler (2004)	

These results raise the question whether there are specific factors that can constrain lexical access. For L2 word recognition, the studies described above suggest that sentence context can be a constraining factor, whereas for isolated L1 word recognition, cross-lingual interactions seem to require sufficient language proficiency/dominance. A further possible constraining factor may be phonology. In a study of isolated L2 word recognition by Schulpen, Dijkstra, Schriefers, and Hasper (2003) the influence of sub-phonemic cues on lexical access was investigated. In this study, Dutch-English bilinguals completed a cross-modal priming task with auditory primes and visual targets. Reaction times were slower for interlingual homophone pairs (e.g., /li:s/ – LEASE, /li:s/ is the Dutch translation equivalent for *groin*) than for monolingual controls (e.g., freIm/ – FRAME), which suggests that bilinguals activated both meanings of the homophones. Crucially, the English pronunciation of the homophone led to faster decision times on the related English target word than the Dutch version of the homophone, which indicates that the degree of cross-lingual activation spreading is affected by sub-phonemic differences between homophones. For isolated L1 word recognition in a visual world paradigm, Ju and Luce (2004) found that Spanish-English bilinguals fixated interlingual distracters (nontarget pictures whose English names shared a phonological similarity with the Spanish targets) more frequently than control distracters, but only when the Spanish target words were altered to contain English-appropriate voice onset times.

In the present study, we investigated whether a meaningful sentence context may restrict cross-lingual interactions in L1 auditory word recognition. We also tested whether sub-phonemic cues modulate cross-lingual lexical activation transfer. In contrast with Schulpen et al. (2003) and Ju and Luce (2004) we used existing natural variation in phonological similarity between L1 and L2 representations instead of experimentally manipulating pronunciations. In order to confirm previous results on L2 word recognition, and extend them with the results on the influence of sub-phonemic cues, we first investigated these questions when listening in L2. In Experiment 1, unbalanced Dutch-English bilinguals, immersed in an L1 dominant environment, listened to low-constraining sentences in L2. We investigated whether they fixated more on competitor pictures with a name in the irrelevant L1 that was phonologically related to the target (e.g., *fles*, ‘bottle’, given target *flower*) than on distracter pictures with a name in L1 that was phonologically unrelated to the L2 target. In Experiment 2 we investigated whether we could also observe between-language competition when these bilinguals were listening to semantically coherent sentences in L1. Additionally, we also analyzed effects of cross-lingual phoneme similarity on the basis of similarity judgments of an independent group of participants. Typically, more similar items shared a consonant cluster such as /fl/, /sl/, of /sp/; items judged as less related tended to have a vowel as the second phoneme or had a consonant cluster involving /r/; vowel space is different between Dutch and English, and these languages realize /r/ with different phones. Even if phonological cues are not used as a cue to fully restrict lexical activation to only one lexicon, between-language competition may still be stronger when the target and the competitor are perceived as sounding more similar.

EXPERIMENT 1: L2

Method

Participants

Twenty-two students from Ghent University participated in Experiment 1. All were unbalanced Dutch-English bilinguals. They started to learn English (L2) around age 14 at secondary school. Although they used their L1 (Dutch) most of the time, they were regularly exposed to their L2 through popular media and English university textbooks.

Stimulus materials

Twenty target nouns were embedded in low-constraining L2 sentences (see Appendix A). All sentences were semantically compatible with both the competitor and the distracters, and were pronounced by a native speaker of British English. The names of targets, competitors, and distracters were plausible, but not predictable from the sentence context. This was assessed in a sentence completion study with twenty further participants. Production probabilities for targets, competitors and distracters were low (targets: 0.007, competitors: 0.005, distracters: 0.002). Each target was paired with a competitor picture of which the onset of the L1 translation overlapped phonologically with the target name. Target names were one, two or three syllables long, and all target-competitor pairs overlapped with two or three phonemes. The names of targets and competitors did not differ (dependent samples t-tests yielded *ps* > .23) from each other with respect to number of phonemes, number of syllables, word frequency, neighborhood size, and age-of-acquisition (see Table 2).

Table 2. Mean lexical characteristics of target and competitor names in Experiments 1 and 2 (in Experiment 2 targets were competitors, and vice versa).

Condition	Number of phonemes	Number of syllables	Word frequency[a]	Neighbor-hoodsize[b]	Age-of-acquisition[c]
Target	4.80 (1.47)	1.45 (0.60)	1.48 (0.50)	4.40 (4.20)	5.14 (0.91)
Competitor	5.25 (1.62)	1.65 (0.67)	1.34 (0.69)	4.20 (4.14)	5.15 (0.78)
p	> .40	> .38	> .46	> .89	> .59

Note. Standard deviations are indicated in parentheses. Reported p-values indicate significance levels of dependent samples t-tests between targets and competitors. [a] Mean log frequency per million words, according to the CELEX lemma database (Baayen, Piepenbrock, & Van Rijn, 1993). [b] Neighborhoodsize (Coltheart, Davelaar, Jonasson, & Besner, 1977) calculated using the WordGen program (Duyck, Desmet, Verbeke, & Brysbaert, 2004) on the basis of the CELEX lemma database (Baayen et al., 1993). [c] Age-of-acquisition ratings collected by Ghyselinck, Custers, and Brysbaert (2003).

For each target-competitor pair a phonological similarity score was calculated. Fifteen other participants from the same bilingual population listened to the overlapping part of the target-competitor pair, and judged its phonological similarity on a scale ranging from 1 (very different) to 9 (very similar). By means of a median-split procedure, target-competitor pairs were classified either as very similar (M = 7.47, SD = 0.69) (e.g., *flower* /flaʊɜ/ –

fles /flɛs/ [bottle]) or as less similar (*M* = 4.90, *SD* = 0.76) (e.g., *comb* /kəʊm/ – *koffer* /kɔ fə/ [suitcase]). In addition to the target and the competitor, each display (for an example: see Figure 1) contained two phonologically unrelated distracters (e.g., *dog* and *orange*). Thirty new filler displays that were semantically and phonologically unrelated were included in the experiment. Pictures were selected from the Severens, Van Lommel, Ratinckx, and Hartsuiker (2005) picture set. All pictures were black-and-white drawings, arranged in a two-by-two grid.

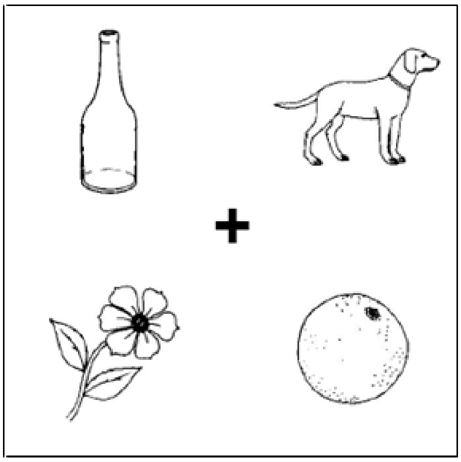


Figure 1. Example of a visual display presented to participants. In this example the picture of the flower is the L2 target, the picture of the bottle is the L1 competitor (the Dutch translation equivalent of bottle is fles), and the pictures of the dog and the orange are unrelated distracters.

Apparatus

Using WaveLab software, sentences were recorded in a sound-attenuated booth by means of a SE Electronics USB1000A microphone with a sampling rate of 44.1 kHz and a 16-bit sample size. Eye movements were recorded from the right eye with an Eyelink 1000 eye tracking device (SR Research). Viewing was binocular, but eye movements were only recorded from the right eye. Participant's fixation locations (i.e., the positions on the screen where participants were looking at and did not make any eye movements) were sampled every millisecond.

Procedure

Participants were instructed to listen carefully to the L2 sentences. They were not required to perform any explicit task (see Altmann, 2004; Kamide, Altmann, & Haywood, 2003; Huettig et al., 2011 for discussion). The appearance of the displays was synchronized with the auditory presentation of the sentences. On average, the onset of the target started 1219 ms after sentence onset. A new trial started 1000 ms after sentence offset. For calibration, participants had to look at 9 points that appeared sequentially on the screen.

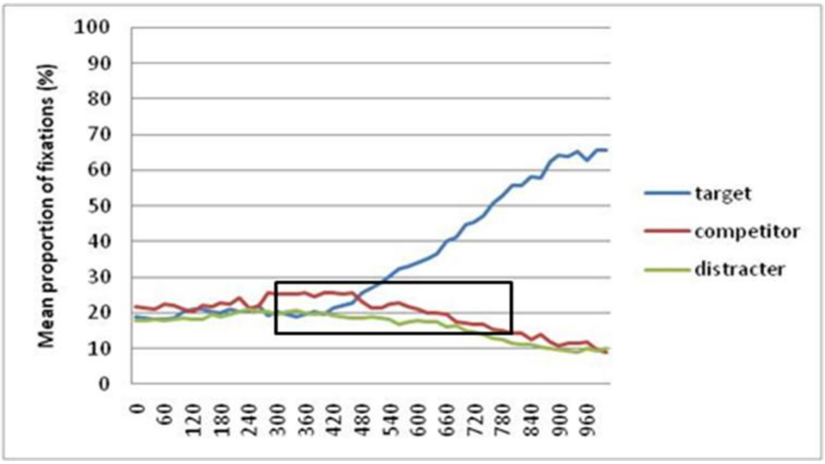
Results

Time window 0-300 ms after target onset

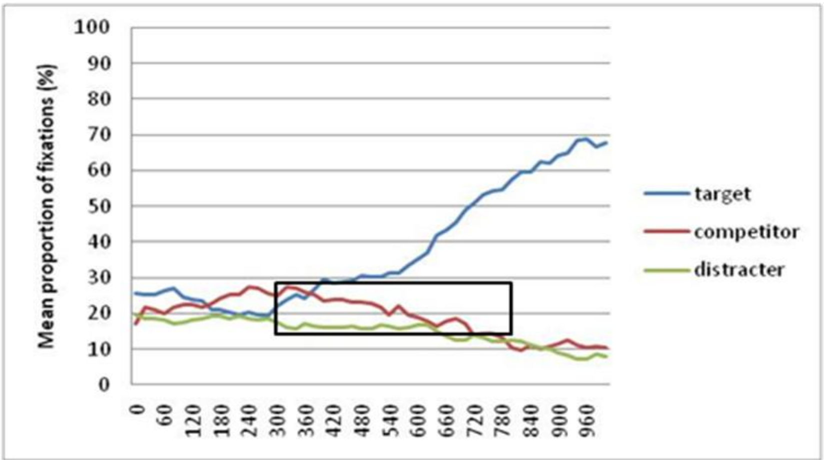
To control for baseline effects during this early time window, an ANOVA with picture (competitor vs. distracter) and phonological overlap (very similar vs. less similar) as within-participants variables, and proportion of fixations as dependent variable was conducted. The main effect of picture was not significant, $F1(1,21) = 2.05$, $p = .17$; $F2(1,18) = 1.51$, $p = .23$, nor was the main effect of phonological overlap, $F1(1,21) = 1.08$, $p = .31$; $F2 < 1$. The interaction between picture and phonological overlap was also not significant, *F1* < 1; *F2* < 1. This ensures that competitor and distractor pictures did not differ in their intrinsic capture of visual attention.

Time window 300-800 ms after target onset

An ANOVA with picture (competitor vs. distracter) and phonological overlap (very similar vs. less similar) as within-participants variables, and proportion of fixations as dependent variable demonstrated a main effect of picture, $F1(1,21) = 8.01$; $p < .01$; $F2(1,18) = 7.04$, $p < .05$, which indicates that participants fixated significantly more on competitor pictures of which the Dutch name is phonologically related to English target names (M = 19.83 %) than to unrelated distracters (M = 16.43 %). The main effect of phonological overlap was not significant, $F1(1,21) = 1.56$; $p = .25$; $F2(1,18) = .34$, $p = .57$, and neither was the interaction between picture and phonological overlap, $F1 < 1$; $F2 < 1$ (see Figure 2).



(a)



(b)

Figure 2. Fixation proportions for English targets, competitors, and averaged distracters in Experiment 1 when the phonological overlap between the English target name and the Dutch competitor name was very similar (Figure 2a) or less similar (Figure 2b).

Additionally, a linear regression analysis showed that the phonological similarity score of target-competitor pairs was not a significant predictor of the lexical competition effect for that pair, $F < 1$; $R^2 = .01$; $\beta = -.007$, $r = -.11$ (see Figure 3). This implies that nonnative listeners experience competition from L1 competitors when listening to low-constraining sentences in L2 (even though L1 is irrelevant), and independent of the phonological similarity between the target and the competitor.

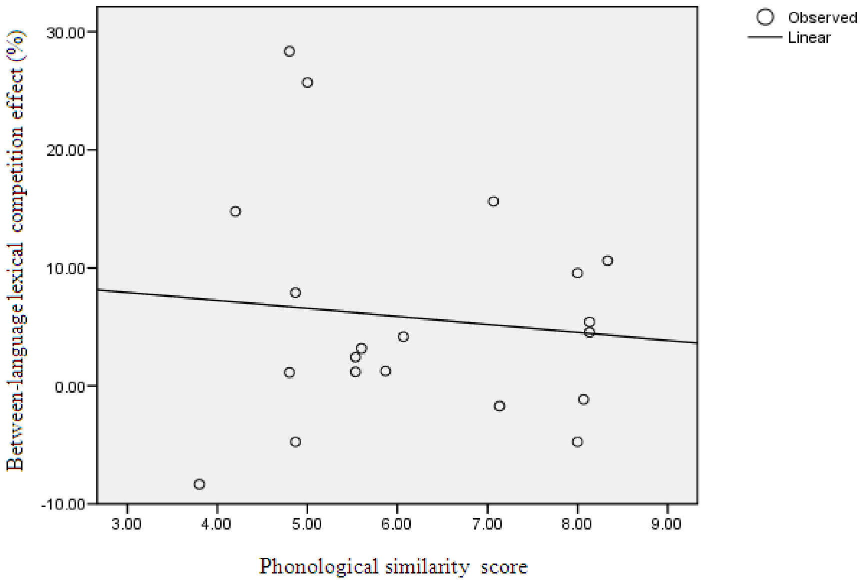


Figure 3. Scatterplot representing the between-language competition effect (%) in L2 (Experiment 1) as a function of phonological similarity between items.

EXPERIMENT 2: L1

In Experiment 2, we tested for between-language competition when listening to semantically coherent sentences in the native language (L1). Again, we also investigated whether this effect is influenced by the degree of phonological similarity between languages.

Method

Twenty-two students from the same bilingual population participated in Experiment 2. Stimulus materials, apparatus, and procedure were identical to Experiment 1, except that targets were now competitors and vice versa (see Appendix B). This ensures comparability of L1 and L2 experiments. On average, the onset of the target started 1388 ms after sentence onset. Sentences were now pronounced by a native Dutch speaker. Targets, competitors, and distracters were again plausible, but not predictable from the sentence context. This was assessed in a sentence completion study with seventeen further participants. In this completion study, participants were asked to complete the 30 critical sentences with a Dutch target. Production probabilities for targets, competitors and distracters were again low (targets: 0.00, competitors: 0.01, distracters: 0.00).

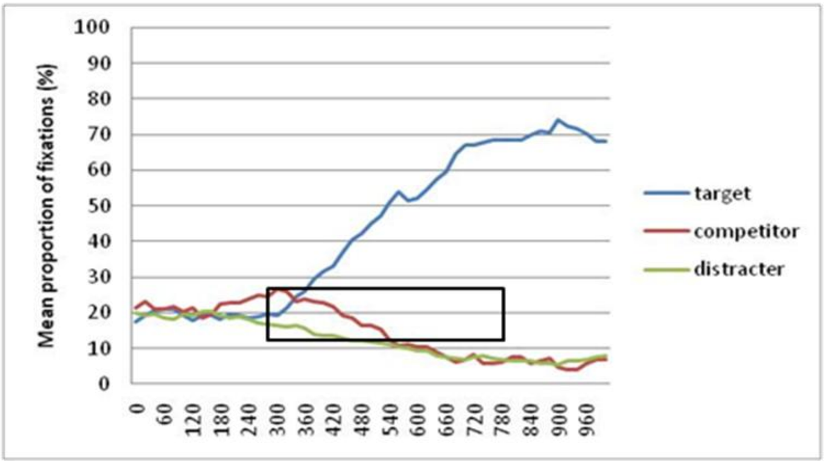
Results

Time window 0-300 ms after target onset

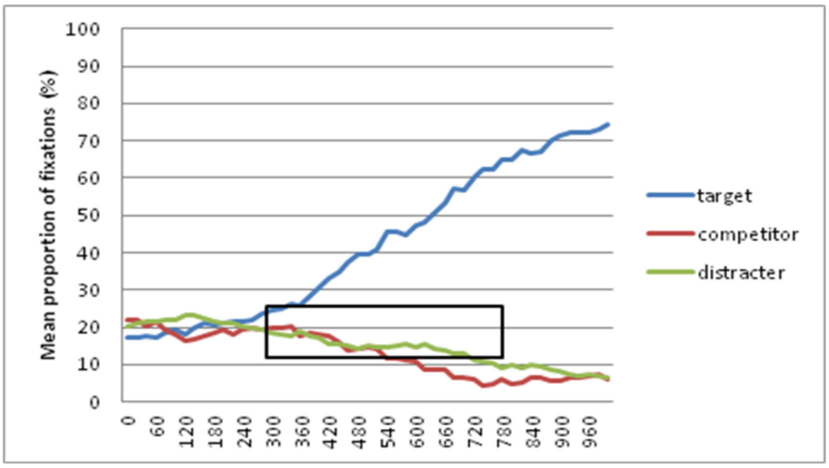
Baseline picture effects were assessed as in Experiment 1. The main effect of picture was not significant, $F1 < 1$; $F2 < 1$, as was the main effect of phonological overlap, $F1 < 1$; $F2 < 1$. The interaction between picture and phonological overlap was also not significant, $F1(1,21) = 1.16$, $p = .29$; $F2 < 1$.

Time window 300-800 ms after target onset

An ANOVA with picture (competitor vs. distracter) and phonological overlap (very similar vs. less similar) as within-participants variables, and proportion of fixations as dependent variable demonstrated that the main effect of picture was not significant, $F1 < 1$; $F2 < 1$, and neither was the main effect of phonological overlap, $F1(1,21) = 2.85$, $p = .11$; $F2(1,18) = 2.14$, $p = .16$. However, the interaction between picture and phonological overlap was significant, $F1(1,21) = 5.71$, $p < .05$; $F2(1,18) = 7.47$, $p < .05$. Closer inspection revealed that participants only fixated more on competitors than on unrelated distracters when the phonological overlap between the English competitor name and the Dutch target name was very high (see Figure 4a), $F1(1,21) = 6.37$, $p < .05$; $F2(1,18) = 6.78$, $p < .05$. When the English competitor name and the Dutch target name were phonologically less similar (see Figure 4b), fixation proportions on competitors and unrelated distracters did not differ, $F1 < 1$; $F2 < 1$.



(a)



(b)

Figure 4. Fixation proportions for Dutch targets, competitors, and averaged distracters in Experiment 2 when the phonological overlap between the Dutch target name and the English competitor name was very similar (Figure 4a) or less similar (Figure 4b).

Additionally, a linear regression analysis showed that the phonological similarity score of target-competitor pairs was a significant, and very strong, predictor of the lexical competition effect for that pair, $F(1,19) = 5.58$, $p < .05$; $R^2 = .24$; $\beta = .03$, $r = .50$ (see Figure 5). This provides evidence for language-nonselectivity when listening to sentences in L1, but with the constraint that the L2 representations only appear to influence L1 recognition when the phonological overlap between the relevant L1 and L2 representations is relatively large.

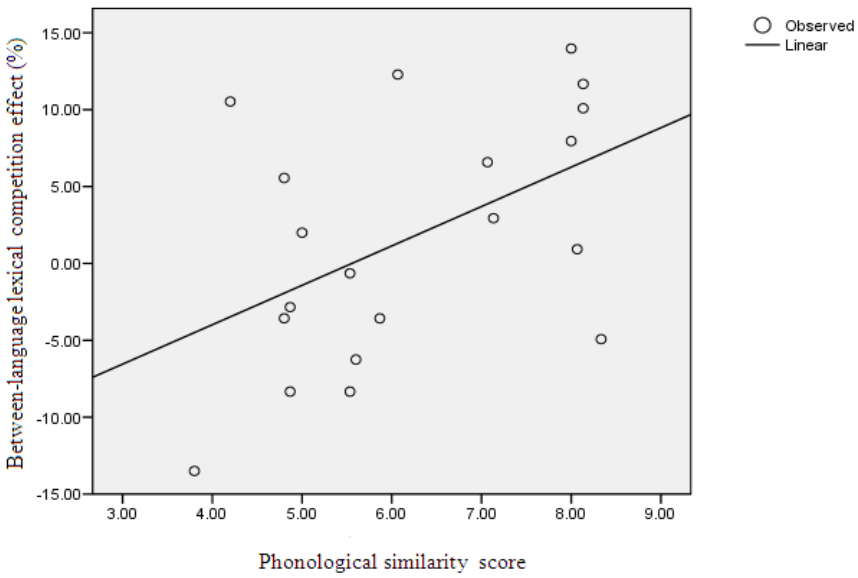


Figure 5. Scatterplot representing the between-language competition effect (%) in L1 (Experiment 2) as a function of phonological similarity between items.

