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The influence of semantic constraints on bilingual word recognition during sentence reading

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Abstract

The present study investigates how semantic constraint of a sentence context modulates language-nonselective activation in bilingual visual word recognition. We recorded Dutch-English bilinguals' eye movements while they read cognates and controls in low and high semantically constraining sentences in their second language. Early and late eye movement measures yielded cognate facilitation, both for low- and high-constraint sentences. Facilitation increased gradually as a function of cross-lingual overlap between translation equivalents. A control experiment showed that the same stimuli did not yield cognate effects in English monolingual controls, ensuring that these effects were not due to any uncontrolled stimulus characteristics. The present study supports models of bilingual word recognition with a limited role for top-down influences of semantic constraints on lexical access in both early and later stages of bilingual word recognition.

Keywords: bilingualism, visual word recognition, sentence processing, semantic constraint, reading, cognate effect

Ever since it was estimated that about half of the world's population is bilingual (Grosjean, 1982), research on bilingualism has attracted the attention of a growing community of researchers. An important issue in this domain concerns the organization of the bilingual language system. One viewpoint is that bilinguals have two separate lexicons, one for each language. When reading in one language, only words from the corresponding lexicon become activated. However, many studies have provided evidence for an alternative viewpoint that assumes an integrated lexicon. These studies discovered that lexical representations of the first language (L1) are accessed when people are reading in their second language (L2) (e.g., Brysbaert, van Dyck, & van de Poel, 1999; Costa, Caramazza, & Sebastian-Galles, 2000; Dijkstra, Grainger, & Van Heuven, 1999; Dijkstra, Timmermans, & Schriefers, 2000; Duyck, 2005; Duyck, Diependaele, Drieghe, & Brysbaert, 2004; Haigh & Jared, 2007; Jared & Kroll, 2001; Lemhöfer & Dijkstra, 2004; Schwartz, Kroll, & Diaz, 2007) and vice versa (e.g., Duyck, 2005; Van Assche, Duyck, Hartsuiker, & Diependaele, 2009; Van Hell & Dijkstra, 2002). Similarly, studies on auditory word recognition (e.g., Marian, Blumenfeld, & Boukrina, 2008; Marian, Spivey, & Hirsch, 2003), word production (e.g., Costa, Santesteban, & Cano, 2005; Kroll, Bobb, & Wodniecka, 2006), and the bilingual Stroop task (e.g., Altarriba & Mathis, 1997; Chen & Ho, 1986; Tzelgov, Henik, & Leiser, 1990; Tzelgov, Henik, Sneg, & Baruch, 1996) have also provided evidence for language-nonselective activation of lexical representations in both languages. In the present study, we investigated whether cross-lingual lexical activation transfer is modulated by the semantic constraint imposed by a sentence. In the following sections, we first discuss the cognate facilitation effect, which is a reliable marker of nonselective activation. Then, we present monolingual and bilingual studies regarding the role of sentence constraint on lexical access.

Isolated word recognition

Many bilingual studies have investigated lexical activation in the non-target language by presenting cognates (translation equivalents with full or partial form overlap, e.g., Dutch-English *schip*-*ship*) and matched control stimuli in isolation, using tasks such as visual lexical decision (e.g., Caramazza & Brones, 1979; Dijkstra et al., 1999; Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Lemhöfer & Dijkstra, 2004), picture naming (e.g., Costa et al., 2000; Gollan & Acenas, 2004), and word naming (e.g., Schwartz et al., 2007). These studies have demonstrated that cognates are recognized or produced faster than monolingual matched control words (i.e., the *cognate facilitation effect*). In Lemhöfer, Dijkstra, and Michel (2004), this effect is shown to accumulate over languages: using Dutch-English-German trilinguals performing a German (L3) lexical decision task, they report faster responses for L1-L2-L3 cognates than for L1-L3 cognates. Additionally, cognate facilitation even occurs when bilinguals perform a lexical decision task in their native language (Van Assche et al., 2009; Van Hell & Dijkstra, 2002). These results provide very strong evidence for language-nonselective activation of lexical representations.