GENERAL DISCUSSION

The present study provides evidence for cross-lingual lexical interactions in bilingual auditory word recognition. When listening in L2, participants fixated more on competitor pictures that had a phonological similar onset in L1 than on phonologically unrelated distracter pictures. This effect was robust both when perceived cross-lingual onset overlap was very large (e.g., when a target picture of a *flower* was presented together with a competitor picture of a *fles* (bottle)), and when this overlap was smaller (e.g., when a target picture of a *comb* was presented together with a competitor picture of a *koffer* (suitcase)). This is consistent with the results of isolation studies by Marian and Spivey (2003) and Weber and Cutler (2004), but contrasts with sentence studies by Chambers and Cooke (2009) and FitzPatrick and Indefrey (2010). Hence, the semantic context and language associated with a sentence does not necessarily annul cross-lingual interactions.

Crucially, we also showed for the first time that cross-lingual lexical interactions are not annulled by a sentence context when listening in the native language. Participants also fixated significantly more on pictures with an overlapping L2 onset than on phonologically unrelated distracters, but only when the perceived phonological similarity was relatively large (e.g., flower – fles *(bottle)*). If the onset overlap of the Dutch target and the English competitor was less strong (e.g., comb – koffer *(suitcase)*), distracter pictures did not interfere with L1 target recognition.

In addition to the complete lack of L1 sentence studies, this study is also important to explain the inconsistent findings on the influence of L2 knowledge on L1 recognition in isolation. Because cross-lingual competition in L1 processing is heavily influenced by variation in the phonological overlap between the lexical representations of both languages, this could explain why

Weber and Cutler (2004) did not find a L1 effect, unlike Marian and colleagues. Indeed, the Weber and Cutler stimuli would correspond to the stimuli with partial overlap in the present study, also showing no effect. Although it was already argued that the size of the between language competition effect may be influenced by factors such as language proficiency, language mode, and language background (e.g., Marian & Spivey, 2003; Marian, Spivey, & Hirsch, 2008), the present study shows that lexical competition across languages may already be influenced by small variations in phonological similarity. It is plausible that such an effect emerges especially in L1 processing: overall activation is much weaker in L2 representations, so that cross-lingual competition arising from them is more susceptible to variations in the degree of activation transfer.

At a theoretical level, the between-language competition effect is consistent with monolingual models of auditory word recognition as the Distributed Model of Speech Perception (Gaskell & Marslen-Wilson, 1997), the Neighborhood Activation Model (Luce & Pisoni, 1998), and Shortlist (Norris, 1994; Norris; McQueen, Cutler, & Butterfield, 1997) if they are extended with the assumption that L2 representations are part of the same system as, and interact with, L1 representations. Moreover, the fact that L2 knowledge only competes with L1 recognition when the phonological similarity between languages is sufficiently strong, may be explained if these models assume that language-specific sub-phonemic cues results in (bottom-up) higher activation in the lexical representations of the target language. However, this sub-phonemic information could also be working through top-down competition if it is the case that language-specific phonemes and variations activate specific language nodes before lexical representations are activated. The latter would be predicted by interactive activation models such as TRACE (Elman & McClelland, 1988; McClelland & Elman, 1986).

To conclude, the present study reports lexical competition effects between languages, when listening to unilingual sentences in both L2 and L1. This suggests that bilingual listeners do not use the cues that are inherent to the speech provided by a sentence context to restrict activation to a single lexicon. The resulting cross-lingual competition effects are highly sensitive to phonological similarity, especially in L1 processing, when competitive L2 activation is weak.

ACKNOWLEDGMENTS

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APPENDIX A

Experimental stimuli used in Experiment 1. The overlapping portions of the target-competitor pairs are underlined.

<table>
<tr><th colspan="5">Very similar phonological overlap</th></tr>
<tr><th>English target</th><th>Dutch competitor</th><th>Translation competitor</th><th>Unrelated distracter</th><th>Unrelated distracter</th></tr>
<tr><td>box</td><td>bokaal</td><td>goblet</td><td>skirt</td><td>tail</td></tr>
<tr><td colspan="5">⇨ The shot of the man hit a box and missed the target.</td></tr>
<tr><td>curtain</td><td>kussen</td><td>pillow</td><td>pig</td><td>shirt</td></tr>
<tr><td colspan="5">⇨ My friend Hannah was looking at a curtain in that neighborhood.</td></tr>
<tr><td>duck</td><td>duim</td><td>thumb</td><td>cloud</td><td>tape</td></tr>
<tr><td colspan="5">⇨ Her little brother has drawn a duck and is now playing outside.</td></tr>
<tr><td>flower</td><td>fles</td><td>bottle</td><td>dog</td><td>orange</td></tr>
<tr><td colspan="5">⇨ That man finally got a flower, and that’s why he is happy.</td></tr>
<tr><td>slide</td><td>sleutel</td><td>key</td><td>king</td><td>lobster</td></tr>
<tr><td colspan="5">⇨ One day she found a slide in the garden.</td></tr>
<tr><td>speaker</td><td>spook</td><td>ghost</td><td>mouse</td><td>seal</td></tr>
<tr><td colspan="5">⇨ I had a dream about a speaker during my sleep.</td></tr>
</table>

spoon	spiegel	mirror	floor	truck
⇨ For his design of the **spoon** the designer won the first prize.				
stairs	stoel	chair	neck	cell
⇨ To have a better look at the **stairs** she walked to the other side.				
stamp	steen	rock	feather	peanut
⇨ When Josh showed up with a **stamp**, everybody laughed.				
strawberry	strik	bow	toe	flashlight
⇨ She discovered a **strawberry** when she opened the box.				

Less similar phonological overlap

English target	Dutch competitor	Translation competitor	Unrelated distracter	Unrelated distracter
broom	broek	pants	peach	record
⇨ During a walk in the city, he saw a **broom** in the store.				
carpet	kast	cupboard	hammer	button
⇨ They almost found everything, but were still looking for a **carpet** in that house.				

carrot	kerk	church	spider	dentist

⇨ The stranger could not believe his eyes when he saw a **carrot** in that village.

comb	koffer	suitcase	shoe	nail

⇨ The woman made a painting of the **comb** with the red paint.

drill	draaimolen	carrousel	house	bird

⇨ Lucie took her bike and bought a **drill** at the market.

farm	fakkel	torch	basket	brush

⇨ She received a **farm** as a birthday present.

road	rolstoel	wheelchair	cheese	boy

⇨ Because I wanted to see the **road** I looked outside.

scissors	citroen	lemon	chicken	trash

⇨ The only thing she wanted were **scissors** to throw with.

tree	trommel	drum	necklace	bucket

⇨ She saw a **tree** at the corner of the street.

wallet	wasknijper	clothespin	canopener	train

⇨ He says that a **wallet** is the most stupid invention.

APPENDIX B

Experimental stimuli used in Experiment 2. The overlapping portions of the target-competitor pairs are underlined.

Very similar phonological overlap

Dutch target	Translation target	English competitor	Unrelated distracter	Unrelated distracter
bokaal	goblet	box	skirt	tail
⇨ Het schot van de man raakte een **bokaal** en miste het doel. (The shot of the man hit a goblet and missed the target.)				
kussen	pillow	curtain	pig	shirt
⇨ Mijn vriendin Hannah bekeek een **kussen** in die buurt. (My friend Hannah was looking at a pillow in that neighborhood.)				
duim	thumb	duck	cloud	tape
⇨ Haar kleine broer maakte een tekening van een **duim** en speelt nu buiten. (Her little brother has drawn a thumb and is now playing outside.)				
fles	bottle	flower	dog	orange
⇨ Die man kreeg eindelijk een **fles**, en was daarom gelukkig. (That man finally got a bottle, and that's why he is happy).				

sleutel	key	slide	king	lobster

⇨ Op een dag vond ze een **sleutel** in de tuin. (One day she found a key in the garden.)

spook	ghost	speaker	mouse	seal

⇨ Ik had een droom over een **spook** tijdens mijn slaap. (I had a dream about a ghost during my sleep.)

spiegel	mirror	spoon	floor	truck

⇨ Voor zijn ontwerp van een **spiegel** won de ontwerper de eerste prijs. (For his design of a mirror the designer won the first prize.)

stoel	chair	stairs	neck	cell

⇨ Opdat ze beter kon kijken naar een **stoel** wandelde ze naar de andere kant. (To have a better look at a chair she walked to the other side.)

steen	rock	stamp	feather	peanut

⇨ Toen Jos aankwam met een **steen**, lachte iedereen. (When Josh showed up with a rock, everybody laughed.)

strik	bow	strawberry	toe	flashlight

⇨ Ze ontdekte een strik toen ze de doos opende. (She discovered a bow when she opened the box.)

Less similar phonological overlap

Dutch target	Translation target	English competitor	Unrelated distracter	Unrelated distracter
broek	pants	broom	peach	record
⇨ Tijdens een wandeling in de stad, zag hij een **broek** in de winkel. (During a walk in the city, he saw pants in the store.)				
kast	cupboard	carpet	hammer	button
⇨ Ze vonden bijna alles, maar waren nog op zoek naar een **kast** in dat huis. (They almost found everything, but were still looking for a cupboard in that house.)				
kerk	church	carrot	spider	dentist
⇨ De vreemde kon zijn ogen niet geloven bij het zien van een **kerk** in dat dorp. (The stranger could not believe his eyes when he saw a church in that village.)				
koffer	suitcase	comb	shoe	nail
⇨ De kunstenares schilderde een **koffer** met de rode verf. (The artist made a painting of the suitcase wit the red paint.)				
draaimolen	carrousel	drill	house	bird
⇨ Lucie nam haar fiets en zag een **draaimolen** op de markt. (Lucie took her bike and saw a carrousel at the market.)				

fakkel	torch	farm	basket	brush

⇨ Ze kreeg een **fakkel** als geschenk voor haar verjaardag. (She received a torch as a birthday present.)

rolstoel	wheelchair	road	cheese	boy

⇨ Omdat ik wou kijken naar een **rolstoel** keek ik naar buiten. (Because I wanted to see a wheelchair I looked outside.)

citroen	lemon	scissors	chicken	trash

⇨ Ze wilde niets anders dan **citroen** om mee te gooien. (The only thing she wanted was lemon to throw with.)

trommel	drum	tree	necklace	bucket

⇨ Ze zag een **trommel** op de hoek van de straat. (She saw a drum at the corner of the street.)

wasknijper	clothespin	wallet	canopener	train

⇨ Volgens hem is een **wasknijper** de stomste uitvinding. (He says that a clothespin is the most stupid invention.)

CHAPTER 4
THE INFLUENCE OF SENTENCE CONTEXT AND ACCENTED SPEECH ON LEXICAL ACCESS IN SECOND-LANGUAGE AUDITORY WORD RECOGNITION[1]

Until now, research on bilingual auditory word recognition has been scarce, and although most studies agree that lexical access is language-nonselective, there is less consensus with respect to the influence of potentially constraining factors. The present study investigated the influence of three possible constraints. We tested whether language-nonselectivity is restricted by (a) a sentence context in a second language (L2), (b) the semantic constraint of the sentence, and (c) the native language of the speaker. Dutch-English bilinguals completed an English auditory lexical decision task on the last word of low- and high-constraining sentences. Sentences were pronounced by a native Dutch speaker with English as the L2, or by a native English speaker with Dutch as the L2. Interlingual homophones (e.g., lief (sweet) – leaf /li:f/) were always recognized more slowly than control words. The semantic constraint of the sentence and the native accent of the speaker modulated, but did not eliminate interlingual homophone effects. These results are discussed within language-nonselective models of lexical access in bilingual auditory word recognition.

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[1] Lagrou, E., Hartsuiker, R. J., & Duyck, W. (in press). The influence of sentence context and accented speech on lexical access in second-language auditory word recognition. *Bilingualism: Language and Cognition.*

INTRODUCTION

During the last decades, much research on bilingual word recognition has focused on the question whether lexical access is language-selective or not. By now, there is evidence from the visual (e.g., Dijkstra & Van Heuven, 1998; Duyck, 2005; Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Van Assche, Duyck, Hartsuiker, & Diependaele, 2009), and to a much lesser extent from the auditory domain (e.g., Ju & Luce, 2004; Lagrou, Hartsuiker, & Duyck, 2011; Marian & Spivey, 2003; Schulpen, Dijkstra, Schriefers, & Hasper, 2003; Spivey & Marian, 1999; Weber & Cutler, 2004) in favor of a language-nonselective account of lexical access. According to this account, lexical representations from both lexicons are activated at least to a certain degree during word recognition, even when only one language is task-relevant. It is less clear, however, whether there are factors that can constrain language-nonselective lexical access, such as the context of the to-be-recognized words. In the visual domain, a few studies have recently addressed this question (Duyck et al., 2007; Libben & Titone, 2009; Schwartz & Kroll, 2006; Titone, Libben, Mercier, Whitford, & Pivneva, 2011; Van Assche et al., 2009; Van Assche, Drieghe, Duyck, Welvaert, & Hartsuiker, 2011; Van Hell & de Groot, 2008), whereas such evidence is almost completely lacking for the auditory domain. In the present study, we therefore investigated whether the auditory presentation of a meaningful sentence context is a factor that can constrain lexical access to the currently relevant lexicon. Moreover, we examined whether the semantic predictability of target words in the sentence is a restricting factor, and additionally, we investigated the influence of sub-phonemic cues, inherent to the native accent of the speaker, on parallel language activation.

Bilingual Word Recognition in Isolation

Evidence for language-nonselective lexical access in bilingual auditory word recognition was first reported by Marian and colleagues.[2] In the eyetracking study of Spivey and Marian (1999), late Russian-English bilinguals who were very proficient in their L2 and living in a L2- dominant environment, were instructed in their L2 to pick up a real-life object (e.g., *"Pick up the marker"*). The participants fixated more on competitor items with a name in the irrelevant L1 that was phonologically similar to the target (e.g., a stamp; *marka* in Russian) than on distracter objects with a name in L1 that was phonologically unrelated to the L2 target. Additionally, there was evidence for language-nonselectivity even when participants were listening in L1. When Russian-English bilinguals received an instruction like: *"Podnimi marku"* ("Pick up the stamp"), they looked more often to interlingual competitor objects *(marker)* than to distracter objects. Analogous to the findings with the English instructions, this can be explained because the English translation equivalent of *marka (stamp)* is more phonologically similar to the Russian target word *marku* than to the distracters.

These results were partly replicated by Weber and Cutler (2004) in a later study with Dutch-English bilinguals. These bilinguals, who were living in an L1 dominant environment, were instructed to click on one of four pictures presented in a display, and move it to another location on the computer screen (e.g., *"Pick up the desk and put it on the circle"*). There

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[2] Although the instructions that participants received in the studies by Marian and colleagues and by Weber and Cutler (2004) actually consist of more than one word, we nevertheless considered these studies as isolation studies. We did this because the (very short) preceding sentences in these studies were identical across trials, and hence characterized by the same syntactic structure, lacking any semantic variation (i.e., *"Click on the…"*).

were more fixations on competitor objects whose name had a phonetically similar L1 onset than to distracter objects (e.g., when instructed to pick up the *desk*, there were more fixations on a picture of a *lid* than on control items, because *lid* is the translation equivalent of the Dutch word *deksel*, phonologically overlapping with the L2 target *desk*). However, when these participants were instructed in their L1 (e.g., target *deksel*) competitor items (*desk)* were not fixated longer than control items, which suggests that non-target language representations in L2 are not activated strongly enough to influence L1 recognition.

In one of Schulpen et al.'s (2003) experiments, Dutch-English bilinguals completed a cross-modal priming task in which primes were presented auditorily and targets visually. Visual lexical decision times were longer when the target was preceded by an interlingual homophone than when the target was preceded by a monolingual control. For instance, responses after the pair /li:s/ – LEASE were slower than after /freIm/ – FRAME (/li:s/ is the Dutch translation equivalent for *groin*). The observation of longer reaction times after interlingual homophone pairs suggested that bilinguals activated both the Dutch and the English meaning of the homophone. Furthermore, the authors observed that the auditory presentation of the English pronunciation of the interlingual homophone led to faster decision times on the related English target word than the Dutch version of the interlingual homophone. This indicates that these subtle differences between homophones may affect the degree of cross-lingual activation spreading, which will turn out to be important for the present study. These differences are most likely situated at the sub-phonemic level (e.g., languages often differ in the length of voice onset time [VOT]), but it is possible that there are suprasegmental differences too (e.g., Lee & Nusbaum, 1993).

Further studies on the influence of sub-phonemic cues on lexical access in bilinguals were reported by Lagrou et al. (2011) and Ju and Luce (2004). Lagrou et al. conducted a lexical decision experiment in L2 or L1 with Dutch-English bilinguals, living in a L1 dominant environment. The participants responded more slowly to homophones (e.g., *lief (*sweet) – *leaf* /li:f/) than to matched control words, both in L2 and L1, whereas a monolingual English control group showed no effect. Moreover, this study investigated whether the listener's selectivity of lexical access is influenced by the speaker's L1. With this aim, targets were pronounced by a native Dutch speaker with English as the L2 or by a native English speaker with Dutch as the L2. Although the speaker's accent contains language cues that might affect the activation of target and non-target languages (Schulpen et al., 2003), there was no interaction between the homophone effect and the native language of the speaker. In sum, the results of this study suggest that bilinguals do not use these language- and speaker- specific sub-phonemic cues to restrict lexical access to only one lexicon, even though this implies a less efficient strategy for lexical search.

Ju and Luce (2004) also found evidence for language-nonselective lexical access. Here however, the effect was modulated by sub-phonemic information related to language-specific voice-onset times (VOTs). In a visual world eyetracking study, Spanish-English bilinguals fixated pictures of interlingual competitors (nontarget pictures whose English names (e.g., *pliers*) shared a phonological similarity with the Spanish targets (e.g., *playa* "beach")) more frequently than control distracters. However, this effect was only found when the Spanish target words were altered to contain English-appropriate voice onset times. When the Spanish targets had Spanish VOTs, no L1 interference was found. The results of this study suggest that bilingual listeners may still use fine-grained, sub-phonemic, acoustic information related to language specific VOT to regulate cross-lingual lexical activation. At first sight, this is in contrast with the result of Lagrou et al. (2011). However, in the Ju and Luce study, a salient acoustic feature (voicing) was manipulated systematically, so that this artificial cue was a reliable and consistent predictor of language membership, whereas the stimuli in the Lagrou et al. study differed on a wider range of acoustic parameters (i.e., all sub-phonemic cues related to the native accent of the speaker). Moreover, in the study of Ju and Luce all stimuli started with voiceless stops, whereas the stimuli of Lagrou et al. started with a variety of sounds (i.e., nasals and fricatives).

Bilingual Word Recognition in a Sentence Context

Monolingual studies have demonstrated that contextual information is used to facilitate word recognition in the native language. For example, when reading ambiguous words, context helps to select the correct interpretation (e.g., Binder & Rayner, 1998; Onifer & Swinney, 1981; Rayner & Frazier, 1989). Moreover, predictable words are processed faster than non-predictable words (e.g., Schwanenflugel & LaCount, 1988; Schwanenflugel & Shoben, 1985; Stanovich & West, 1983). Semantic information provided by sentence context may also influence lexical selection in bilingual visual word recognition. For example, Schwartz and Kroll (2006) and Van Hell and de Groot (2008), found that the cognate facilitation effect (i.e., faster RTs on cognates than on matched control items) and the homograph effect (i.e., slower RTs on interlingual homographs than on matched control items), markers of cross-lingual lexical interactions in the visual domain, were annulled or diminished when reading high constraining sentences. In the study by Van Assche et al. (2011), cross-lingual interactions in high-constraining sentences were significant, both on the early and late reading times, whereas in a study by Libben and Titone (2009), this was only the case on the early reading time measures and not on the late comprehension measures. According to Titone et al. (2011), a possible explanation for the differences between studies could be that bilinguals differ in the relative degree of L2 proficiency or other variables that were not taken into account. Taken together, these studies indicate that semantic constraint influences, but does not annul, the co-activation of representations from both languages in the bilingual lexicon, at least in visual language processing.

In the auditory domain, research on bilingual word recognition in a sentence context is more scarce. Chambers and Cooke (2009) investigated whether interlingual lexical competition is influenced by the prior sentence context. In this visual world study, English-French bilinguals with varying proficiency levels listened to L2 sentences, and were instructed to click on the image that represented the sentence-final word. Each display contained an image of the final noun target (e.g., *chicken*), an interlingual near-homophone (e.g., *pool*) whose name in English is phonologically similar to the French target (e.g., *poule*), and two unrelated distracter items. The interlingual competitors were fixated more than unrelated distracter items when the prior sentence information was compatible with the competitor (i.e., both the French target and the interlingual near-homophone are plausible in the sentence context) (e.g., *Marie va décrire la poule* [Marie will describe the chicken]), but not when this sentence information was incompatible with the competitor (i.e., only the French target, but not the interlingual near-homophone is plausible in the sentence context) (e.g., *Marie va nourrir la poule* [Marie will feed the chicken]). These findings suggest that semantic constraints imposed by a sentence context may override activation of non-target language lexical competitors in the auditory domain.