Theoretical explanations of this cognate effect can be divided into two general categories. A first category proposes a similar type of representation for cognates and noncognates, but with varying degrees of orthographic, phonological, and semantic overlap (e.g., Dijkstra & Van Heuven, 2002; Van Hell & De Groot, 1998). The currently most explicit model of bilingual word recognition in this category is the Bilingual Interactive Activation+ (BIA+) model (Dijkstra & Van Heuven, 2002). This updated version of the original BIA model (Dijkstra et al., 1999; Dijkstra & Van Heuven, 1998) is a bilingual extension of the well-known Interactive Activation model (McClelland & Rumelhart, 1981). It assumes that the bilingual lexicon contains entries from both languages in a unified store and is accessed in a language nonselective way. Upon the presentation of a word, orthographic, phonological, and semantic representations become activated (bottom-up) in both languages depending on the overlap with the input word. The cross-lingual activation spreading from these three codes speeds up the activation of cognates compared to noncognates. A second category of theoretical models assumes that there are qualitative differences in the representation of cognates and noncognates (De Groot & Nas, 1991; Kirsner, Lalor, & Hird, 1993; Sánchez-Casas & García-Albea, 2005). For instance, in the model of Kirsner et al. (1993), morphology is an important aspect in the organization of the bilingual lexicon. Cognate translations are considered as a special type of morphologically related items. Sánchez-Casas and García-Albea (2005) propose an extension of the BIA model (Dijkstra & Van Heuven, 1998) in which cognate translations share a common morphological root, whereas noncognate translations do not. The morphological level is supposed to be a mediating level between meaning and form. In the current study on the role of sentence constraint on lexical access, we also test whether cognate facilitation is a continuous effect based on the degree of cross-lingual overlap in the two languages. Such continuous effects of cross-lingual overlap would be more in line with the first group of models than with the second one, as there is no reason to expect graded effects of cognate status if it is assumed that cognates have qualitatively different representations from noncognates.

Although the BIA model was originally designed to account for isolated (out-of-context) visual word recognition, the recent BIA+ model (Dijkstra & Van Heuven, 2002) also makes predictions on how linguistic context effects may influence language-nonselective activation transfer, starting out from a distinction between a word identification system (the bilingual lexicon) and a task/decision system. Linguistic context (e.g., semantic and syntactic constraints) is assumed to directly affect activation in the word identification system. Non-linguistic context (e.g., task instructions, participant's expectations) on the other hand, is assumed to affect the task/decision system. The BIA+ model also includes a set of language nodes which act as language membership representations within the word identification system. This influence of language membership is relatively small (these nodes have no top-down connections in BIA+, unlike the earlier BIA) indicating that it will generally not affect word recognition. As language information does not provide strong selection constraints, we predict that the mere presentation of a word in a sentence context (and the language cues it provides) should not modulate cross-lingual activations. However, Dijkstra and Van Heuven predict that a semantic linguistic context may impose constraints on the degree of non-selectivity through boosted semantics which feed back to the orthographic level. The present study sets out to test this prediction that lexical access is influenced by semantic constraint of a sentence.

Word recognition in sentence contexts

From the monolingual domain, it is well known that contextual information guides lexical access in L1. For instance, many studies have shown that context aids in the interpretation of ambiguous words (e.g., *bank* as a riverside or a financial institution) (e.g., Binder & Rayner, 1998; Onifer & Swinney, 1981; Rayner & Frazier, 1989). In a neutral sentence context, meaning activation is determined by the relative frequencies of the ambiguous word's meanings. However, a strong biasing context can alter this activation (e.g., Duffy, Kambe, & Rayner, 2001). Also, many studies have shown that more predictable words (originating from a predictive sentence context) are processed faster than non-predictable words (e.g., Schwanenflugel & LaCount, 1988; Schwanenflugel & Shoben, 1985; Stanovich & West, 1983). In eyetracking paradigms, these predictable words are skipped more often and get shorter fixation durations (e.g., Balota, Pollatsek, & Rayner, 1985; Rayner & Well, 1996). In short, these studies demonstrate that sentence context is used to generate semantic, syntactic, and lexical restrictions for the processing of upcoming words in a sentence (e.g., Schwanenflugel & LaCount, 1988).

The present study tests whether these monolingual sentence effects generalize to the bilingual domain, focusing on the following question: is lexical access and its susceptibility to cross-lingual interaction effects modulated by the semantic constraint of the sentence? A study by Altarriba, Kroll, Sholl, and Rayner (1996; see also Altarriba, Kambe, Pollatsek, & Rayner, 2001, on cognate processing in low-constraint sentences) on a related issue suggests that the semantic context of a sentence may indeed be used to selectively activate words of only one language. In this study, Spanish-English bilinguals read English (L2) low- or high-constraint sentences while their eye movements were being recorded. In one condition, the target word was replaced by its Spanish translation. An example is the low-constraint sentence *They chose a calle* [street] *that could be easily closed off for the parade* or the high-constraint sentence *You need to look both ways before crossing a calle* [street] *as busy as that one*. The presentation of a high-frequency Spanish word in a high-constraint sentence resulted in longer reading times on first fixation duration (relative to the presentation of the same target in a low-constraint sentence). This result did not occur for low-frequency Spanish words, most likely because lexical access of low-frequency words occurs more slowly, resulting in more processing time to resolve the conflict. When the English target was presented in a high-constraint sentence, reading times were facilitated compared to a low-constraint sentence. Although the words *calle* and *street* both met the syntactic and semantic restrictions of the high-constraint sentence, facilitation was only found for the word that met the lexical restriction of the language of the sentence. This suggests that a semantically constraining sentence context can be used as a cue for lexical access, by activating not only semantic and syntactic restrictions for upcoming words, but also its language.