FitzPatrick and Indefrey (2010) recorded EEGs from Dutch-English bilinguals listening to sentences in L2, containing semantic incongruities that typically elicit a N400 component. When listening to an incongruity in L2, this component is delayed in comparison with the component when listening to an incongruity in L1. In one condition of this study, the last word of the sentence was a word with initial overlap with an L1 translation equivalent of the most probable sentence completion (e.g., “My Christmas present came in a bright-orange *doughnut”* (initial overlap with “doos” where *doos* is Dutch for *box*). There was an N400 effect to L1 translation equivalents that were initially congruent with the sentence context. Importantly, this N400 had the same timing as the N400 in response to a semantic incongruity whose translation equivalent did not have initial congruence. Thus, when listening to sentences in L2, L1 competitors were not activated (or these L1 competitors are at least not considered for semantic integration). Because these sentences are quite semantically constraining towards the targets, FitzPatrick and Indefrey argued that sentences that bias towards specific lexical representations in the target language yield no cross-lingual effects.

Although both studies above used meaningful sentences in their studies, there have been no bilingual studies on auditory word recognition that directly manipulated the degree of semantic sentence constraint within-study, assessing its influence on cross-lingual interactions. The results of Chambers and Cooke (2009) and FitzPatrick and Indefrey (2010) suggest that contextual factors may have a larger impact on the degree of language selectivity in the auditory domain than in visual word recognition. However, it may also be the case that modulations by semantic constraint may be more pronounced for words with interlingual form overlap only (i.e., homographs and homophones, as used here) than for the typical cognates (e.g., Van Assche et al., 2011) in the visual studies, because such a constraint is compatible with the (shared) meaning of the L1 and L2 reading of cognates but only compatible with one of the two readings of a homograph/homophone. As such, a suggested interaction between sentence constraint and modality (visual vs. auditory) may be a by-product of the type of critical stimuli used to assess cross-lingual interactions. For the auditory domain, it remains possible that under high constraint, only one homophone meaning is considered, rendering the stimulus similar to one without form overlap.

The Present Study

Our goal was to address three questions. First, we investigated whether there is parallel language activation when listening to meaningful sentences in L2. Second, we investigated the influence of semantic constraint on lexical access when listening in L2. Third, we also tested whether sub-phonemic cues, provided by the native accent of a speaker, are used to restrict lexical access when listening to sentences. Our previous study (Lagrou et al., 2011) suggested that these sub-phonemic cues inherent to the native accent of the speaker are not used to restrict lexical access to the currently relevant lexicon when listening to words in isolation. However, in daily life people usually do not listen to isolated words, but have conversations with other people. Of course, a continuous stream of auditory input contains far more cues that could provide the listener with information about the language in use, which makes it more likely that such cues are indeed used to restrict lexical access when the input consists of sentences compared to isolated words. On the other hand, both in real life and in our experiments, speakers sometimes speak in a language that is the L2 to them, so that the cues picked up from the speaker's accent may be misleading with respect to language membership. Because cues based on speaker accent are not always valid indicators of the language for recognition, it is possible that listeners still do not exploit them to regulate the degree of language selectivity. The present design may reveal which of these two hypotheses is correct.

To summarize, we investigated whether L1 knowledge influences lexical access when listening to sentences in L2. With this aim, Dutch-English bilinguals completed an English lexical decision task on the last word of spoken sentences. In critical trials, this last word was either an interlingual homophone or a matched control word. To investigate the influence of sentence constraint, sentences were either low- or high-constraining. To test whether lexical access is sensitive to cues related to the native accent of the speaker, sentences were pronounced by a native Dutch speaker or by a native English speaker.

METHOD

Participants

Sixty-four students from Ghent University participated in the experiment for course credits or a monetary fee. All were native Dutch speakers and reported English as their L2.[3] They started to learn English around the age of 14 years at secondary school, and because they were regularly exposed to their L2 through popular media, entertainment, and English university textbooks, they were all quite proficient in their L2, even though they lived in a clearly L1-dominant environment.[4] After the experiment, participants were asked to rate their L1 (Dutch) and L2 (English) proficiency with respect to several skills (reading, writing, speaking, understanding, general proficiency) on a 7-point Likert scale ranging from "very bad" to "very good". We also assessed general L3 (French) proficiency. Means are reported in Table 1. Mean self-reported L1 (M = 6.03), L2 (M = 5.03), and L3 (M = 4.00) general proficiency differed significantly (dependent samples t-tests yielded ps < .001).

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[3] Although French is typically the second language of children raised in Flanders, we consider it here as the third language because our participants are much more proficient in English. So in this study, L2 is defined in terms of current dominance, and not of age of acquisition.

[4] In a previous study in our lab, a comparable group of participants was asked to report their exposure level in Dutch, English, French and other languages. Participants reported that they are exposed to Dutch during 92 % of the time, to English during 6 % of the time, and to French during merely 1 % of the time, which is almost negligible and not much more than for other languages such as German and Spanish (somewhat less than 1 % of the time).

Table 1. Self-reported rating (7-point Likert scale) of L1, L2, and L3 proficiency. Standard deviations are indicated in parentheses.

Language	Skill	
L1 (Dutch)	Writing	5.78 (0.87)
	Speaking	5.85 (0.99)
	Reading	6.12 (0.82)
	Understanding	6.35 (0.74)
	General Proficiency	6.03 (0.68)
L2 (English)	Writing	4.71 (1.01)
	Speaking	4.98 (0.99)
	Reading	5.34 (0.99)
	Understanding	5.52 (1.00)
	General Proficiency	5.03 (0.85)
L3 (French)	General Proficiency	4.00 (1.25)

Participants were not informed that their L1 knowledge would be of any relevance to the experiment. Thirty-three participants listened to the sentences pronounced by the native Dutch speaker, 31 participants listened to the sentences pronounced by the native English speaker. One participant who made more than 20 % errors was excluded from all analyses.

Stimulus Materials

Target stimuli consisted of 240 stimuli: 30 interlingual Dutch-English homophones (e.g., *lief* (sweet) – *leaf* /li:f/), 30 matched English control words, 60 English filler words, and 120 nonwords. All targets were selected from the stimulus list of Lagrou et al. (2011), in order to increase comparability across studies, and therefore make it possible to assess the context effects while keeping stimuli constant. Targets were between three and seven phonemes long, and control words were matched with these homophones with respect to number of phonemes and English frequency as reported in the CELEX database (*p*s > .32). Nonwords were created with the WordGen stimulus software (Duyck, Desmet, Verbeke, & Brysbaert, 2004). They were phoneme strings with no Dutch or English meaning, but with a legal English phonology, and they were matched with interlingual homophones and control words with respect to word length. For each target, a low- and high- constraining sentence was constructed, resulting in 480 sentences. Sentences were matched in terms of number of words and syntactic structure. Targets were always in the final position of the sentence. To ensure that participants would not see the same target twice, sentences were divided across two lists. The low- and high-constraining sentences for each homophone-control pair are included in the Appendix. Sentences were pronounced by a native Dutch speaker who was also a highly proficient English speaker, or by a native English speaker who was also a highly proficient Dutch speaker. Using WaveLab software, stimulus materials were recorded in a sound-attenuated booth by means of a SE Electronics USB1000A microphone with a sampling rate of 44.1 kHz and a 16-bit sample size. Sentence- and target-durations were measured with WaveLab software.

Sentence Completion

To verify the constraint manipulation of the sentences containing an interlingual homophone or control word, a sentence completion study was conducted with twenty further participants. Participants saw each sentence without the interlingual homophone/control word, and were instructed to complete the sentence with the first word that came to mind when reading the sentence. Production probabilities for interlingual homophones and control words were extremely low for low-constraining sentences, and were very high for high-constraining sentences. Production probabilities for the irrelevant L1 translation equivalents of the homophone were extremely low for low- and high- constraining sentences (see Table 2).

Additionally, another fifteen participants were asked to rate the plausibility of the low constraining sentences on a scale from 1 (not at all plausible) to 9 (very plausible). A paired t-test demonstrated that plausibility ratings for homophone sentences (M = 5.79, SD = 0.50) did not differ from ratings for control word sentences (M = 6.06, SD = 1.51), $t(29) = -0.76$, p = .46.

Table 2. Production probabilities for interlingual homophones, control words, and L1 translation equivalents of the homophone in low- and high-constraining sentences. Standard deviations are indicated in parentheses.

	Sentence constraint	
Word type	Low	High
Interlingual homophone	0.01 (0.02)	0.81 (0.08)
Control word	0.02 (0.04)	0.77 (0.17)
L1 translation equivalent	0.02 (0.11)	0.0008 (0.006)

Speakers

The native Dutch speaker was a 25-year-old female with Dutch as L1 and English as L2. She had 12 years of L2 experience. Her English was very fluent but characterized by a clear Dutch accent. The native English speaker was a 45-year-old female with English as L1 and Dutch as L2. She had L2 experience since she moved to the Dutch-speaking part of Belgium 15 years ago. Her Dutch was very fluent but characterized by a clear English accent.

Procedure

Participants received written instructions in English (their L2) to perform an English lexical decision task on the last word of each sentence. They wore a headphone through which sentences were presented auditorily. Before the experiment, a practice session of 24 trials was completed. Each trial started with a 500 ms presentation of a fixation cross in the center of the screen. After another 200 ms the sentence was presented. Then participants had to decide whether the last word was an English word or a nonword. When a word (nonword) was presented, participants used their right (left) index finger to press the right (left) button of a response box. Visual feedback was presented on the screen during 200 ms (i.e., when an error was made the screen turned red, when the response was correct, “OK!” appeared). The next trial started 500 ms later. After the experiment, participants completed a questionnaire assessing self-ratings of L1 and L2 proficiency (reading, speaking, writing, understanding, and general proficiency), and general L3 proficiency on a seven-point Likert scale, and a backward translation test to verify that they knew the L2 words.

RESULTS

On average, participants made 6.54 % errors (*SD* = 2.30). Errors, trials with RTs faster than 300 ms after target onset, and trials with RTs more than 2.5 standard deviations above the participant’s mean RT after target offset for word targets were excluded from the analyses. As a result, 8.29 % of the data were excluded from the analyses. In all experiments, reported latency analyses are based on RTs measured from (auditory) target offset.[5] We reported these measures because the native and non-native speaker differed in pronunciation duration ($p < .01$). Importantly, the pronunciation durations did not differ systematically for low- and high-constraining sentences ($p > .15$) (see Table 3).

[5] When latency analyses were based on reaction times measured from (auditory) target onset, the same pattern of results was obtained.

Table 3. Mean pronunciation durations of target words (homophones and controls) as a function of constraint and speaker.

	Low-constraint	High-constraint
Speaker		
Native Dutch speaker	380	361
Native English speaker	470	442

An ANOVA on the reaction times (see Figure 1 and Table 4) with target type (interlingual homophone vs. control) and sentence constraint (low vs. high) as the independent within-subjects variables and speaker (native Dutch vs. native English) as the independent between-subjects variable revealed a main effect of target type, $F1(1,61) = 234.50$, $p < .001$, $\eta^2_p = .79$; $F2(1,29) = 27.01$, $p < .001$, $\eta^2_p = .48$, indicating that reaction times were significantly slower on interlingual homophones than on control words. Importantly, the main effect of sentence constraint was significant, $F1(1,61) = 325.92$, $p < .001$, $\eta^2_p = .84$; $F2(1,29) = 152.36$, $p < .001$, $\eta^2_p = .84$, indicating that participants responded significantly faster on targets that were preceded by a high-constraining sentence context than on targets that were preceded by a low-constraining sentence context. This ensures validity of the constraint manipulation. The main effect of speaker was also significant, $F1(1,61) = 10.24$, $p < .01$, $\eta^2_p = .14$; $F2(1,29) = 80.23$, $p < .001$, $\eta^2_p = .74$, indicating that participants responded faster when the sentences were pronounced by the native English speaker than when they were pronounced by the native Dutch speaker. Moreover, the interaction between sentence constraint and target type was also significant, $F1(1,61) = 28.49$, $p < .001$, $\eta^2_p = .32$; $F2(1,29) = 9.30$, $p < .01$, $\eta^2_p = .24$, showing a larger homophone effect in the low-constrained condition. Planned comparisons demonstrated that the homophone effect was significant when the target was preceded by a low-constraining sentence, *F1*(1,61) = 173.23, $p < .001$, $\eta^2_p = .74$; *F2*(1,29) = 46.68, $p < .001$, $\eta^2_p = .62$, but also when the target was preceded by a high-constraining sentence, *F1*(1,61) = 56.85, $p < .001$, $\eta^2_p = .48$; *F2*(1,29) = 6.32, $p < .05$, $\eta^2_p = .18$. The interaction between target type and speaker was significant in the by-subjects analysis, *F1*(1,61) = 6.84, $p < .05$, $\eta^2_p = .10$; *F2*(1,29) = 3.06, $p = .09$, $\eta^2_p = .10$, with a larger effect for the Dutch native speaker. Planned comparisons demonstrated that the homophone effect was significant when sentences were pronounced by the native Dutch speaker, *F1*(1,61) = 168.76, $p < .001$, $\eta^2_p = .80$; *F2*(1,29) = 23.26, $p < .001$, $\eta^2_p = .42$, but also when sentences were pronounced by the native English speaker, *F1*(1,61) = 76.95, $p < .001$, $\eta^2_p = .82$; *F2*(1,29) = 21.10, $p < .001$, $\eta^2_p = .45$. No further interaction was significant, all *F1* < 1, *F2* < 1.

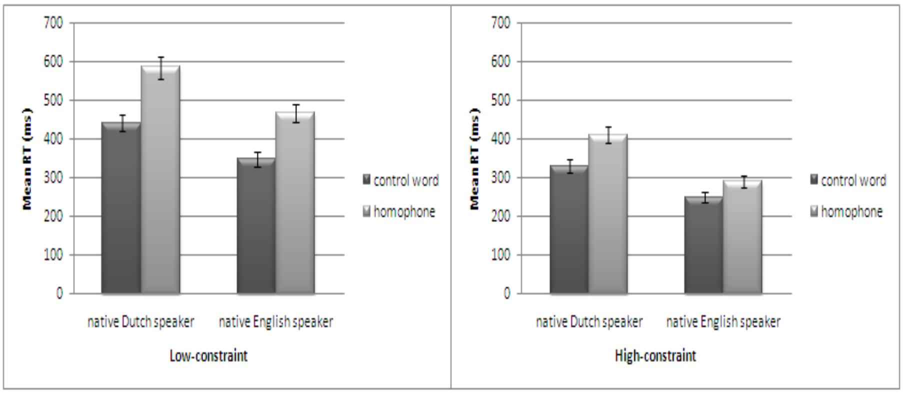

Figure 1. RTs on homophones and matched control words as a function of sentence constraint (low vs. high) and native accent of the speaker (native Dutch vs. native English). The vertical bars represent the 95 % confidence interval.

Table 4. Mean RTs and Effect (in Milliseconds) as a function of word type, constraint and speaker.

Constraint	Speaker	Control words	Homophones	Effect
Low-constraint				
	Native Dutch speaker	444	587	143
	Native English speaker	349	463	114
High-constraint				
	Native Dutch speaker	332	412	80
	Native English speaker	248	285	37

It is conceivable that the interactions of the interlingual homophone effect with semantic constraint and speaker accent are influenced by the overall faster reaction times on high-constraining sentences and sentences pronounced by the native English speaker, yielding smaller homophone effects. On this account, semantic information and cues inherent to the native accent of the speaker speed up word recognition, but are not used as a strict cue to restrict lexical search to a single language, and therefore do not modulate the degree of language-nonselectivity. To test this hypothesis taking into account baseline RT differences across constraint conditions, we first calculated the percentage homophone interference score for each semantic context.[6] For each participant, and for both the low- and high constraining sentences, the difference between the reaction times on homophone sentences and the reaction times on control sentences was divided by the reaction times on control sentences. A paired t-test demonstrated that this interference score was not significantly different for low- and high-constraining sentences, p = .26. Second, we also calculated the percentage homophone interference score for both the Dutch and the English speaker. Again, a paired t-test revealed that the interference score was not significantly different for both speakers, p = .87. This analysis supports the possibility that the interaction effects of the homophone effect with both semantic constraint and the native language of the speaker reflect overall RT differences. In any case, in each of the separate conditions, the homophone effect, as a marker of cross-lingual lexical interactions, was significant.

Because the results of the plausibility ratings of the low-constraining sentences demonstrated that some of the low-constraining sentences may not have been very plausible, we ran an additional analysis in which we excluded the low-constraining sentences and their high-constraining counterpart of which the homophone or control word had a plausibility score lower than 4 on a scale from 1 (not at all plausible) to 9 (very plausible). As a consequence, ten sentences were excluded from this analysis. These sentences are marked in the Appendix with an asterisk. However, the exclusion of these sentences did not change the pattern of results, except that the interaction between sentence constraint and target type was only significant in the analysis by subjects, $F1(1,61) = 15.23$, $p < .001$, $\eta^2_p = .28$ but not in the analysis by items, $F2 < 1$, probably because this of course limited the number of critical stimuli considerably.

[6] We thank an anonymous reviewer for this suggestion.

GENERAL DISCUSSION

The present study investigated whether lexical access is language-nonselective when listening to words that are embedded in meaningful sentences in L2. Furthermore, we examined whether the degree of language-nonselectivity is modulated by the semantic constraint of the sentences and by the (native or non-native) accent of the speaker of the sentences. Dutch-English late bilinguals, immersed in a L1 dominant environment, completed an L2 auditory lexical decision task on the last word of low- and high-constraining sentences that were pronounced by a native Dutch or by a native English speaker. The results showed that reaction times were significantly slower on interlingual homophones (e.g., *lief* (sweet) – *leaf* /li:f/) than on matched control words. This indicates that our bilingual listeners activated both the L2 and the L1 representation of the homophones, and it implies that sub-phonemic cues provided by the stream of speech in a sentence are not used to restrict lexical access to a single lexicon. We found this effect, even though the participants in this study were late bilinguals that are moderately proficient in their L2, and typically use it less than 5% of the time (for a quantification of language dominance in this homogenous population, see Duyck & Warlop, 2009). A question that needs to be investigated in future research concerns whether these cross-lingual effects may interact with lower/higher L2 proficiency levels than those of the current study. The current results extend the monolingual finding of Frazier and Rayner (1990) for example, who reported that intralingual homophones are recognized more slowly than non-homophones. The present study also extends previous work on isolated auditory word recognition (e.g., Lagrou et al., 2011; Marian & Spivey, 2003; Schulpen et al., 2003; Spivey & Marian, 1999; Weber & Cutler, 2004) to word recognition in more ecologically valid contexts, namely sentences.

Second, we considered the influence of factors potentially modulating cross-lingual activation spreading, namely semantic constraint of the sentence and speaker accent. The main effect of sentence constraint is consistent with earlier findings in monolingual and bilingual studies of visual word recognition. In the monolingual domain (e.g., Schwanenflugel & LaCount, 1988; Schwanenflugel & Shoben, 1985; Stanovich & West, 1983) participants are typically faster to recognize words that are highly predictable from the preceding sentence context. In the bilingual visual domain, faster reading times for high-constraining sentences than for low-constraining sentences were also found, for example, by Van Assche et al. (2011). Here, we generalize this effect to auditory bilingual word recognition. Importantly, the interaction between the homophone effect and semantic constraint of the sentence was significant, which indicates that the homophone effect was smaller, but not completely annulled, when the preceding sentence context was highly constraining towards the target. This suggests that the semantic constraint of the sentence affects the activation level of representations from both the native and the nonnative language in the bilingual language system, but this activation pattern does not completely eliminate cross-language activation as such. Note that studies in the domain of visual word recognition show a mixed pattern of results, with some studies finding that semantic constraint eliminates cross-lingual effects (Schwartz & Kroll, 2006; Van Hell & de Groot, 2008) and other studies showing that such effects survive a highly semantically constraining sentence (Libben & Titone, 2009; Titone et al. , 2011; Van Assche et al., 2011). In the bilingual auditory domain, the results of Chambers and Cooke (2009) and FitzPatrick and Indefrey (2010) suggest that semantic constraints imposed by a sentence context may annul activation of non-target language lexical competitors. The findings from the present study, however, demonstrate that such a constraint may influence word recognition, but does not *necessarily* eliminate cross-lingual lexical interactions. A possible explanation for these divergent results could be that we used interlingual homophones, of which the lexical and phonological overlap is maximal. In contrast with our stimuli, Chambers and Cooke used near-homophones and the stimuli of FitzPatrick and Indefrey only shared an overlapping onset. Hence, cross-lingual activation spreading in those studies was much weaker and therefore probably also more easily overridden by the stronger semantic context manipulation.

Third, we tested whether the homophone interference effect was modulated by the native accent of the speaker. The results showed that participants are faster when sentences are pronounced by the native English speaker than when they are pronounced by the native Dutch speaker. It is possible that the threshold for word recognition is exceeded faster when the pronunciation provides a closer match to the listener's stored representation, which is indeed the case when English sentences are pronounced by a native English speaker.[7] This explanation is also compatible with the results of Adank, Evans, Stuart-Smith, and Scott (2009), who demonstrated that listeners have difficulties processing speech with a nonnative accent. At least, the fact that reaction times are influenced by the native accent of the speaker demonstrates that the different accents of our speakers indeed contained language-specific acoustic information, which constitutes a valid manipulation check for the assumed sub-phonemic differences between languages. In future research, it would be interesting to investigate more in detail whether this accent-effect arises because Dutch speech increases the salience of Dutch or the fact that accented speech is less intelligible overall. The results also showed that the homophone effect was reduced (but not eliminated) when sentences were pronounced by the native English speaker. This suggests that sub-phonemic cues, inherent to the speaker's L1 are used to some extent as a cue to restrict lexical search to a single lexicon. These

[7] For these participants, L2 comprehension is typically more frequent than L2 production. And, because most L2 exposure originates from media, television, music, etc., participants are more exposed to speech produced by native speakers than by Flemish (Dutch) speakers.

findings are consistent with Schulpen et al. (2003), who reported that the English pronunciation of (auditorily presented) interlingual homophones led to stronger priming of the English target than the Dutch pronunciation of that same homophone. They are also partly consistent with Ju and Luce (2004), who found that L1 recognition (Spanish) was influenced by L2 (English) competitors if L1 materials contained L2 sub-phonemic features (i.e., English VOTs), even though the strong acoustic feature (i.e., voicing) in that study was manipulated systematically, whereas the present stimuli differed on a wider range of acoustic parameters, so that such information is less reliable as a cue for lexical selection.

These findings have several theoretical implications. First, this study demonstrates that the language-nonselective nature of lexical access is not fundamentally altered by the preceding (low-constraining) sentence context: even unilingual language context is not used as a restrictive lexical cue, even though this might be an efficient strategy to speed up word recognition as this would surely eliminate a sizable proportion of the considered lexical candidates. Note however that Vitevitch (2012) conducted a corpus analysis which challenges the fact that many lexical candidates are active at the same time.

Second, the current results show that a highly constraining sentence context does influence the language-nonselectivity of lexical access in the bilingual language system. Nevertheless, it does not prevent activation of lexical representations in the non-target language, not even when these representations do not meet these semantic restrictions (the critical stimuli were interlingual homophones and therefore only have form overlap across languages).

Third, the results of the present study also demonstrate that speech-specific cues provided by the native accent of the speaker are used to some extent to modulate the language-nonselective nature of bilingual lexical access. However, the fact that the homophone effect remained significant when sentences were pronounced by the native Dutch speaker demonstrates that these sub-phonemic cues are not applied to completely restrict lexical access to the currently relevant lexicon.

Our interlingual homophone effects can be explained by extending monolingual models of auditory word recognition such as the Distributed Model of Speech Perception (Gaskell & Marslen-Wilson, 1997), NAM (Luce & Pisoni, 1998), Shortlist (Norris, 1994; Norris, McQueen, Cutler, & Butterfield, 1997), and TRACE (Elman & McClelland, 1988; McClelland & Elman, 1986) if they are extended with the assumption that L2 representations are part of the same system as, and interact with, L1 representations. The results of the present study also demonstrate that there is an influence of top-down factors such as the semantic constraint of the sentence or sub-phonemic information provided by the native accent of the speaker, to inhibit lexical representations belonging to a particular language. Thus, at a theoretical level, the results of the present study are compatible with a model of bilingual auditory word recognition that supports language-nonselective bottom-up activation with a role for top-down connections that does not result in a functionally language-selective system. Because the homophone effect was reduced, but did not disappear in the high constraint condition and in the condition in which sentences were pronounced by the native English speaker, we can conclude that this role is limited. These findings are partly in line with the visual domain, for which there is a dominant model of bilingual word recognition, i.e., the BIA+ model (Dijkstra & Van Heuven, 2002). This model consists of language nodes which act as language membership representations within the word identification system, but these nodes do not have top-down connections that regulate cross-lingual activation.

In sum, the present study provides evidence for the conclusion that lexical access is language-nonselective. However, when the semantic context is highly constraining and when the native accent of the speaker is compatible with the target language, cross-lingual interactions are reduced (but not eliminated) by these semantic and accent-specific cues when listening to sentences in L2.

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APPENDIX

Experimental stimuli. Asterisks indicate sentences excluded from the additional analysis for eliciting plausibility scores lower than 4 on a scale from 1 (not at all plausible) to 9 (very plausible). Note that when a sentence was categorized as implausible, both the low- and high constraining homophone and control word sentence were excluded from the analysis.

Low-constraining sentences

1. **bay – hug**
On their trip to Italy the travelers saw a large **bay**.
On that rainy day the old man gave that woman a **hug**.

2. **beat – nose**
The boy with the glasses enjoyed the **beat**.
The girl with the pony tail had a beautiful **nose**.

3. **bill – skin**
At the end of the evening, she looked surprised at the **bill**.
At the end of the day she had a beautiful **skin**.

4. **bone – lion**
In my mother’s soup you can always find a **bone**.
In the zoo you can see more than one **lion**.

5. **boss – rush**
After a long ride we finally reached the **boss**.
After a long day at work we had to **rush**.

6. **bull – page**
The man suddenly realized that he had to deal with a dangerous **bull**.
The writer just imagined that he had written his last **page**.

7. **cook – fast**
At last it turned out to be a very good **cook**.
At last we noticed that he was really **fast**.

8. **cow – bag**
There was a lot of damage because of this terrible **cow**. *
There was too much food to put in one **bag**.

9. **day – boy**
After that car accident my sister had a terrible **day**.
After that search they finally found a **boy**.

10. **hook – farm**
Because the little girl had been bad, she had to sit in a room with a scary **hook**. *
Because she wanted an active life, she had bought a very big **farm**.

11. **lake – soft**
They went for a walk and suddenly saw a **lake**.
They were surprised to notice that it was not so **soft**.

12. **lane – king**
If you want to go to the museum, then follow this **lane**.
If you want to go to the city, maybe you will see the **king**.

13. **lead – risk**
The answer to that question was given by a **lead**. *
The crime was committed by the murderer who had taken more than one **risk**.

14. **leaf – wine**
When you walk in the forest, there is a chance that you find a **leaf**.
When you go shopping, it is nice to buy some **wine**.

15. **list – wing**
Everything that is written on that sheet is just a **list**.
Everything is fine, except that there is a problem with the **wing**.

16. **mail – fork**
After only five minutes Ann finished her last **mail**.
After only two months the child learned how to use a **fork**.

17. **mess – safe**
The woman opened the door of the room and the only thing she saw was a **mess**.
She opened the door of the bathroom and saw that everything was **safe**.

18. **mood – silk**
They did not dare to disagree with the director’s proposal because there was not enough **mood**. *
The girl did not like that very much because the only thing she wanted was **silk**.

19. **pet - fox**
The boy’s birthday present was a new **pet**.
The woman’s greatest fear was to be killed by a **fox**.

20. **plane – towel**
The couple enjoyed a romantic afternoon sitting in the **plane**. *
My sister asked for her birthday a new **towel**.

21. **praise – poison**
He said that he is an important person, and that’s why he wants **praise**.
Because he had no idea what he wanted, he asked for **poison**. *

22. **pray – claw**

Some people say they want nothing else but **pray**.

Some days I am really afraid of that **claw**. *

23. **proof - widow**

If you want to be sure about something you need the right **proof**.

If you want to go to the cemetery, you should join that **widow**.

24. **raise – elbow**

That man showed his appreciation for that woman by giving her a nice **raise**.

The child fell of his bike and had now a painful **elbow**.

25. **room – wife**

Now that she earns more money she has a lot of **room**. *

Now that he is a little bit older he really wants a **wife**.

26. **slim – deaf**

John loves his new girlfriend because she is so **slim**.

Marc does not like discussing that topic because he is **deaf**.

27. **tail – meat**

While we were washing the dog, the child looked at the **tail**.

While we were eating a salad, my father ate **meat**.

28. **track – taste**

After we figured out how the murderer killed his victim we lost every **track**. *

After she had that car accident she lost every **taste**.

29. **vet – spy**

Because our cat was very skinny, we had to ask for some **vet**. *

Because our neighbors do not like my brother, they said he is a **spy**. *

30. **way – old**

You will never find what you are looking for if you keep searching in that **way**.

You will have to drink a lot of milk if you want to become **old**.

High-constraining sentences

1. **bay – hug**

An area of water bordered by land is what we call a **bay**.

On the day Mary was sad, her friend comforted her with a kiss and a **hug**.

2. **beat – nose**

The boy with the glasses listened to a song with a heavy **beat**.

The girl with the pony tail had a cold and had to blow her **nose**.

3. **bill – skin**

At the end of the evening she said she had to pay the **bill**.

At the end of the summer she had a tanned **skin**.

4. **bone – lion**

In my mother's garden the dog is hiding a **bone**.

In the zoo you can see the king of the animals, which we call the **lion**.

5. **boss – rush**

After more than twenty years I was fired by my **boss**.

After lunch he was late and had to **rush**.

6. **bull – page**

The toreador suddenly realized that he had to deal with a dangerous **bull**.

The teacher just told the reading students that they had to turn a **page**.

7. **cook – fast**

At last the boss of the restaurant hired a new chef to **cook**.

At last he was on time because he drove really **fast**.

8. **cow – bag**

There was only one farmer able to milk that **cow**.

There was a person to put all the shopping goods in a **bag**.

9. **day – boy**

After twenty-four hours we were awake for one night and one **day**.

After these parents had four girls, they finally had a **boy**.

10. **hook – farm**

Because the captain lost his hand, he had replaced it with a sharp **hook**.

Because she wanted to breed cattle, she lived on a big **farm**.

11. **lake – soft**

They did not want to swim in the big see, but in a small **lake**.

They were buying pillows in a fabric that is very **soft**.

12. **lane – king**

If you want to be precise, a street surrounded by trees is what we call a **lane**.

If you want permission, maybe you should ask the queen and the **king**.

13. **lead – risk**

The chief decided what his workers had to do, so he took the **lead**.

The man wanted to put all his money in that bet, and therefore took a great **risk**.

14. **leaf – wine**

When the fall is coming in September most trees are losing more than one **leaf**.

When you go to France for a holiday it is nice to have some cheese and **wine**.

15. **list – wing**
The teacher reads aloud every student's name that is written on that **list**.
Everything is fine, except that this bird cannot fly because of a broken **wing**.

16. **mail – fork**
After work Ann always checks on her computer whether she has **mail**.
After only two months, the child learned how to eat with knife and **fork**.

17. **mess – safe**
The burglars destroyed everything and really made a **mess**.
She closed all windows and doors of her house, because that was for her the only way to feel **safe**.

18. **mood – silk**
They wanted to cheer her up because she was in a bad **mood**.
The girl wanted a new dress in an expensive fabric like satin or **silk**.

19. **pet – fox**
The boy wanted a dog or a cat as a new **pet**.
A red-brown animal with a fluffly tail that often kills chickens is a **fox**.

20. **plane – towel**
The couple enjoyed a romantic flight sitting in the **plane**.
My sister enjoys taking a bath to dry her then with a soft and fresh **towel**.

21. **praise – poison**
The Bible says that the Lord is the person you should honor and **praise**.
Because there were too many rats in the building, they were given **poison**.

22. **pray – claw**
Some people are very catholic and go to church to **pray**.
Some cats like trees, because they use them to sharpen their **claw**.

23. **proof – widow**
If you want to put the criminal in jail you have to find the right evidence or **proof**.
If your husband dies, you are what we call a **widow**.

24. **raise – elbow**
The scientist asked his boss for more money, so he asked for a **raise**.
The part of your body where your arm flexes is your **elbow**.

25. **room – wife**
Now that she has three kids, she wants a house with more than one **room**.
Now that they are married you should name them husband and **wife**.

26. **slim – deaf**
John has lost a lot of weight, and now he is really thin and **slim**.
Marc does not hear what you say because he is **deaf**.

27. **tail – meat**
While we were looking at the pig, it moved its curly **tail**.
While she was a vegetarian, she never ate **meat**.

28. **track – taste**
After the criminal escaped they could not find him, so they lost every **track**.
After she bought those new shoes, people complemented her with her good **taste**.

29. **vet – spy**
Because our cat was sick, we had to take her to the **vet**.
Because he gathers secret information about his enemies, we call him a **spy**.

30. **way – old**
You will be more popular when you live your life in a different **way**.
You will see that this book is suited for young and **old**.

CHAPTER 5
DOES THE SEMANTIC CONSTRAINT OF THE SENTENCE INFLUENCES LANGUAGE SELECTIVITY OF LEXICAL ACCESS WHEN LISTENING IN THE NATIVE LANGUAGE?[1]

The present study investigated whether the semantic constraint of a sentence context modulates language-nonselective lexical access in bilingual auditory word recognition when listening in the native language (L1). Therefore, Dutch-English bilinguals completed an auditory lexical decision task in L1 on the last word of low- and high-constraining sentences. In these sentences, the critical stimuli were interlingual homophones (e.g., lief (sweet) – leaf /li:f/). Participants responded significantly slower to these stimuli than to matched control words. Importantly, there was no interaction between homophony and semantic constraint, which suggests that the semantic sentence constraint does not necessarily result in language-specific lexical access, even not when listening in the native language.

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[1] Lagrou, E., Hartsuiker, R. J., & Duyck, W. (manuscript submitted for publication). Does the semantic constraint of the sentence influences language selectivity of lexical access when listening in the native language?

INTRODUCTION

Much bilingual research during the last decade has focused on the question whether lexical access in word recognition is language-selective or not. According to one point of view bilinguals have two separate lexicons. So, when reading or listening in one language, only words from this lexicon are activated. However, by now there is much evidence for another viewpoint according to which bilinguals have one lexicon that integrates words from both the native (L1) and nonnative (L2) lexicon. Evidence in favor of this account has especially been reported in the visual domain (e.g., Dijkstra & Van Heuven, 1998; Duyck, 2005; Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Van Assche, Duyck, Hartsuiker, & Diependaele, 2009), with a few exceptions in the auditory domain (e.g., Ju & Luce, 2004; Lagrou, Hartsuiker, & Duyck, 2011; Marian & Spivey, 2003; Schulpen, Dijkstra, Schriefers, & Hasper, 2003; Spivey & Marian, 1999; Weber & Cutler, 2004). More recent research has started to investigate whether there are factors that can constrain this language-nonselectivity (e.g., context or talker factors). In the present study, we investigated two such factors. In particular, we tested whether lexical access remains language-nonselective when listening to sentences in the native language (L1). Additionally, we also tested the influence of the semantic constraint of the sentence. The issue of language-selectivity in an auditory sentence context in L1 and its possible modulation by semantic constraint of the sentence has so far not been investigated. Although previous studies mostly agree that lexical access is language-nonselective when reading or listening in L2, the evidence for language-nonselectivity in L1 is not consistent, and the relevant studies are restricted to recognition of isolated speech/words (e.g., Spivey & Marian, 1999; Weber & Cutler, 2004). Compared with L2 recognition, it is less likely that lexical access in L1 is language-nonselective because it is conceivable that L2 representations are too weak to compete with L1 representations. Moreover, Lagrou, Hartsuiker, & Duyck (in press) demonstrated that when listening in

L2, the activation of lexical representations of the non-target language (i.e., L1) is modulated, but not eliminated, by the semantic constraint of the sentence. As a consequence, it might be that several factors conspire to render lexical access language-selective. Because the evidence in favor of L2 lexical activation during L1 auditory word recognition in sentence context is so scarce, it is interesting to explore the extremes of such lexical interactions: Do sentences that generate strong lexical restrictions towards a specific word in the target language completely eliminate interlingual effects? To our knowledge, there are currently no studies that have directly tested the influence of this type of constraint on listening in the native language. So, this is the aim of the present study.

In the following paragraphs, we will first give an overview of the literature on bilingual auditory word recognition in L2 and in L1. Then we will present some studies on bilingual word recognition that investigated the influence of semantic constraint on lexical access.

Bilingual Auditory Word Recognition

Although research on bilingual auditory word recognition remains much more scarce than research in the visual domain, there are now several studies that agree that lexical access is language-nonselective when listening in L2. For example, pioneering studies by Marian and colleagues (Marian & Spivey, 2003; Spivey and Marian, 1999), and subsequent work by Weber and Cutler (2004) and Lagrou et al. (2011) all found that listening in a second language is influenced by knowledge of the native language. In studies by Marian and colleagues late Russian-English bilinguals who were highly immersed in English participated in a visual world study in which they were instructed in their L2 to pick up a real-life object (e.g., "*Pick up the marker*"). The participants fixated more on competitor objects with a name in the irrelevant L1 that was phonologically similar to the target (e.g., a stamp;

marka in Russian) than on distracter objects with a name in L1 that was phonologically unrelated to the L2 target. This effect was replicated with a group of Dutch-English bilinguals, in a comparable eyetracking study by Weber and Cutler. The results of an auditory lexical decision study by Lagrou et al. are consistent with these eyetracking results. In the latter study, bilinguals (but not monolinguals) showed slower L2 lexical decisions on interlingual homophones (e.g., *lief* (sweet) – *leaf* /li:f/) than on matched control words, suggesting that when listening in L2, lexical access is language-nonselective.

The evidence for language-nonselectivity in bilingual auditory word recognition is less consistent for listening in the native language. Spivey and Marian (1999) instructed Russian-English bilinguals also in their L1 (e.g., *"Podnimi marku"* meaning "Pick up the stamp"), and found that they also fixated more on competitor items with a name in the irrelevant L2 that was phonologically similar to the target (e.g., *marker*). However, this was not the case in the study by Weber and Cutler (2004). In this study, Dutch-English bilinguals who were instructed in their L1 did not fixate more on the irrelevant L2 competitor that was phonologically similar to the target. A clear difference between studies that could account for this inconsistency is that the bilinguals of Marian and colleagues were L2 immersed and as a consequence probably much more proficient. Using a different paradigm, Lagrou et al. (2011) did however reach similar conclusions as Spivey and Marian. They found that lexical decision times were slower for interlingual homophones than for controls when listening in L1, even though the participants in this study were non-immersed and less proficient in their L2 than the bilinguals in the study by Spivey and Marian, and thus comparable to the group op bilinguals that participated in the Weber and Cutler study. More evidence for language-nonselective lexical access in L1 comes from a visual world eyetracking study by Ju and Luce (2004), but here the effect was modulated by sub-phonemic information related to language-specific voice onset times (VOTs). In this study, Spanish-English bilinguals fixated pictures of interlingual competitors (nontarget pictures whose English names (e.g., *pliers*) shared a phonological similarity with the Spanish targets (e.g., *playa*, “beach”)) more frequently than control distracters. However, this effect was only found when the Spanish target words were altered to contain English-appropriate voice onset times. When the Spanish targets had Spanish VOTs, no L1 interference was found.

The Influence of Semantic Constraint

In the literature on monolingual word recognition, several studies have demonstrated that readers automatically use contextual information to facilitate word recognition. Studies by Binder and Rayner (1998), Onifer and Swinney (1981), and Rayner and Frazier (1989) showed that ambiguous words are easier to interpret when there is a context to facilitate the recognition process. In the literature on bilingual auditory word recognition the number of studies testing such effects is quite scarce, although some bilingual studies in the visual domain have investigated semantic constraint effects. Schwartz and Kroll (2006) and Van Hell and de Groot (2008) showed that cross-lingual interactions were annulled or strongly diminished when reading high-constraint sentences. However, studies by Libben and Titone (2009) and Van Assche, Drieghe, Duyck, Welvaert, & Hartsuiker (2011) demonstrated that cross-lingual interactions remained significant, even when reading sentences that were highly constraining towards the lexical representation in the target language.

As for listening in L2, one of the rare studies that investigated the influence of semantic constraint was that by Chambers and Cooke (2009). These authors conducted a visual world study in which English-French bilinguals were instructed to listen to sentences in L2 and click on the image that represented the last word of the spoken sentence. Each display contained an image of the final noun target (e.g., *poule*, meaning *chicken*), an interlingual near-homophone whose name in English is phonologically similar to the French target (e.g., *pool*), and two unrelated distracter items. When the sentence information was compatible (i.e., both the French target and the interlingual near-homophone are plausible in the sentence context) (e.g., *Marie va décrire la poule* [Marie will describe the chicken]) with the competitor, interlingual competitors were fixated more than unrelated distracter images. However, this was not the case when sentence information was incompatible with the competitor (i.e., only the French target, but not the interlingual near-homophone is plausible in the sentence context) (e.g., *Marie va nourrir la poule* [Marie will feed the chicken]). This shows that sentence context strongly constrains cross-lingual interactions in L2 recognition.

FitzPatrick and Indefrey (2010) also demonstrated that the semantic constraint of a sentence influences cross-lingual interactions in the bilingual lexicon. In their study, EEGs were recorded from Dutch-English bilinguals who were listening to L2 sentences with a semantic incongruity that typically elicit a N400 component. When listening to incongruities in L2, this N400 is delayed compared with the component when listening to an incongruity in L1. When the last word of the sentence was a word with initial overlap with an L1 translation equivalent of the most probable sentence completion (e.g., "My Christmas present came in a bright-orange *doughnut"* (initial overlap with "doos" where *doos* is Dutch for *box*) the observed N400 had the same timing as the N400 that is elicited by a semantic incongruity whose translation equivalent did not have initial congruence. Thus, when listening to sentences that are quite semantically constraining in L2, L1 competitors were not activated (or these L1 competitors are at least not considered for semantic integration).

However, although the sentences that were used in these two studies were plausible, they were low-constraining, and thus not very strongly restrictive towards the L2 representation of the interlingual target. A study that did not only present low-constraining, but also high-constraining sentences, and thus manipulated the semantic constraint of the sentence directly, was conducted by Lagrou et al. (in press). In this study the authors tested three possible constraining factors, i.e., the presentation of target words in a (low-constraining) sentence, the native accent of the speaker, and the semantic constraint of the sentence. With this aim, Dutch-English bilinguals completed an L2 auditory lexical decision task on interlingual homophones (e.g., *lief* (sweet) – *leaf* /li:f/) and control words that were presented at the end of a sentence in L2. The results demonstrated that lexical access in an L2 sentence context was modulated by the semantic constraint of the sentence (and also by the native accent of the speaker). Nevertheless, although the presentation of a highly constraining sentence context significantly reduced cross-lingual interactions in the bilingual lexicon, the effect remained significant in the high-constraint sentences.

The Present Study

The aim of this study was to investigate whether lexical access in bilingual auditory word recognition is language-nonselective when listening to sentences in L1. Importantly, we also tested whether this effect is modulated by the semantic constraint of the sentence. In the study by Lagrou et al. (in press) we already found evidence that cross-lingual interactions when listening to sentences in L2 were modulated by the semantic constraint of the sentence. More specifically, we observed that the homophone effect (i.e., slower RTs on homophones than on control words) was reduced, but not eliminated when listening to high-constraint sentences. Because there is evidence from previous studies that effects from L2 on native language listening might be less robust, it could be that the presentation of a highly constraining sentence context when listening in L1 results in a situation where multiple factors conspire to make lexical access language-selective. This would predict that when listening to high-constraint L1 sentences the interlingual homophone effect is wiped out.

To test this hypothesis, Dutch-English bilinguals completed an L1 auditory lexical decision task on the last target word of low- and high-constraint sentences in L1. This last word could be either an interlingual homophone or a matched control word. The homophones were also used in Lagrou et al. (2011) and caused interference in bilingual auditory word recognition but no effect at all when the subjects were monolingual English speakers.[2] If lexical access in L1 sentence listening is not language-selective, we expect to find a slower RT on homophones than on control words in the low constraining sentences. This would imply that (sub)-phonemic cues, inherent to the speech signal are not used to restrict lexical access to the currently relevant lexicon, even though sentences contain much more of these cues than isolated speech. If the semantic constraint of the sentences influences lexical activation so strongly that non-target language representations may not longer compete with target recognition, we expect to find a reduced, and maybe even completely annulled homophone effect in the high constraining sentences.

METHOD

Participants

Thirty-nine students from Ghent University participated in the experiment for course credits or a monetary fee. All were native Dutch speakers and reported English as their L2. They started to learn English around age 14 at secondary school, and because they were regularly exposed to their L2 through popular media, entertainment, and English university textbooks, they were all quite proficient in their L2, even though they live in a

[2] In that study and here we did not test monolingual Dutch speakers, because such speakers do not exist.

clearly L1-dominant environment (using L1 about 95% of the time). After the experiment, participants were asked to rate their L1 (Dutch) and L2 (English) proficiency with respect to several skills (reading, writing, speaking, understanding, general proficiency) on a 7-point Likert scale ranging from "very bad" to "very good". We also assessed general L3 (French) proficiency. Means are reported in Table 1. Mean self-reported L1 (M = 6.23), L2 (M = 5.08), and L3 (M = 4.18) general proficiency differed significantly (dependent samples t-tests yielded ps < .001). Participants were not informed that their L2 knowledge would be of any relevance to the experiment.

Table 1. Self-reported rating (7-point Likert Scale) of L1, L2, and L3 Proficiency.

Language	Skill	
L1 (Dutch)	Writing	5.97 (0.87)
	Speaking	6.13 (0.89)
	Reading	6.36 (.93)
	Understanding	6.56 (0.60)
	General Proficiency	6.23 (0.63)
L2 (English)	Writing	4.74 (0.91)
	Speaking	5.05 (1.10)
	Reading	5.38 (0.96)
	Understanding	5.46 (0.85)
	General Proficiency	5.08 (0.84)
L3 (French)	General Proficiency	4.18 (1.10)

Stimulus Materials

Target stimuli consisted of 144 stimuli: 24 interlingual Dutch-English homophones (e.g., *lief* (sweet) – *leaf* /li:f/), 24 matched Dutch control words, 24 Dutch filler words, and 72 nonwords. All targets were selected from the stimulus list of Lagrou et al. (2011), in order to increase comparability across studies, and therefore make it possible to assess the context effects while keeping the stimuli constant. Interlingual homophones and control words were matched item by item with respect to number of phonemes, L2 word frequency, neighborhood size, bigram frequency, number of syllables, and pronunciation duration (see Table 2).

Table 2. Mean lexical characteristics of homophones and control words.

Condition	Number of phonemes	Word frequency[a]	Neighbor hoodsize[b]	Bigram frequency[c]	Number of syllables	Duration[d]
Homophones	3.04 (0.62)	1.57 (0.61)	13.21 (6.60)	22627 (10284)	1 (0)	357.50 (74.32)
Control words	3.13 (0.51)	1.50 (0.47)	13.50 (6.64)	23137 (16969)	1 (0)	376.52 (80.88)
P	> .49	> .37	> .67	> .85	identical	> .14

Note. Standard deviations are indicated in parentheses. Reported p-values indicate significance levels of dependent samples t-tests between targets and competitors. [a] Mean log frequency per million words, according to the CELEX lemma database (Baayen, Piepenbrock, & Van Rijn, 1993). [b] Neighborhoodsize (Coltheart, Davelaar, Jonasson, & Besner, 1977) calculated using the WordGen program (Duyck, Desmet, Verbeke, & Brysbaert, 2004) on the basis of the CELEX lemma database (Baayen et al., 1993). [c] Mean summated bigram frequency (calculated using WordGen, Duyck et al., 2004). [d] Pronunciation duration in ms.

Filler words and nonwords were created with the WordGen stimulus software (Duyck, Desmet, Verbeke, & Brysbaert, 2004). Filler words did not differ from homophones and controls with respect to the matching criteria mentioned above. Nonwords were phoneme strings with no Dutch or English meaning, but with a legal Dutch phonology, and they were matched with interlingual homophones and control words with respect to number of phonemes and bigram frequency. For each target, a low- and high-constraining sentence was constructed, resulting in 288 sentences. Sentences were matched in terms of number of words and syntactic structure. For the low-constraining sentences, the preceding sentence context was identical for targets and control words, whereas this was not the case for the high-constraint sentences. In this case, the preceding sentence context was highly constraining towards either the target or the control word. Targets were always in the final position of the sentence. To ensure that participants would not see the same target twice, sentences were divided across two lists. The low- and high constraint sentences for each homophone-control pair are included in the Appendix. Sentences were pronounced by a native Dutch speaker who was also a very high-proficient English speaker. Using WaveLab software, stimulus materials were recorded in a sound-attenuated booth by means of a SE Electronics USB1000A microphone with a sampling rate of 44.1 kHz and a 16-bit sample size. Sentence- and target durations were measured with WaveLab software.

Sentence Completion

To verify the constraint manipulation of the sentences containing an interlingual homophone or control word, a sentence completion study was conducted with twenty further participants. Participants saw each sentence without the interlingual homophone/control word, and were instructed to complete the sentence with the first word that came to mind when reading the sentence. Production probabilities for interlingual homophones (e.g., *bos*, meaning “forest” but sounding like “*boss*” /bOs/) and control words (e.g., *tak*, meaning ”branch”) were extremely low for low-constraining sentences, and were very high for high-constraining sentences. Production probabilities for the irrelevant L1 translation equivalents of the L2 reading of the homophone (e.g., *blad*, meaning "leaf") were extremely low for low- and high-constraining sentences (see Table 3).

Table 3. Production probabilities for interlingual homophones, control words, and L1 translation equivalents of the L2 reading of the homophone in low- and high-constraint sentences. Standard deviations are indicated in parentheses.

	Sentence constraint	
Word type	Low	High
Interlingual homophone	0.02 (0.02)	0.88 (0.08)
Control word	0.03 (0.05)	0.82 (0.17)
L1 translation equivalent	0.01 (0.09)	0.0006 (0.004)

Additionally, another fifteen participants were asked to rate the plausibility of the low constraint sentences on a scale from 1 (not at all plausible) to 9 (very plausible).[3] A paired t-test demonstrated that plausibility ratings for homophone sentences (M = 7.14, SD = 2.30) did not differ from ratings for control word sentences (M = 6.17, SD = 2.38), $t(23) = 1.13$, p = .27.

[3] An additional analysis was completed in which we excluded the low-constraining sentences and their high-constraining counterpart of which the homophone or control word had a plausibility score lower than 4 on this scale. As a consequence, four sentences were excluded from this analysis. Importantly, the exclusion of these sentences did not change the overall pattern of results.

Procedure

Participants received written instructions in Dutch (their L1) to perform a Dutch lexical decision task on the last word of each sentence. They were instructed to put on a headphone through which sentences would be presented auditorily. Before the experiment, a practice session of 12 trials was completed. Each trial started with a 500 ms presentation of a fixation cross in the center of the screen. After another 200 ms the sentence was presented. Then participants had to decide whether the last word was a Dutch word or a nonword. When a word (nonword) was presented, participants used their right (left) index finger to press the right (left) button of a response box. Visual feedback (i.e., when an error was made the screen turned red, when the response was correct, "OK!" appeared on the screen) was presented on the screen during 200 ms. The next trial started 500 ms later. After the experiment, participants completed a questionnaire assessing self-ratings of L1 and L2 proficiency (reading, speaking, writing, understanding, and general proficiency), and general L3 proficiency on a 7-point Likert scale.

RESULTS

On average, participants made 3.61 % errors (*SD* = 1.18). Errors, trials with RTs faster than 300 ms after target onset, and trials with RTs more than 2.5 standard deviations above the participant's mean RT after target offset for word targets were excluded from the analyses. As a result, 4.72 % of the data were excluded from the analyses. Reported latency analyses are based on RTs measured from (auditory) target onset. When latency analyses were based on reaction times measured from (auditory) target offset, the same pattern of results was obtained.

An ANOVA on the reaction times (see Figure 1 and Table 4) with target type (interlingual homophone vs. control) and sentence constraint (low vs. high) as the independent within-subjects variables, revealed a main effect of target type, $F1(1,38) = 10.26$, $p < .01$, $\eta^2_p = .21$; $F2(1,23) = 10.17$, $p < .01$, $\eta^2_p = .31$, indicating that reaction times were significantly slower for interlingual homophones than for control words. The main effect of sentence constraint was also significant, $F1(1,38) = 173.66$, $p < .001$, $\eta^2_p = .82$; $F2(1,23) = 6.33$, $p < .05$, $\eta^2_p = .22$, indicating that participants responded significantly faster on targets that were preceded by a high-constraining sentence context than on targets that were preceded by a low-constraining sentence context. Planned comparisons demonstrated that the homophone effect was significant in the low constraint condition, $F1(1,38) = 6.60$, $p < .05$, $\eta^2_p = .15$; $F2(1,23) = 6.48$, $p < .05$, $\eta^2_p = .22$) and in the high constraint condition, $F1(1,38) = 5.33$, $p < .05$, $\eta^2_p = .12$, $F2\ (1,23) = 5.52$, $p < .05$, $\eta^2_p = .19$. Importantly, the interaction between sentence constraint and target type was not at all significant, $F1 < 1$; $F2 < 1$.

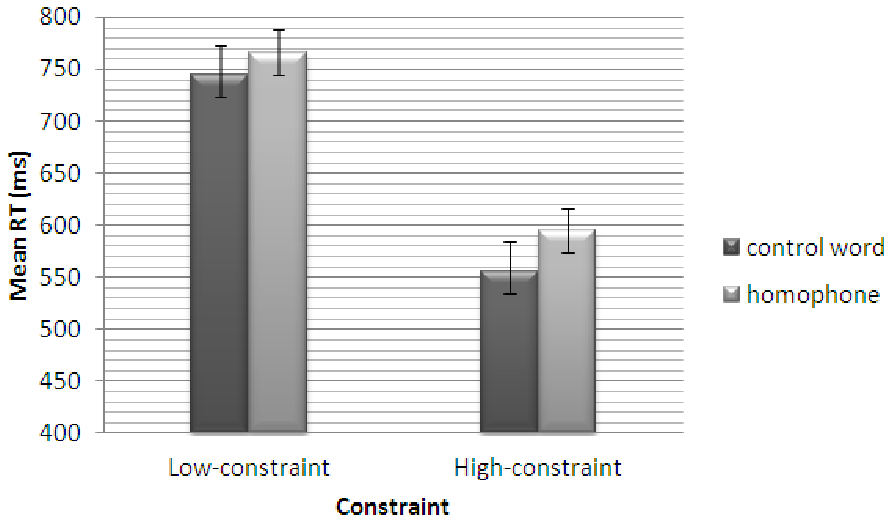

Figure 1. Graphical presentation of RTs on homophones and matched control words as a function of sentence constraint (low vs. high).The vertical bars represent the 95 % confidence interval.

Table 4. Mean RTs and Effect (in Milliseconds) as a function of word type and constraint. Standard deviations are presented between brackets.

	Homophones	Control words	Effect
Constraint			
Low-constraint	766 (20)	744 (21)	22
High-constraint	595 (22)	556 (28)	39

GENERAL DISCUSSION

The goal of this study was to investigate whether cross-lingual interactions are modulated by a sentence context when listening in the native language. Importantly, we also tested whether this effect was influenced by the semantic constraint of the sentence. With this aim, a group of Dutch-English bilinguals completed a Dutch auditory lexical decision task on the last word of an auditorily presented sentence. To examine the influence of semantic constraint, target words that overlapped with a non-target language were presented at the end of both low- and high constraining sentences. The results showed that participants responded significantly slower on interlingual homophones (e.g., *lief* (sweet) – *leaf* /li:f/) than on matched control words. This was the case when listening to low constraining sentences, but crucially also when listening to high constraining sentences. Moreover, there was no interaction between the homophone effect and the semantic constraint of the sentence. So, the semantic and lexical restrictions imposed by the sentence context are not sufficient to override competition from a lexical representation in a non-target language, even if this is the non-dominant, least proficient language. These results have several implications, which we will discuss in the next paragraphs.

First, the fact that we observed a homophone effect when listening to sentences in L1 extends the results from isolated (i.e., not in a sentence context) bilingual word recognition in L2 and in L1 (e.g., Ju & Luce, 2004; Lagrou et al., 2011; Marian & Spivey, 2003; Spivey & Marian, 1999; Weber & Cutler, 2004). These results indicate that the mere presentation of a sentence context, even when listening in L1, is not sufficient to modulate cross-lingual interactions in the bilingual lexicon. Hence, the (sub)-phonemic cues, inherent to the speech signal, are not used to restrict lexical access to the currently relevant lexicon even though sentences contain much more of these cues than isolated words.

Second, we found a main effect of semantic constraint, indicating that participants responded faster to high-constraint sentences than to low-constraint sentences. This replicates many findings from the monolingual domain (e.g., Frazier & Rayner, 1990; Schwanenflugel & LaCount, 1988; Schwanenflugel & Shoben, 1985; Stanovich & West, 1983), in which faster reaction times were observed for highly predictable sentences compared to RTs for nonpredictable sentences. For this study, this constitutes an important check of the constraint manipulation.The main effect of constraint is also in agreement with the results from bilingual visual word recognition by for example Van Assche et al. (2011) in which faster reading times were observed for high-constraint sentences compared to low-constraint sentences.

Crucially, the present study also investigated whether the homophone effect is modulated by the semantic constraint of the sentence. Because there was no trace of an interaction between this interlingual effect and the constraint manipulation, we can conclude that cross-lingual interactions are not strongly influenced by this specific manipulation when listening in L1. This is a surprising and remarkable finding, because this suggests that even when bilinguals have conversations in their native language, and when the content of the interlocutor's speech it is highly predictable, one is still influenced by knowledge of a second language.

This finding extends the results from sentence studies in the bilingual visual domain (e.g., Libben & Titone, 2009; Schwartz & Kroll, 2006; Titone et al., 2011; Van Assche et al., 2011; Van Hell & de Groot, 2008). In these studies, the results concerning the observation of cross-lingual interactions when reading high-constraint sentences were somewhat mixed: Schwartz & Kroll (2006) and Van Hell & de Groot (2008) demonstrated that cross-lingual interactions were actually reduced or diminished in a high-constraint context, but Van Assche et al. (2011) found evidence for language-nonselectivity both when reading low- and high constraining sentences. Libben and Titone (2009) also found evidence for cross-lingual interactions when reading low- and high-constraint sentences, but for the high-constraint sentences cross-lingual interactions were only observed in early (and not in late) eyetracking measures of reading. Hence, the results from the present study are most in line with the Van Assche et al. (2011) study, in which evidence for language-nonselectivity was found both when processing low- and high-constraint sentences. Given that this study draws on the same bilingual population as tested here, one possibility is that the slight inconsistencies across studies are related to the language profile of the participants.

The results of the present study are not in complete agreement with studies on nonnative spoken word recognition (e.g., Chambers & Cooke, 2009, FitzPatrick & Indefrey, 2010; also our own study, Lagrou et al., in press), in which cross-lingual interactions were modulated by the semantic constraint of the sentence. For example, because Lagrou et al. found evidence for the fact that cross-lingual interactions are reduced (but not eliminated) when listening to a high constraining sentences context in L2, we were rather surprised that the homophone effect in L1 was not influenced by the semantic constraint of the sentence, and this for two reasons. First, we expected that L2 representations would be too weak to interfere with L1 representations, especially when they are part of a high-constraining sentence that provides the listener with many sub-phonemic cues that are informative with respect to the target language. Second, we predicted that several factors would conspire to eliminate language-nonselective access. Specifically, we expected that the combined effect of several constraints (i.e., presentation of interlingual homophones in a spoken sentence, in a highly constraining context, and in L1) would strongly influence activation in lexical target representations, so that the homophone interference effect could be eliminated or at least reduced. This was not the case, so the present data constitute very strong evidence for a language-nonselective account of lexical access when listening to sentences in L1 in which cross-lingual interactions are not eliminated or even reduced by the semantic constraint of the sentence.

A possible explanation for the different results in L2 and L1 word recognition with respect to the influence of semantic constraint could be related to the speed of word recognition. In L2 listening, proficiency is lower, which makes recognition slower. Therefore, manipulations (such as semantic constraint) that strongly influence (speed up) this slow target activation, are likely to mask the weaker spreading activation effect arising from non-target language representations. In L1 listening, word recognition is much faster, so that a semantic constraint manipulation effect has a smaller impact on target activation. Given this smaller effect, it is plausible that also the interaction of the semantic effect with the homophone interference effect is more limited. This could explain why we observed no such interaction in the present study.

At a theoretical level, these results put constraints on the further development and extension to bilingualism of monolingual models of auditory word recognition such as the Distributed Model of Speech Perception (Gaskell & Marslen-Wilson, 1997), NAM (Luce & Pisoni, 1998), Shortlist (Norris, 1994; Norris, McQueen, Cutler, & Butterfield, 1997), and TRACE (Elman & McClelland, 1988; McClelland & Elman, 1986). To account for our findings, these models would need to be extended with the assumption that L2 representations are part of the same system as, and interact with, L1 representations. These models would then predict cross-lingual interactions between the native and the nonnative lexicon (which was demonstrated in the present study by the observation of slower RTs on interlingual homophones than on matched control words). However, the role of top-down factors such as the semantic constraint of the sentence is very limited, as we did not observe an interaction between the homophone effect and the semantic constraint of the sentence. Thus, the findings are most compatible with models that assume only a restricted role for such top-down effects.

The results of this study can also help to further constrain the Bilingual Language Interaction Network for Comprehension of Speech (BLINCS) that was introduced recently by Shook and Marian (in press). According to BLINCS, the two languages of a bilingual are separated, but integrated. This allows cross-lingual interactions because there are lateral links between translation equivalents. Moreover, because items that map together are simultaneously active, they inhibit one another. Although this model can account for many phenomena in bilingual language processing, it still has to be expanded to capture for example the effects of linguistic context. Hence, at this point the model does not make concrete predictions on the influence of semantic constraints.

To summarize, this study provides evidence for an account of lexical access that is language-nonselective even when listening in L1. Moreover, the presence of cross-language interactions when the preceding sentence context was highly constraining towards the representation in the target language indicates that this language-nonselectivity is not overriden by the semantic constraint of the sentence.

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APPENDIX

Experimental stimuli.

Low-constraining sentences
1. **biet [beet] – rits [zipper]** Luc ging naar de winkel en kocht daar een **biet/rits**. [Luc went to the store and bought a beet/zipper.]
2. **bij [bee] – gek [fool]** Tijdens hun wandeling werden ze lasting gevallen door een **bij/gek**. [During their walk they were attacked by a bee/fool.]
3. **bil [buttock] – jas [coat]** De dokter bekeek heel aandachtig haar **bil/jas**. [The doctor took a good look at her buttock.]
4. **boel [business] – boer [farmer]** De man besefte opens dat hij te maken had met een gevaarlijke **boel/boer**. [The man suddenly realized that he had to deal with a dangerous farmer.]
5. **boon [bean] – peer [pear]** In de tuin van mijn vader vond ik een **boon/peer**. [In my father's garden I found a bean/pear.]
6. **bos [forest] – tak [branch]** De kunstenaar maakte een schilderij van een **bos/tak**. [The artist made a painting of a forest/branch.]

7. **brief [letter] – paard [horse]**
Toen ze jarig was, kreeg ze als geschenk een **brief/paard**.
[When it was her birthday, the present she received was a letter/horse.]

8. **dij [thigh] – zus [sister]**
Omdat ze zo geschrokken was, gaf ze en trap tegen haar **dij/zus**.
[Because she was so frightened, she gave a kick against her thigh/sister.]

9. **hiel [heel] – kous [stocking]**
Tijdens die avontuurlijke tocht bleef Els haperen met haar **hiel/kous**.
[During that adventurous journey Els got stuck with her heel/stocking.]

10. **hoek [corner] – rook [smoke]**
Hij kwam binnen en zag haar staan in de **hoek/rook**.
[He came in and saw her in the corner/smoke.]

11. **koek [biscuit] – zeep [soap]**
Eva vroeg haar moeder om een nieuwe **koek/zeep**.
[Eva asked her mother for a new biscuit/soap.]

12. **kou [cold] – bus [coach]**
De moeder van dat meisje stond me op te wachten in de **kou/bus**.
[The mother of that girl was waiting for me in the cold/coach.]

13. **lied [song] – lach [laugh]**
De leerlingen luisterden aandachtig naar haar **lied/lach**.
[The pupils listened attentively to her song/laugh.]

14. **lief [sweet] – bang [scared]**
De nieuwe bewoners van dat appartement waren erg **lief/bang**.
[The new inhabitants of that appartment were very sweet/scared.]

15. **lijk [corpse] – touw [rope]**
Op hun wandeltocht vonden de leidsters van de jeugdbeweging een **lijk/touw**.
[During their walk the leaders of that youth movement found a corpse/rope.]

16. **mes [knife] – koe [cow]**
Thijs bekeek samen met zijn vader een afbeelding van een **mes/koe**.
[Thijs was looking with his father to an image of a knife/cow.]

17. **pet [cap] – das [tie]**
Ze vonden de ring van die vrouw onder een **pet/das**.
[They found the ring of that woman under a cap/tie.]

18. **plein [square] – troon [throne]**
Hij genoot ervan om de avond door te brengen op een **plein/troon**.
[He enjoyed spending the evening at the square/throne.]

19. **prijs [reward] – straf [punishment]**
Ruben had heel wat veranderd, en daarom kreeg hij een **prijs/straf**.
[Ruben had changed a lot, and that's why he received a reward/punishment.]

20. **proef [test] – traan [tear]**
Jammergenoeg eindigde die dag met een **proef/traan**.
[Unfortunately that day was closed with a test/tear.]

21. **reis [trip] – tuin [garden]**
Mijn vriendin Sanne kon blijven vertellen over die **reis/tuin**.
[My friend Sanne could keep telling about that trip/garden.]

22. **slim [smart] – saai [boring]**
Tine vond de nieuwe leerkracht in die school heel erg **slim/saai**.
[Tine found the new teacher in the school very smart/boring.]

23. **vet [fat] – lui [lazy]**
Die zwarte kater van de buren was echt **vet/lui**.
[That black cat of the neighbours was very fat/lazy.]

24. **wei [meadow] – hok [shed]**
Hij verstopte de schatkist van de zeerover in een **wei/hok**.
[He hide the treasure-chest of the pirate in a meadow/shed.]

High-constraining sentences

1. **biet [beet] – rits [zipper]**
De jongen at graag rode kool, maar ook rode **biet**.
[The boy loved to eat red cabbage, but also red beet.]
Hij kon zijn jas dichtmaken met knopen, maar ook met een **rits**.
[He could close his coat with buttons, but also with a zipper.]

2. **bij [bee] – gek [fool]**
De imker vertelde ons dat honing afkomstig is van de **bij**.
[The beekeeper told us that honey comes from the bee.]
Hij verbleef in de psychiatrie, want de dokter noemde hem een **gek**.
[He lived a psychiatric centre, because the doctor said he was a fool.]

3. **bil [buttock] – jas [coat]**
Op het einde van de avond kneep de man stiekem in haar linker **bil**.
[At the end of the evening the man secretly squized her left buttock.]
In de winter draagt hij een muts, een sjaal een een warme **jas**.
[During winter he wears a hat, a scarf and a warm coat.]

4. **boel [many] – boer [farmer]**

De jongen kreeg meer dan één geschenk, in feite kreeg hij er zelfs een hele **boel**.

[The boy received more than one present, in fact he even received many.]

De koeien zaten ‘s winters in de stal die eigendom was van de **boer**.

[During winter the cows were in the stable of the farmer.]

5. **boon [bean] – peer [pear]**

In de trein zei ze dat ze hem leuk vond, dus ze had voor hem een **boon**.

[In the train she told that she liked him, so she had a preference for him. (saying)]

De bekendste fruitsoorten zijn wellicht de appel en de **peer**.

[The most common fruits are probably the apple and the pear.]

6. **bos [forest] – tak [branch]**

Toen Roodkapje haar grootmoeder ging bezoeken, moest ze de weg volgen door het donkere **bos**.

[When Little Red Riding Hood visited her grandmother, she had to follow the road through the dark forest.]

Terwijl hij dat verhaal vertelde, sprong hij van de hak op de **tak**.

[While he told that story, he skipped from one subject to another. (saying)]

7. **brief [letter] – paard [horse]**

Toen hij op reis was, schreef hij zijn ouders af en toe een **brief**.

[While he was on a trip, from time to time he wrote his parents a letter.]

Die ruiter was de beste in het berijden van een **paard**.

[That horseman was the best in riding a horse.]

8. **dij [thigh] – zus [sister]**

Het lichaamsdeel tussen heup en knie noemen we een **dij**.

[The part of the body between hip and knee is what we call a thigh.]

Af en toe gaan we een weekendje weg samen met mijn broer en **zus**.

[From time to time we go a weekend away with my brother and sister.]

9. **hiel [heel] – kous [stocking]**

Omdat ze zo dicht voor me wandelde trapte ik per ongeluk op haar **hiel**.

[Because she walked so close before me I accidently stepped on her heel.]

Net wanneer ze wilden vertrekken naar het feest, ontdekte Mieke een ladder in haar **kous**.

[Just when they wanted to set off for the party, Mieke discovered a run in her stocking.]

10. **hoek [corner] – rook [smoke]**

Omdat het kleine meisje stout was geweest, zette haar moeder haar in de **hoek**.

[Because the little girl had been bad, her mother put her in the corner.]

Zij stak haar sigaret binnen op, en nu zagen we bijna niets meer door de **rook**.

[She lit her cigarette indoors, and now we almost couldn't see a thing because of the smoke.]

11. **koek [biscuit] – zeep [soap]**

Uiteindelijk bakte hij een taart en ook een trommel vol met **koek**.

[Eventually he baked a cake and also a tin of biscuits.]

Vooraleer Marie ging slapen, waste ze zich met water en **zeep**.

[Before Marie went to bed, she washed herself with water and soap.]

12. **kou [cold] – bus [coach]**

Er was geen sprake van warmte tijdens de winter, maar eerder van **kou**.

[It was not warm during winter, but rather cold.]

Wie gebruik maakt van het openbaar vervoer neemt vaak de trein, de tram of de **bus**.

[People using public transport often take the train, tram or coach.]

13. **lied [song] – lach [laugh]**

Terwijl we rond het kampvuur zaten, zongen we samen een mooi **lied**.

[While we were sitting around the campfire, we were singing a beautiful song.]

Hij keek niet kwaad, want op zijn gezicht zag ik een **lach**.

[He wasn't angry, because on his face there was a laugh.]

14. **lief [sweet] – bang [scared]**

Ik wilde die kinderen graag helpen want ze waren zo **lief**.

[I wanted to help those children because they were so sweet.]

Terwijl ze naar die griezelige film keken, waren de kinderen erg **bang**.

[While they were looking at that frightening movie, the children were very scared.]

15. **lijk [corpse] – touw [rope]**

Toen hij zo geschrokken was, zag hij zo bleek als een **lijk**.

[When he was frightened, he was as pale as a corpse.]

De indianen bonden de gevangenen vast met een **touw**.

[The indians tied up the prisoners with a rope.]

16. **mes [knife] – koe [cow]**

De vrouw waste de tomaten en sneed ze in stukken met een **mes**.

[The woman washed the tomatoes and cut them into pieces with a knife.]

De boer vertelde de kinderen dat melk afkomstig was van de **koe**.

[The farmer told the children that milk is produced by the cow.]

17. **pet [cap] – das [tie]**

Wanneer de zon schijnt bedekt hij zijn hoofd met een hoed of een **pet**.

[When the sun is shining he covers his head with a hat or a cap.]

Wanneer Peter naar een feestje gaat, draagt hij altijd een strik of een **das**.

[When Peter goes to a party, he always wears a bow or a tie.]

18. **plein [square] – troon [throne]**

De kinderen en jongeren kwamen op woensdagnamiddag samen op het **plein**.

[The children and youngsters gathered on Wednesday afternoon at the square.]

De koning regeerde over het land al zittend op zijn **troon**.

[The king governed his country sitting on his throne.]

19. **prijs [reward] – straf [punishment]**

Hij zei dat hij het winnende lot in de tombola had, en kreeg daarom een mooie **prijs**.

[He told that he had the winning ticket in the tombola, and that’s why he received a beautiful reward.]

Omdat de kleuter ruzie gemaakt had op school, kreeg hij van de juf een **straf**.

[Because the infant had a fight at school, the teacher gave him a punishment.]

20. **proef [test] – traan [tear]**

Vooraleer ze zich kon inschrijven doorstond ze een mondelinge test en een fysieke **proef**.

[Before she could subscribe she passed an oral and a physical test.]

Ik denk nog vaak terug aan die dag met een lach, maar ook met een **traan**.

[I often think back to that day with a laugh, but also with a tear.]

21. **reis [trip] – tuin [garden]**

De man boekte voor de verjaardag van zijn vrouw een verre en exotische **reis**.

[For the birthday of his wife the man booked a far and exotic trip.]

Kris verzorgde de planten en reed het gras af in zijn prachtige **tuin**.

[Kris was taking care of the plants and was cutting the grass in his wonderful garden.]

22. **slim [smart] – saai [boring]**

Jan heeft de beste resultaten van de klas want hij is heel **slim**.

[Jan has the best grades of the class because he is very smart.]

Hij interesseerde zich niet voor dat vak en vond de lessen erg **saai**.

[He wasn’t interested in that subject and found the lessons very boring.]

23. **vet [fat] – lui [lazy]**

Omdat ze op haar voeding lette at ze geen frieten, want die waren te **vet**.

[Because she payed attention to her diet she didn’t eat fries, because they were too fat.]

Hij doet geen moeite om een nieuwe job te zoeken, want hij is erg **lui**.

[He doesn’t put a lot of effort on finding a new job, because he is very lazy.]

24. **wei [meadow] – hok [shed]**

Je zult de koeien zien die de hele dag grazen in die **wei**.

[You will see the cows grazing the whole day in that meadow.]

De kippen slapen ‘s nachts buiten in het **hok**.

[The chickens sleep at night outside in the shed.]

CHAPTER 6
GENERAL DISCUSSION

In this dissertation we investigated whether lexical access is language-nonselective when listening in the native and in a nonnative language. Additionally, we also examined whether bilinguals use sub-phonemic cues provided by the native accent of speakers, or phonological differences between languages to restrict lexical access. Finally, the influence of sentence context and semantic constraint on cross-lingual interactions during lexical processing was tested. In this General Discussion, we summarize the main empirical findings of the thesis, and we discuss the implications of these results for the theoretical models on bilingual auditory word recognition. We conclude this chapter with some directions for future research.

INTRODUCTION

In contrast with the numerous studies that have investigated lexical access in bilingual visual word recognition (e.g., Dijkstra & Van Heuven, 1998; Libben & Titone, 2009; Schwartz & Kroll, 2006; Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Van Assche, Duyck, Hartsuiker, & Diependaele, 2009), far fewer studies have investigated bilingual auditory word recognition. Moreover, whereas reading research now agrees on the fact that lexical access is language-nonselective, the evidence in favor of a language-nonselective account in the auditory domain is mixed, and many important research questions have not been addressed.

The aim of the present dissertation was therefore to clarify the nature of lexical access in bilingual auditory word recognition, and the possible factors that influence it. More specifically, in this dissertation we investigated whether lexical access is language-nonselective when listening in L2 *and* in L1. We tested whether this was the case when listening to isolated words in Chapter 2, and when listening to sentences in Chapters 3, 4, and 5. Additionally, the influence of several constraints on lexical access was investigated more thoroughly. In Chapters 2 and 4, we manipulated the native accent of the speaker in order to explore whether sub-phonemic speaker cues referring to either the target or non-target language are used as a cue to restrict lexical access to the currently relevant lexicon. The influence of sub-phonemic cues was investigated further in Chapter 3, where we asked a group of bilinguals to judge the phonological similarity between languages, and tested whether between-language competition is a function of similarity between lexical representations across languages. Finally, Chapters 4 and 5 were conducted to reveal whether the semantic constraint of sentences is a factor that restricts lexical access to only a single language.

BILINGUAL AUDITORY WORD RECOGNITION IN ISOLATION

Although studies on auditory word recognition by bilinguals mostly agree on the fact that lexical access is language-nonselective when listening to isolated speech in L2, the evidence in favor of a language-nonselective account of lexical access when listening to isolated speech in L1 is more mixed. Whereas the seminal studies by Marian and Spivey (2003a, b) and Spivey and Marian (1999) demonstrated cross-lingual interactions from L1 to L2 a*nd* vice versa, Weber and Cutler (2004) only replicated the cross-lingual lexical interaction effect when Dutch-English bilinguals listened in L2, but not in L1. However, a crucial difference between these studies concerns the L2 proficiency level and immersion status of the participants. In the studies by Marian and colleagues, bilinguals were high-proficient, and immersed in a L2 dominant environment, which is different from the unbalanced bilinguals in the study of Weber and Cutler. The Dutch-English bilinguals that participated in our studies were very comparable to the bilinguals of Weber and Cutler, and although they are quite proficient in their L2, they are unbalanced bilinguals living in a L1 dominant environment.

In Chapter 2 we answered two major questions: First, we investigated whether lexical access is language-nonselective when listening to isolated words in L2 and in L1. Second, we also manipulated the native accent of the speaker in order to test whether sub-phonemic differences between speakers, more specifically native accents corresponding to either the target or non-target language, modulate cross-lingual lexical activation. In Experiment 1, Dutch-English bilinguals completed an English (L2) lexical decision task in which targets were pronounced by a native or a nonnative English speaker. We demonstrated that participants responded more slowly to interlingual homophones (e.g., *lief* (sweet) – *leaf* /li:f/) than to matched control words. This effect was equally strong when targets were pronounced by a nonnative English speaker (speech cues referring to the non-target language Dutch), than when the speaker was a native English speaker (no Dutch cues in the speech signal). Crucially, in Experiment 3 a different group of similar Dutch-English bilinguals completed a Dutch (L1) lexical decision task with the same critical items. Targets were again pronounced by a native or a nonnative Dutch speaker. Recognition was again slower for interlingual homophones than for matched control words, and the effect was again independent of the speaker's native language. As a control, a monolingual group of participants completed the English lexical decision task (Experiment 2). The absence of a homophone interference effect here validates that the effects in Experiments 1 and 3 were due to bilingual lexical interactions, and not to any other uncontrolled variable.

First, the existence of a bidirectional homophone interference effect when the task is completed by the Dutch-English bilinguals provides very convincing evidence for a language-nonselective account of lexical access. This demonstrates that we are not only influenced by knowledge of our native language when listening to a second language, but also that we are influenced by knowledge of a (weaker) L2 when listening in our native language. The latter finding contrasts with the results from Weber and Cutler (2004), who only observed interference from L1 to L2. The crucial difference between this and our study, which may explain this divergent pattern of results, likely concerns the degree of cross-lingual phonological overlap. In the present study, interlingual homophones with almost complete overlap between languages were used, whereas Weber and Cutler used items that shared only a few phonemes across languages. Because Marian and Spivey (2003a, b) and Spivey and Marian (1999) however did find an effect in L1 with similar low phonological overlap, it appears that both L2 proficiency (resulting in higher baseline level lexical activation) and cross-lingual lexical similarity may determine lexical competition across languages. At least, our findings show that even in unbalanced bilinguals that only use L2 a limited percentage of the time, lexical search yields competition across languages between highly similar lexical representations. This is consistent with interaction activation models of word recognition, in which lexical competition is indeed depending on lexical overlap between competing candidates (see below).

Second, there was no interaction effect between homophone interference and the native language of the speaker that pronounced the targets. This indicates that the sub-phonemic cues provided by the native accent of the speaker did not modulate lexical activation towards a single (target) language. This is quite surprising, given the fact that the use of these cues would actually be an efficient strategy to restrict the number of lexical candidates, and given the results of Ju and Luce (2004). These authors observed that Spanish-English bilinguals fixated pictures with English names that were phonologically similar to Spanish targets more frequently than distracter pictures, but only when the Spanish targets were altered to contain English-appropriate voice onset times. These results, together with the findings from our study, suggest that bilinguals *can* use sub-phonemic cues to regulate cross-lingual activation, but that this depends on the nature of the cues. The language-appropriate voice onset times helped bilinguals in restricting lexical access to the target lexicon, but this cue only concerns one specific speech feature that was consistently applied (in artificially manipulated materials) throughout the experiment. In our study, manipulation of the speaker's native language (instead of materials) yielded a more natural and diverse variation of sub-phonemic cues. However, although the native accent was not used as a restrictive cue for lexical search in the present study, we still found some interesting main effects related to the speaker's L1, supporting the effectivity of the manipulation. Both for our bilingual and monolingual groups of participants, we observed overall faster reaction times when the targets were pronounced by the native speaker (i.e., in the English lexical decision task reaction times were faster when the native English speaker pronounced the targets, whereas reaction times were faster when the native Dutch speaker pronounced the targets in the Dutch lexical decision task). This is consistent with the work from Adank, Evans, Stuart-Smith, and Scott (2009) who also observed longer reaction times when participants listened to a speaker with a nonnative accent. This can be explained by the fact that the native speaker's pronunciation of the targets provides a better match with stored lexical representations than the utterances of nonnative speakers, and therefore is recognized faster. In future research, it would be interesting to investigate whether this finding interacts with the typical L2 input that the listener receives: would faster recognition occur for listeners that are more often exposed to nonnative speakers than to native speakers (unlike the participants of this study, e.g., in certain Hispanic communities in the United States)?

SENTENCE CONTEXT EFFECTS ON LEXICAL ACCESS

After we confirmed that lexical access is language-nonselective when listening to isolated words in L2 and in L1, we wanted to examine whether there are factors that (can) constrain this language-nonselectivity. In Chapter 2, we already tested one possible constraint, namely the native accent of the speaker, but several other variables have not been tested. In Chapter 3, we investigated whether embedding targets words in a (unilingual) sentence context is such a factor. After all, in contrast with isolated words, sentences rarely contain language switches and therefore constitute in itself a strong language cue for the words to be recognized in that sentence. Also, sentences contain much more sub-phonemic cues related to a specific language, so that this massive bottom-up activation may also boost activation in lexical representations belonging to the language related to those cues. Additionally, we tested whether the degree of phonological similarity is a factor that can constrain lexical access to the currently relevant lexicon.

To investigate this, we set up a visual world study in which eye movements were registered. This paradigm was also used in most research on bilingual auditory word recognition (e.g., Chambers & Cooke, 2009; Spivey & Marian, 1999; Weber & Cutler, 2004). In this visual world study, Dutch-English bilinguals were instructed to look at a visual display presented on a computer screen while they listened to plausible, but low-constraining sentences in L2 (Experiment 1) or in L1 (Experiment 2). Each display contained an image of a target picture (e.g., for L2: *flower*), a competitor picture with an onset that was phonologically overlapping with the translation in the nontarget language (e.g., for L2: *fles* meaning “bottle” in English), and two unrelated distracter pictures (e.g., *dog* and *orange*). When listening in L2, the results demonstrated that participants fixated more on competitor pictures that had a phonological similar onset in L1 than on unrelated distracters, indicating that there was between-language lexical competition. This effect was independent of the degree of phonological similarity (i.e., we observed lexical competition when the phonological overlap between the English target and the Dutch competitor was high, as well as when this overlap was low). This is in line with previous results on isolated auditory word recognition (e.g., Marian & Spivey, 2003a, b; Spivey & Marian, 1999; Weber & Cutler, 2004). When listening in L1, participants also fixated more on competitor pictures with an onset that was phonologically similar to the target, but this was only the case when the overlapping part of the target and the competitor was judged as phonologically very similar. For example, with the phonologically very similar target-competitor pair *flower-fles* (bottle), cross-lingual interactions were still observed, whereas this was not the case with the phonologically less similar pair *comb-koffer* (suitcase). These results were confirmed by a linear regression analysis in which we demonstrated that the degree of cross-lingual overlap did not predict the size of the between-language competition effect when listening to low-constraining sentences in L2, but was still a predictor of the competition effect when listening to similar low-constraining sentences in L1.

These findings demonstrate that the presentation of words in a sentence context is not sufficient to restrict lexical access to only one lexicon. This suggests that sub-phonemic cues inherent to speech are not used to constrain the degree of language-nonselectivity, even though full sentences contain much more phonological cues than isolated words. However, for L1 recognition, the between-language competition effect was modulated by phonological differences between languages, consistent with interactive activation models of word recognition (see below).

SEMANTIC CONSTRAINT EFFECTS ON LEXICAL ACCESS

In Chapters 4 and 5 we focused on the influence of the semantic constraint of the sentence on the language-nonselective nature of lexical access. Earlier, many monolingual studies have demonstrated that contextual information can be used to facilitate word recognition (e.g., Binder & Rayner, 1998; Onifer & Swinney, 1981), so that predictable words are processed faster than non-predictable words (e.g., Schwanenflugel & LaCount, 1988; Schwanenflugel & Shoben, 1985; Stanovich & West, 1983). As a consequence, it would be plausible that the semantic constraint of a sentence is applied to reduce cross-lingual interactions in the bilingual lexicon, by cueing the meaning of the interlingual homophone that is compatible with the spoken language.

In Chapter 4 we investigated whether lexical access is language-nonselective when listening to words embedded in meaningful sentences in L2, and whether the degree of language-nonselectivity is modulated by the semantic constraint of the sentence. Additionally, we also manipulated the native accent of the speaker to test whether this is used as a cue to restrict lexical access. With this aim, Dutch-English bilinguals listened to low- and high-constraining sentences in L2 in which the final word could again be an interlingual homophone (e.g., *leaf* – *lief* (sweet) /li:f/). To investigate the influence of the speaker's native accent, these sentences were pronounced by a native Dutch or by a native English speaker. After the spoken sentence was presented, participants were asked to make a lexical decision on the last word/nonword of the sentence. The results demonstrated that interlingual homophones were recognized slower than control words, which suggests that the bilinguals in this study activated both the L2 and the L1 meaning of the homophone, even though the speech signal of a complete sentence contains many sub-phonemic cues about the language in use. This confirms the findings of Chapter 3, and indicates that the sub-phonemic cues in the speech signal are not used to restrict lexical access to the currently relevant lexicon.

Moreover, we found a main effect of semantic constraint, demonstrating that participants responded faster after sentences that were high-constraining towards the L2 interpretation of the homophone than after sentences that were low-constraining. Crucially, the interaction between the homophone effect and the semantic constraint of the sentence was significant, revealing that cross-lingual interactions were reduced, but not annulled for the high-constraining sentences. This is a very important finding, because this demonstrates that listeners can exploit such constraints to reduce the degree of language-nonselectivity. However, note that the homophone interference effect did not completely disappear when the preceding sentence context was high-constraining, indicating that lexical access was still fundamentally language-nonselective, although to a lesser degree. These results were not completely in line with the studies by Chambers and Cooke (2009) and FitzPatrick and Indefrey (2010), because these authors suggested that semantic constraints imposed by a sentence context can completely annul activation of non-target language lexical competitors. A possible explanation for these different results may lie in the fact that the cross-lingual overlap in our study was larger. Whereas we used interlingual homophones with complete phonological overlap, Chambers and Cooke used near homophones, and FitzPatrick and Indefrey used items that only shared an overlapping onset. As a consequence, in their studies it was probably easier to override cross-lingual activation spreading by a sentence context that was very constraining towards the L2 target representation. At a theoretical level, this shows that cross-lingual interactions are influenced by both top-down factors (sentence constraint), and similarity between lexical competitors.

Finally, we also tested whether the homophone interference effect was modulated by the native accent of the speaker. The fact that we observed a main effect of speaker (i.e., participants responded faster when the sentences were pronounced by the native English speaker) confirms the results of Chapter 2, in which we observed a similar main effect. This suggests that the native pronunciation of speech resembles the listener's stored lexical representation better. Hence, the threshold for word recognition is exceeded faster. Moreover, we also found an interaction between the homophone effect and the native language of the speaker. This contrasts with the results of our isolation study in Chapter 2 where cross-lingual interactions were not modulated by sub-phonemic cues provided by the native accent of speakers. Apparently, when a complete sentence is pronounced by a native speaker, the number of sub-phonemic cues related to the target language increases, which makes the nontarget language less salient. As a consequence, the homophone interference effect is reduced. Again, note that even though the homophone effect was reduced when sentences were pronounced by the native English speaker, the effect did not disappear, indicating that lexical access was still language-nonselective, but to a lesser degree.

In our final Chapter 5 we tested whether lexical access is language-nonselective when listening to sentences in L1, and whether these cross-lingual interactions are modulated by the semantic constraint of the preceding sentence context. With this aim, Dutch-English bilinguals completed a Dutch auditory lexical decision task on the last word of low- and high-constraining sentences. In fact, this is a crucial test of the assumption of language-nonselectivity because in this experiment multiple factors (i.e., a sentence context, in the native language, that is high-constraining towards the L1 representation of the target) coincide and bias towards language-selective lexical access. After all, we already observed in Chapter 4 that the degree of language-nonselectivity is decreased when the preceding sentence context is highly constraining. Because effects from L2 when listening in L1 seem more susceptible to constraining factors, we therefore predicted that the homophone interference effect would disappear in this study. However, this was not what we found. The results demonstrated that there was a homophone interference effect (i.e., participants responded more slowly to interlingual homophones than to matched control words). This observation is in line with our previous findings, and indicates that the mere presentation of a sentence context, even when listening in L1, is not sufficient to modulate cross-lingual interactions in the bilingual lexicon. So, sub-phonemic cues inherent to the speech signal are not exploited, even though this is actually not very efficient, and even though sentences contain much more sub-phonemic cues about the target language than isolated speech. There was also a main effect of semantic constraint: reaction times were faster when the sentence context was high-constraining. As in Chapter 4, this replicates the findings from the monolingual domain (e.g., Frazier & Rayner, 1990; Schwanenflugel & LaCount, 1988; Schwanenflugel & Shoben, 1985; Stanovitch & West, 1983). For our bilingual study, this suggests that we successfully manipulated the semantic constraint of the sentences. However, there was not a trace of an interaction between the homophone effect and the semantic constraint of the sentence. This suggests that cross-lingual interactions when listening in the native language are not at all modulated by the predictability of the sentence. Thus, even when bilinguals have a conversation in their L1, and even though they can predict very well what meaning their interlocutor will convey, they still activate both the L1 and L2 representations of interlingual homophones. This is a surprising finding, especially because previous studies on the influence of semantic constraint suggested that cross-lingual interactions might be modulated by such a constraint. Evidence for such a modulation was found in L2 studies by Chambers and Cooke (2009) and by FitzPatrick and Indefrey (2010). Moreover, in Chapter 4, we also demonstrated that the semantic constraint of the sentence reduces, but not annuls, the degree of language-nonselective lexical access when listening in L2. It is not immediately obvious how this could be explained, but one possibility is related to the speed of word recognition. More specifically, because unbalanced bilinguals are by definition less proficient in their L2 than in their L1, recognition of L2 words is slower. Because of these slower reaction times, manipulations (such as the semantic constraint of the sentence) that can speed up word recognition in L2 are more likely to mask the weaker spreading activation effect from the non-target representations. Moreover, because L1 recognition is faster than L2 recognition, it is more difficult for such constraints to influence cross-lingual interactions.

In the next paragraph, we link the empirical findings in this dissertation to the theoretical models that have been developed to account for the data patterns in bilingual auditory word recognition.

THEORETICAL IMPLICATIONS

The main research question of this dissertation concerned whether lexical access is language-nonselective when listening in the native and in a nonnative language. The evidence in favor of such an account was very convincing: All empirical chapters supported the assumption that lexical access is language-nonselective. In Chapters 2, 4, and 5, Dutch-English bilinguals completed an auditory lexical decision task. In each of these chapters we found that reaction times were slower on interlingual homophones than on control words, reflecting cross-lingual lexical competition. In Chapter 3, we replicated such effects using another paradigm (a visual world study). Findings from both paradigms suggested that there are cross-lingual interactions in the bilingual lexicon, both when listening in L2 and in L1. These findings can be explained by monolingual models on auditory word recognition, if they are extended with the assumption that L2 representations are part of the same system as, and interact with, L1 representations. If this assumption is included in these models, between-language competition, and thus slower reaction times on interlingual homophones than to matched control words is predicted. If the Cohort model (Marslen-Wilson, 1987, 1990; Marslen-Wilson & Tyler, 1980; Marslen-Wilson & Welsh, 1978) would be extended to account for the results on bilingual word recognition, lexical items from both languages are activated in parallel resulting in a bilingual cohort that extends across the two languages.

In the end, as the auditory input unfolds, only the appropriate target is selected, as it is in a monolingual context. Hence, this model would predict longer reaction times for interlingual homophones than for matched control words. Similar predictions are made by TRACE (Elman & McClelland, 1988; McClelland & Elman, 1986) and Shortlist (Norris, 1994; Norris, McQueen, Cutler, & Butterfield, 1997).

This observation is also predicted by the only two models on bilingual auditory word recognition: BIMOLA (Léwy & Grosjean, 1997) and BLINCS (Shook & Marian, in press). According to BIMOLA (which is not further developed), bilinguals have two language networks that are both independent and interconnected. They are independent in the sense that the model allows bilinguals to speak one language, but they are interconnected because the monolingual speech of bilinguals often shows interference from another language, and because bilinguals can code-switch quickly when they speak. According to the model top-down activation is spreading as a function of the bilingual's language mode. This implies that when a bilingual is in a monolingual language mode, one language network is strongly activated while the other is only very weakly activated, whereas in the bilingual language mode, both language networks are activated (but one more than the other). According to BIMOLA, the auditory presentation of homophones first activates the phoneme representations and subsequently the lexical representations in both the native and the nonnative language. Hence, when words that exist in two languages are activated, additional information (and time) is required to make a final decision about which word to select. The fact that interlingual homophones are recognized more slowly than control words implies that there is no selective bottom-up activation of lexical representations belonging to only that language, nor top-down regulation of the target language (which should lead to facilitation effects) or of non-target language representations (which should lead to inhibition effects). Moreover, there is no additional mechanism with language nodes or language schemes required to inhibit the irrelevant language, because the same mechanisms for within-language competition may be used to account for between-language competition. There are just more lexical representations involved in lexical search for bilinguals.

The findings are also in line with the core assumptions of BLINCS (see Figure 1). This model is based on localist connectionist models like BIA+ (from the visual domain) and BIMOLA (from the auditory domain), but also incorporates characteristics of distributed models by including a learning mechanism. It consists of an interconnected network of self-organizing maps that learn by means of an unsupervised learning algorithm. These self-organizing maps allow the separation of a bilingual's two languages without the need for explicit tags or nodes. By using these maps, different levels (i.e., phonological, phono-lexical, ortho-lexical, and semantic) are constructed. When a spoken word is presented, the model determines the unit that resembles the input best on the phonological map, and activates that node and neighboring nodes. Within this level, the model assumes a shared phonological system, where there is no clear delineation between phonemes from different languages. Activation at this level can also be influenced by visual input (e.g., articulatory lip or mouth movements consistent with a specific phoneme). Then, the activation is passed to lexical items that contain that phoneme. At this level, a bilingual's two languages are separated but integrated. Because neighboring nodes are also activated, the model will also activate lexical items with similar phonemes (e.g., when presenting *"pot"*, the item *"bottle"* will also be activated, based on phonological proximity). As speech unfolds, items that match the input are more strongly activated, whereas items that are not longer similar to the input gradually decay. Next, activation from the phono-lexical level is passed on to the ortho-lexical level (where the two languages are also separated but integrated) and the semantic level (shared across both languages, which is similar to the BIA+ model), and activation from these levels feeds back to the phono-lexical level. As a consequence, items that are orthographically and semantically similar also become activated. Additionally, there is also feedback from the phono-lexical level to the phonological level, allowing for lexical knowledge to influence phoneme perception. The structure of the model predicts for example the cognate facilitation effect, because it maps cognates and false-cognates closer together in the phono-lexical space, with an additional advantage for cognates from overlap at the semantic level. Hence, the model predicts both within- en between language competition, which is in line with the main findings from this dissertation.

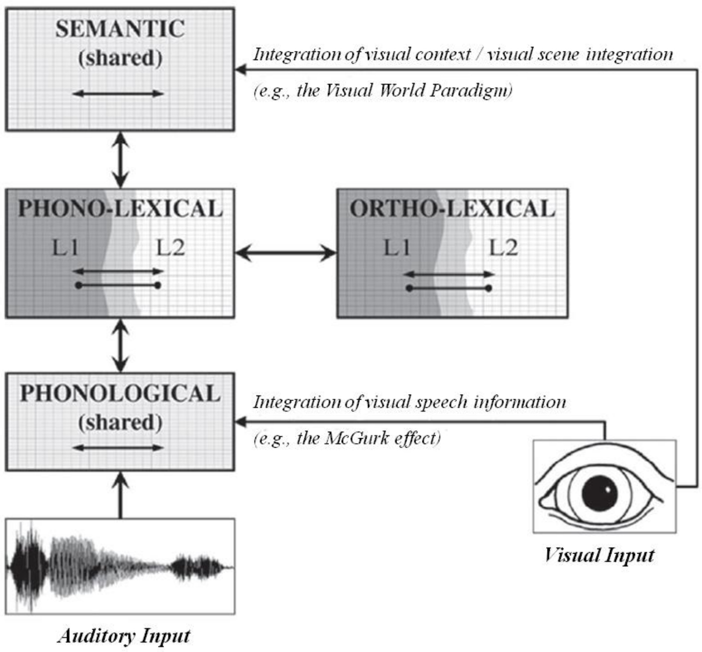

Figure 1. The Bilingual Language Interaction Network for Comprehension of Speech model (Shook & Marian, in press).

A second research question in this dissertation concerned the influence of sub-phonemic cues related to the native accent of speakers and the phonological similarity between languages, on the degree of cross-lingual interactions. More specifically, we investigated whether bilinguals are sensitive to these kinds of sub-phonemic cues and allophonic variations, and whether they use them to restrict lexical access to the currently relevant lexicon. The modulation of cross-lingual effects can originate from the fact that sub-phonemic cues from a non-target language trigger activation in lexical representations belonging to that language (e.g., those containing that sub-phonemic feature) through bottom-up activation. As a consequence, speech with an accent from the non-target language may result in larger interference effects. It may also be explained through a mechanism by which the presence of sub-phonemic cues of an irrelevant language constitutes a dual-language mode (such as the language modes in BIMOLA). Because of this dual-language mode, activation from all representations belonging to that language flows in a top-down manner, yielding larger interference effects. The results of Chapter 2 demonstrated that sub-phonemic cues related to the native accent did not modulate the degree of language-nonselectivity. This suggests that bottom-up activation from these cues is not substantially strong or powerful enough to influence target language recognition. Moreover, this also suggests that there is a very limited role for top-down connections of language nodes (if there even are such nodes) with lexical representations within that language. Note that a similar evolution has taken place in the bilingual visual domain, where such languages nodes existed in the original BIA model of Dijkstra and Van Heuven (1998), but were absent in the later BIA+ model (Dijkstra & Van Heuven, 2002).

However, the results from Chapters 3 and 4 suggested that sub-phonemic cues might influence cross-lingual interactions, but under different conditions. In contrast with the isolation study reported in Chapter 2, Chapters 3 and 4 investigated auditory word recognition in a sentence context. In comparison with isolated speech, sentences contain of course much more sub-phonemic cues that can reveal information about the target language, and also constitute a strong language cue for upcoming words in itself. For example, in Chapter 3, we observed that cross-lingual interactions were influenced by the phonological similarity between languages when bilinguals were listening in their native language. This follows directly from the basic functioning of most interactive models of word recognition, in which competition between representations is often a function of the similarity of these representations. In Chapter 4, which investigated auditory word recognition in a sentence context when listening in L2, cross-lingual interactions were reduced (but not annulled) when the sentences were pronounced by a native speaker of English. This suggests that the accumulation of sub-phonemic cues implies stronger bottom-up or top-down activation, and thus smaller cross-lingual interactions. This can be explained by the Cohort model and by Shortlist if cross-lingual interactions are reduced by means of a bottom-up mechanism. The present findings can also be explained by the TRACE model, as this model allows bidirectional interactions, and thus acknowledges the possible influence of top-down factors. The results are also in line with BIMOLA, because the presence of sub-phonemic cues of a nontarget language (e.g., when the native Dutch speaker pronounced the English targets) could activate the bilingual language mode, implying larger interference. The fact that we did not observe effects related to the native accent of the speaker in Chapter 2, suggests that these cues were not powerful enough in an isolated context to activate the bilingual mode of our bilinguals. However, when targets are part of a sentence, the accumulation in the amount of sub-phonemic cues provided by a nonnative accent seems strong enough to activate both languages.

Effects of sub-phonemic cues on the degree of language-nonselectivity are also possible under the assumptions of BLINCS, especially with phonemes that exist in one language, but not in the other. For example when a phoneme is presented that only exist in English, it is more likely that only English words will be activated. This model would also predict that allophonic variations can guide lexical access towards the target language (e.g., the /r/ is realized differently in English and in Dutch, so when hearing an English /r/ this would rather activate English representations).

Finally, in Chapters 4 and 5 we investigated whether language-nonselective lexical access is modulated by the semantic constraint of the preceding sentence. The results from Chapter 4 when listening in L2 demonstrated that this indeed was the case: cross-lingual interactions were smaller when the sentence context was high-constraining than when the sentence context was low-constraining. However, in Chapter 5 when listening in L1, the degree of cross-lingual interactions was not affected by the semantic constraint of the sentence. These findings suggest that for L2 recognition, there was an influence of top-down factors to inhibit lexical representations belonging to a particular language, but in the case of L1 recognition this influence was absent. The results are in agreement with the assumptions of the Cohort model and the Shortlist model, which can explain these findings by means of a bottom-up information flow. The TRACE model can also account for these results, because this model allows both bottom-up and top-down processes (even if their influence is limited) in bilingual word recognition. Although BIMOLA and BLINCS are not explicit in making predictions about the influence of semantic constraint on the degree of cross-lingual interactions, they would probably predict reduced cross-lingual interactions if they assume that a sentence that is high-constraining towards the target representation could put bilinguals in a monolingual language mode, making the nontarget language less salient (according to BIMOLA), or because of lateral connections between semantically related items (according to BLINCS).

FUTURE RESEARCH

The studies reported in this dissertation provide convincing evidence for a language-nonselective account of lexical access when listening in L2 and in L1. We also investigated whether these cross-lingual interactions are modulated by several constraints (i.e., sentence context, sub-phonemic speech cues, and semantic constraint). The results demonstrated that, these constraints can sometimes reduce the degree of language-nonselectivity, although they cannot completely annul cross-lingual interactions. However, there are several interesting further research questions that were not addressed in this dissertation, but still worth considering in future research.

First, although we investigated the influence of several constraints on bilingual lexical access, there are many other factors that were not directly tested in this dissertation. For instance, in the present dissertation, all experiments drew upon a single, homogenous sample of bilinguals. This increases comparability between chapters, languages, and manipulations, but it does not examine whether the proficiency level, or language context and learning characteristics of bilinguals modulate the degree of nonselective activation when listening. The importance of this factor was already demonstrated in the visual domain. In a study by Van Hell and Dijkstra (2002), L1-L3 cognate effects were observed when reading in the native language, but only for trilinguals that were highly proficient in their L3, and not for trilinguals with a lower proficiency level. Moreover, differences in L2 proficiency can probably explain the divergent findings in the studies by Spivey and Marian (1999) and Weber and Cutler (2004). Both studies investigated whether L1 auditory word recognition is influenced by knowledge of a second language, but only Spivey and Marian found evidence for language-nonselectivity. Two crucial differences between these two very similar studies (i.e., both studies used the visual world paradigm in which participants received instructions to pick up an object, and in which target-competitor pairs shared a phonologically overlapping onset) were the proficiency level and the immersion level of their bilinguals. In the study by Spivey and Marian, the Russian-English bilinguals were high-proficient in their L2, and lived in a L2 dominant environment since a long time, whereas the bilinguals in the study of Weber and Cutler were unbalanced Dutch-English bilinguals living in a L1 dominant environment. Because of this lower L2 proficiency level and lower immersion level, it is possible that it is more difficult to observe interference from a second language when listening in the native language.

Second, when we tested the influence of sub-phonemic cues related to the native accent of the speaker in Chapter 2 (in isolation) and in Chapter 4 (when listening to sentences in L2), we observed a main effect of speaker, which suggested that participants responded faster when targets were pronounced by a native speaker. Thus, for L2 word recognition this implies that recognition is faster when a native English speaker pronounced the targets, whereas for L1 word recognition, reaction times were faster when targets were pronounced by a native Dutch speaker. A possible explanation for this finding is the fact that native speech provides a better match with stored lexical representations than the pronunciations of nonnative speaker. As a consequence, the threshold for recognition is exceeded faster. However, an alternative explanation could be that accented speech is less intelligible overall. To investigate this, a third speaker manipulation should be added, in which Dutch-English homophones are pronounced by a nonnative speaker of for example French. If this alternative explanation is true, for word recognition in L2 (English) we would expect no differences in reaction times between the native Dutch and the native French speaker.

Third, the studies in this dissertation demonstrated that both the L2 and L1 representation of interlingual *homophones*, which share phonology but not spelling across languages, are activated when these items are presented auditorily. However, these findings should be extended with the investigation of whether both representations of interlingual *homographs*, which share spelling but not phonology across languages, are also activated when such an item is presented. This could be tested by means of a L2 lexical decision task on the last word (or nonword) of an auditorily presented sentence in L2. In critical trials, this sentence should be (a) compatible with the L2 representation of the homograph (e.g., *Sarah's mother heard that everything was ok and was very glad*, glad means "slippery" in Dutch), or (b) incompatible with the L2 representation, but compatible with the L1 representation of the homograph (e.g., *Kathy fell because the floor was very glad*), or (c) compatible with a control word, or (d) incompatible with a control word. We expect that lexical decision times will be slower for incompatible sentences, but that lexical decision times on sentences that are compatible with the L1 meaning of the homograph will be faster than lexical decision times on incompatible control sentences, which would demonstrate that both the L2 and L1 representation of the homograph are activated when listening. Additional evidence could be provided by means of an ERP study in which the same sentences are presented, but with the targets embedded in the sentence. Here we expect an N400 component on sentences that are semantically implausible. Moreover, we expect that this component will be reduced in the case that the sentence is implausible when the L2 representation is activated, but plausible when the L1 representation of the homograph is activated.

Fourth, in this dissertation we investigated whether listening in L2 and in L1 is influenced by characteristics of the speech signal in L2 and in L1. However, people do not only listen to speech, but they also have conversations with each other, in which they speak with an interlocutor. Therefore, it would be interesting to investigate the reverse effect, and test whether bilinguals are also influenced by the language and variations in language they heard when speaking themselves. Pickering and Garrod (2004) demonstrated that hearing a particular utterance activates a series of representations associated with that utterance, concerned with for example its sound, grammar, meaning, and lexical items. Subsequently, speakers tend to align, and use for example similar lexical items and grammatical structures as their interlocutor when having a conversation in their native language. Hence, an interesting question would be whether bilinguals adapt their pronunciations as a function of the pronunciation of their interlocutor. So for example, we could test whether there are sub-phonemic speech differences when a Dutch-English bilingual is speaking English with a French-English bilingual or with a native English speaker.

CONCLUSIONS

The research presented in this dissertation provides evidence for a language-nonselective account of lexical access when listening in L2 and in L1. Additionally, we have shown that the language of the sentence, sub-phonemic cues related to the native accent of the speaker, phonological differences between languages, and the semantic constraint of the sentence are factors that cannot restrict cross-lingual interactions in the bilingual lexicon. These results support a profoundly nonselective bilingual language system, and suggest that there is only a limited role for top-down effects to constrain the degree of this nonselectivity.

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CHAPTER 7
NEDERLANDSTALIGE SAMENVATTING

INLEIDING

Ongeveer de helft van de wereldbevolking gebruikt regelmatig twee of meer talen in het dagelijkse leven, en kan daardoor als tweetalig beschouwd worden (Grosjean, 1992). Net omdat tweetaligheid zo vaak voorkomt, is het belangrijk om de onderliggende mechanismen van tweetalige woordherkenning te bestuderen, en te onderzoeken hoe tweetaligen hun verschillende talen representeren. Onderzoek naar visuele woordherkenning heeft aangetoond dat de verschillende talen van een tweetalige in constante interactie met elkaar treden, zelfs wanneer slechts één taal relevant is (e.g., Dijkstra & Van Heuven, 1998; Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Libben & Titone, 2009; Van Assche, Drieghe, Duyck, Welvaert, & Hartsuiker, 2011). In tegenstelling tot het grote aantal studies dat onderzoek heeft gedaan naar visuele woordherkenning bij tweetaligen, is het aantal studies over tweetalige auditieve woordherkenning eerder beperkt. Aangezien tweetaligen niet alleen lezen, maar ook luisteren naar hun moedertaal en naar een tweede taal, roept dit de vraag op of woorden van beide talen ook parallel geactiveerd worden wanneer geluisterd wordt naar deze woorden.

Een interessante reeks van auditieve studies die de parallelle activatie van lexicale representaties onderzocht heeft is te vinden in het werk van Marian en collega’s (e.g., Marian en Spivey, 2003a, b; Spivey en Marian, 1999). In deze studies werd het “visuele-wereld-paradigma” gebruikt, en kregen Russisch-Engels tweetaligen de instructie in hun tweede taal (L2) of in hun moedertaal (L1) om te klikken op één van de vier objecten die afgebeeld waren op het computerscherm. De resultaten toonden aan dat proefpersonen langer keken naar competitor-objecten waarvan de eerste fonemen in de irrelevante taal fonologisch gelijkend waren aan de eerste fonemen van het targetwoord (e.g., wanneer ze de L2 instructie kregen om te klikken op een *marker*, wat “stift” betekent in het Nederlands, keken ze langer naar de afbeelding van een postzegel, *marka* in het Russisch dan naar een distractor item dat fonologisch ongerelateerd was; hetzelfde werd gevonden wanneer ze de instructie in L1 kregen). Weber en Cutler (2004) repliceerden deze bevindingen wanneer Nederlands-Engels tweetaligen instructies kregen in L2 (Engels), maar niet wanneer ze geïnstrueerd werden in L1 (Nederlands).

In het dagelijkse leven beluisteren tweetaligen natuurlijk niet enkel instructies zoals in bovenstaande experimenten, maar treden ze in dialoog met een gesprekspartner, en beluisteren ze spraak die veel gevarieerder is. Precies omwille van het feit dat het beluisteren van gevarieerde zinnen zo’n gangbaar fenomeen is, is het belangrijk om ook te onderzoeken of tweetaligen hun beide talen in parallel activeren wanneer ze luisteren naar zinnen. Chambers en Cooke (2009) deden een studie waarbij Engels-Frans tweetaligen naar Franse zinnen luisterden. Hierbij werd er evidentie gevonden voor parallelle activatie van beide talen wanneer de zin zowel compatibel was met het target als met de competitor, maar niet wanneer de zin incompatibel was met de competitor. Bijvoorbeeld, de zin “*Marie va décrire la poule*” (Marie zal de kip beschrijven) is zowel compatibel met de Franse (poule) als met de Engelse (pool) betekenis van /pu:l/, en hierbij werd dan ook vaker naar de Engelse competitor gekeken dan naar de ongerelateerde afbeeldingen. Dit was echter niet het geval bij de zin “*Marie va nourrir la poule*” (Marie zal de kip eten geven) die wel compatibel is met de Franse, maar niet met de Engelse betekenis van /pu:l/ (een zwembad kun je geen eten geven). Deze studie biedt bijgevolg evidentie voor het feit dat lexicale toegang niet taalselectief is bij het luisteren naar zinnen (want beide talen worden geactiveerd bij het luisteren naar de compatibele zinnen), maar dat de mate van non-selectiviteit beïnvloed (i.e., gereduceerd) wordt door de zinscontext (want bij de incompatibele zinnen wordt enkel de targettaal geactiveerd).

Op een paar uitzonderingen na, werd er tot op de dag van vandaag heel weinig onderzoek verricht naar tweetalige auditieve woordherkenning. Bovendien worden de bevindingen niet consistent gerepliceerd over de verschillende studies heen, en blijven er belangrijke onderzoeksvragen onbeantwoord. In deze thesis werd daarom nagegaan of de mate waarin twee talen in parallel geactiveerd worden beïnvloed wordt door de aanwezigheid van sub-fonemische cues die eigen zijn aan het spraaksignaal en dit bij het luisteren naar woorden in isolatie (Hoofdstuk 2), en bij het luisteren naar zinnen (Hoofdstukken 3, 4, en 5). Bovendien onderzochten we of sub-fonemische cues die gerelateerd zijn aan het moedertaalaccent van de spreker (Hoofdstukken 2 en 4) en fonologische verschillen tussen talen (Hoofdstuk 3) gebruikt worden om lexicale toegang taalselectief te maken. Ten slotte werd nagegaan of de voorspelbaarheid van de zin een invloed heeft op de mate van taalselectiviteit (Hoofdstukken 4 en 5).

TWEETALIGE AUDITIEVE WOORDHERKENNING IN ISOLATIE

In ***Hoofdstuk 2*** hebben we twee belangrijke vragen beantwoord. Ten eerste onderzochten we of lexicale toegang al dan niet taalselectief is bij het luisteren naar woorden in L2 en in L1. Ten tweede werd het moedertaalaccent van de spreker gemanipuleerd om na te gaan of sub-fonemische verschillen die eigen zijn aan het accent van de spreker een modulerende rol spelen bij het parallel activeren van zowel de moedertaal als een tweede taal. In Experiment 1 voerden Nederlands-Engels tweetaligen een Engelse (L2) auditieve lexicale beslissingstaak uit waarbij de targets ofwel uitgesproken werden door een Engelse of door een Nederlandse spreker. De resultaten toonden aan dat proefpersonen trager reageerden op interlinguale homofonen (i.e., woorden die zowel in L1 als in L2 hetzelfde klinken maar een andere betekenis hebben, e.g., *lief* – *leaf* (blad) /li:f/). Bovendien was dit effect even groot wanneer de targets uitgesproken werden door de Engelse spreker, als wanneer de targets uitgesproken werden door de Nederlandse spreker. In Experiment 3 voerde een verschillende groep van gelijkaardige Nederlands-Engels tweetaligen een Nederlandse (L1) auditieve lexicale beslissingstaak uit met dezelfde kritische items. Opnieuw werden de targets ofwel uitgesproken door een Engelse spreker of door een Nederlandse spreker. Net zoals in Experiment 1 werden interlinguale homofonen trager herkend dan controlewoorden, en was het effect onafhankelijk van de moedertaal van de spreker. Ter controle voerde een monolinguale groep Engelse proefpersonen de Engelse lexicale beslissingstaak uit (Experiment 2), en hier werd geen homofoon-interferentie-effect gevonden. Dit toont aan dat de effecten in Experimenten 1 en 3 effectief veroorzaakt werden door de lexicale interacties tussen twee talen, en niet door een andere variabele waarvoor niet gecontroleerd werd.

Ten eerste biedt het bidirectionele homofooneffect overtuigende evidentie voor het feit dat lexicale toegang niet taalselectief is. De resultaten toonden aan dat we niet enkel beïnvloed worden door kennis van onze moedertaal bij het luisteren naar een tweede taal, maar dat we ook beïnvloed worden door kennis van een (zwakkere) tweede taal bij het luisteren in onze moedertaal. Ten tweede werd er geen interactie gevonden tussen het homofooneffect en de moedertaal van de spreker die de targets uitsprak. Dit geeft aan dat de sub-fonemische cues die eigen zijn aan het moedertaalaccent van de spreker niet gebruikt worden om lexicale items van slechts één taal te activeren. Dit is een verrassende bevinding, aangezien het gebruik van dergelijke cues een efficiënte strategie zou kunnen zijn om het aantal lexicale kandidaten te beperken. De resultaten toonden wel aan dat proefpersonen sneller reageerden wanneer de targets uitgesproken werden door een spreker die de targettaal als moedertaal had (i.e., bij de Engelse lexicale beslissingstaak waren de reactietijden sneller wanneer de Engelse spreker de targets uitsprak, terwijl de reactietijden bij de Nederlandse lexicale beslissingstaak sneller waren wanneer de Nederlandse spreker de targets uitsprak). Dit kan verklaard worden door het feit dat de uitspraak van de spreker die de targettaal als moedertaal heeft beter overeenkomt met de opgeslagen lexicale representatie van dat woord, waardoor woorden sneller herkend worden.

DE INVLOED VAN DE ZINSCONTEXT OP LEXICALE TOEGANG

Vervolgens wilden we nagaan of er bepaalde factoren zijn die ervoor kunnen zorgen dat lexicale toegang taalselectief wordt. In ***Hoofdstuk 3*** onderzochten we daarom of het aanbieden van een woord binnen een betekenisvolle zinscontext zo'n beperkende factor is. Dit zou logisch zijn aangezien zinnen, in tegenstelling tot woorden in isolatie, veel meer sub-fonemische cues bevatten die kunnen aangeven welke taal relevant is, en waardoor de irrelevante taal op dat moment minder kans heeft om geactiveerd te worden. Bijkomend werd onderzocht of de fonologische gelijkheid van bepaalde fonemen tussen talen een factor is die lexicale toegang taalselectief kan maken.

Om dit na te gaan, werd het visuele-wereld-paradigma geïmplementeerd waarbij de oogbewegingen van de proefpersonen geregistreerd werden. In deze studie kregen Nederlands-Engels tweetaligen de instructie om naar een visuele display op het computerscherm te kijken terwijl ze luisterden naar plausibele, maar laagvoorspelbare zinnen in L2 (Experiment 1) of in L1 (Experiment 2). Ieder display bevatte een afbeelding van een target (e.g., *flower*, wat "bloem" betekent in het Nederlands), een competitor waarvan de eerste fonemen van het vertalingsequivalent fonologisch gelijkend waren aan de eerste fonemen van het target (e.g., *fles*), en twee fonologisch ongerelateerde distractoren (e.g., *hond* en *appelsien*). Wanneer de proefpersonen naar de zinnen in het Engels luisterden, werd vaker naar competitor afbeeldingen gekeken dan naar ongerelateerde distractoren, wat aantoont dat er lexicale competitie was tussen de moedertaal en de tweede taal. Dit effect was onafhankelijk van de mate van fonologische gelijkheid (i.e., het effect werd zowel gevonden voor target-competitor paren waarvan de onset fonologisch heel gelijkend was zoals bijvoorbeeld *flower* (bloem) – *fles*, als bij target-competitor paren waarvan de onset fonologisch minder gelijkend was zoals bijvoorbeeld *comb* (kam) – *koffer*). Wanneer de proefpersonen naar de zinnen in het Nederlands luisterden, werd er eveneens vaker naar de competitor afbeeldingen gekeken dan naar de fonologisch ongerelateerde distractoren, maar hier werd dit effect enkel vastgesteld bij de target-competitor paren waarvan de onset fonologisch heel gelijkend was. Deze resultaten werden bevestigd door een lineaire regressie-analyse die aantoonde dat de mate van fonologische gelijkheid geen voorspeller was van het lexicale competitie-effect bij het luisteren naar de zinnen in L2, maar wel een voorspeller was van het effect bij het luisteren naar de zinnen in L1 (i.e., hoe groter de fonologische gelijkheid, hoe groter het lexicale competitie-effect).

Deze studie toont aan het aanbieden van woorden in een zinscontext niet voldoende is om lexicale toegang tot slechts één lexicon te beperken. Dit suggereert dat de sub-fonemische cues die eigen zijn aan spraak niet restrictief gebruikt worden, ook al bevatten volledige zinnen veel meer dergelijke cues dan geïsoleerde woorden.

De Invloed van de Voorspelbaarheid van de Zin op Lexicale Toegang

In Hoofdstukken 4 en 5 lag de focus op de invloed van de voorspelbaarheid van de zin op de mate waarin lexicale toegang al dan niet taalselectief is. Eerdere, monolinguale, studies hebben aangetoond dat contextuele informatie gebruikt kan worden om woordherkenning te faciliteren (e.g., Binder & Rayner, 1998; Onifer & Swinney, 1981). Hierdoor worden voorspelbare woorden sneller verwerkt dan onvoorspelbare woorden (e.g., Schwanenflugel & LaCount, 1988; Schwanenflugel & Shoben, 1985; Stanovich & West, 1983). Bijgevolg is het plausibel dat de voorspelbaarheid van de zin eveneens gebruikt wordt om de toegang tot het tweetalige lexicon taalselectief te maken.

In ***Hoofdstuk 4*** onderzochten we of lexicale toegang al dan niet taalselectief is bij het luisteren naar woorden in betekenisvolle zinnen in L2

(Engels). Bovendien gingen we na of de mate van waarin deze toegang al dan niet taalselectief is, gemoduleerd wordt door de voorspelbaarheid van de zin. Ten slotte werd het moedertaalaccent van de spreker gemanipuleerd om te testen of dit als een cue gebruikt wordt om lexicale toegang te beperken tot één lexicon. Hiervoor luisterden Nederlands-Engels tweetaligen naar laag- en hoogvoorspelbare zinnen in L2, waarbij het laatste woord een interlinguale homofoon (e.g., *leaf* (blad) – *lief*) kon zijn. Om de invloed van de moedertaal van de spreker na te gaan, werden de zinnen zowel door een Engelse als door een Nederlandse spreker uitgesproken. Nadat de volledige zin aangeboden werd, voerden de proefpersonen een auditieve lexicale beslissingstaak uit op het laatste woord van de zin. De resultaten toonden aan dat interlinguale homofonen trager herkend werden dan controlewoorden. Dit suggereert dat de tweetaligen in deze studie zowel de Engelse als de Nederlandse betekenis van de homofonen activeerden. Dit bevestigt de bevindingen van Hoofdstuk 3, en toont aan dat sub-fonemische cues in het spraaksignaal niet gebruikt worden om de lexicale toegang te beperken tot één lexicon.

Bovendien was er een significante interactie tussen het homofooneffect en de voorspelbaarheid van de zin. Deze interactie toonde aan dat het homofooneffect kleiner was bij hoogvoorspelbare zinnen, dan bij laagvoorspelbare zinnen, en suggereert dat de interacties tussen talen gereduceerd worden na het horen van een hoogvoorspelbare zin. Echter, zelfs na het horen van een hoogvoorspelbare zin werden interlinguale homofonen trager herkend dan controlewoorden. Dit toont aan dat lexicale toegang nog altijd niet taalselectief is.

Ten slotte stelden we vast dat het homofooneffect kleiner was nadat de Engelse spreker de zinnen uitgesproken had dan wanneer de Nederlandse spreker de zinnen uitsprak. Dit is in tegenstelling tot de bevindingen in isolatie van Hoofdstuk 2, maar toont aan dat de irrelevante taal minder geactiveerd wordt na het horen van een volledige zin (die veel meer sub-fonemische cues bevat dan een geïsoleerd woord) van een spreker die de targettaal als moedertaal heeft.

In ***Hoofdstuk 5*** onderzochten we ten slotte of lexicale toegang al dan niet taalselectief is bij het luisteren naar zinnen in L1 (Nederlands). Bovendien gingen we na of de interacties in het tweetalige lexicon gemoduleerd worden door de voorspelbaarheid van de voorafgaande zinscontext. Hiervoor voerden Nederlands-Engels tweetaligen een Nederlandse auditieve lexicale beslissingstaak uit op het laatste woord van laag- en hoogvoorspelbare zinnen. In feite is dit een cruciale test van de assumptie die ervan uitgaat dat lexicale toegang niet taalselectief is, aangezien er in dit experiment meerdere factoren (i.e., een zinscontext in de moedertaal die hoogvoorspelbaar is) zijn die de mate waarin twee talen in parallel geactiveerd zijn zouden kunnen reduceren. De resultaten toonden aan dat proefpersonen opnieuw trager reageerden op interlinguale homofonen dan op controlewoorden. Dit komt overeen met de bevindingen uit de andere hoofdstukken, en geeft aan dat de aanbieding van een zinscontext niet voldoende is om lexicale interacties in het tweetalige lexicon te moduleren, zelfs wanneer in de moedertaal geluisterd wordt. Bijgevolg worden sub-fonemische cues die eigen zijn aan het spraaksignaal niet gebruikt, zelfs al zou dit in feite een efficiënte strategie zijn om het aantal lexicale kandidaten dat in aanmerking komt om geactiveerd te worden te reduceren, en zelfs ook al bevatten zinnen veel meer sub-fonemische cues dan geïsoleerde spraak. In tegenstelling tot de bevindingen uit Hoofdstuk 4, werd hier geen interactie vastgesteld tussen het homofooneffect en de voorspelbaarheid van de zin. Dus, zelfs wanneer tweetaligen een gesprek voeren in hun moedertaal, en wanneer ze bovendien kunnen voorspellen wat hun gesprekspartner zal zeggen, worden nog steeds zowel de Nederlandse als de Engelse representaties van de interlinguale homofonen geactiveerd.

BESLUIT

Het onderzoek dat in deze thesis voorgesteld werd, biedt overtuigende evidentie voor een visie op lexicale toegang die niet taalselectief is wanneer tweetaligen luisteren in hun tweede taal, maar ook wanneer ze luisteren in hun moedertaal. Bovendien werd aangetoond dat de taal van de zin, subfonemische cues die gerelateerd zijn aan het moedertaalaccent van de spreker, fonologische verschillen tussen talen, en de voorspelbaarheid van de zin factoren zijn die lexicale interacties tussen twee talen niet kunnen beperken tot slechts één lexicon.

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