Schwanenflugel and LaCount (1988) explained the effect of semantic constraint within a feature restriction model. According to this model, a low-constraint sentence generates fewer feature restrictions for an upcoming word than a high-constraint sentence. For example, reading the sentence *Bubble gum got stuck on the sole of his* ___ will generate substantially more features for the upcoming words than reading the sentence *His wife bought him a* ___. Reading will only be facilitated for words that match the features that were generated. In the bilingual case, this would result in the activation of the same semantic representation across languages, at least for the concrete nouns used in most studies (e.g., Kroll & De Groot, 1997; Van Hell & De Groot, 1998). Furthermore, the study by Altarriba et al. (1996) has shown that bilinguals do not only generate semantic restrictions, but also lexical restrictions for upcoming words. This line of reasoning, predicts that the cognate advantage originating from the lexical overlap across languages will be reduced in high-constraint sentences because the semantic context restricts lexical activation in both cognates and noncognates alike. Therefore, it may be expected that the cross-lingual activation of lexical representations for cognate words (resulting in cognate facilitation when no semantic constraints are imposed) will no longer exert significant effects when semantic constraints are imposed. However, Altarriba et al. used stimuli in which words from both languages were mixed in one sentence. Although mixed language-texts are used in some parts of the world, unilingual texts provide a more ecologically valid reading situation. It is possible that the use of mixed-language sentences may have fundamentally changed lexical access. It may therefore be premature to draw definite conclusions from this study about more natural unilingual language processing, which is the condition under investigation in the current study.

Interestingly, only a few recent studies have investigated cross-lingual activation in sentence context by testing the recognition (or production) of words that constitute lexical representations in both languages of a bilingual, namely cognates and interlingual homographs (words that share orthography but not meaning, e.g., Spanish-English *fin* [end]). These studies converge on the conclusion that a low-constraint sentence context cannot eliminate activation of the non-target language (e.g., Duyck et al., 2007; Elston-Güttler, Gunter, & Kotz, 2005; Libben & Titone, 2009; Schwartz & Kroll, 2006; Van Assche et al., 2009; Van Hell & De Groot, 2008). However, results diverge regarding the influence of a semantic constraint provided by sentences. Whereas Schwartz and Kroll (2006) and Van Hell and De Groot (2008) found that semantic constraint may annul or diminish cross-lingual interactions, Libben and Titone (2009) have reported cross-lingual interactions in an eyetracking study with medium constraining sentences. However, these effects were only present in early eyetracking measures, suggesting that top-down factors rapidly inhibit co-language activation (see further).

In Duyck et al. (2007), Dutch-English bilinguals read English (L2) low-constraint sentences containing a cognate or a control word (e.g., *Hilda bought a new* ***ring – coat*** *and showed it to everyone*; *ring*, but not *coat*, is a cognate with Dutch) in an eyetracking paradigm. The goal of this study was to investigate if the sentence context and the language cue it provides could be used to speed up word recognition, because this would limit lexical search to words of only one language. Cognate facilitation was observed on early reading time measures (first fixation durations and gaze durations), but only for identical cognates (i.e., cognates with identical orthographies across languages, e.g., Dutch-English *ring* - *ring*). It seems that the sentence context was strong enough to counteract the cognate effect when cross-lingual orthographic overlap was not sufficiently strong (non-identical cognates). But when cross-lingual orthographic overlap was complete (identical cognates), lexical interactions between languages occurred during sentence reading, as was the case for words presented in isolation.

Another study by Elston-Güttler et al. (2005) showed that cross-lingual activation is very sensitive to the influence of a sentence context. They tested the recognition of interlingual homographs by German-English bilinguals. These homographs were presented at the end of a sentence context with a relatively open end (e.g., *The woman gave her friend a pretty **gift***) and served as the prime for targets that replaced the sentence. Targets were either related to the L1 meaning of the homograph (e.g., *poison* which is the translation of the German meaning of *gift*) or unrelated to the control prime (e.g., *The woman gave her friend a pretty **shell***). Lexical decision times on these targets showed semantic priming from L1 primes, but only in the first block of the experiment and only for participants who saw a German movie prior to the experiment. From this, the authors argued that cross-lingual priming from L1 to L2 was weak because of constraints imposed by the sentence.

Studies by Van Hell and De Groot (2008) and Schwartz and Kroll (2006) provided evidence for the above-mentioned prediction regarding the reduction of the cognate advantage due to the generation of lexical and semantic restrictions in a high-constraint sentence (e.g., Altarriba et al., 1996; Schwanenflugel & LaCount, 1988). Both studies found cognate facilitation in low-constraint sentences, but this effect disappeared when cognates and controls were embedded in high-constraint sentences. In Van Hell and De Groot, Dutch-English bilinguals performed a L2 lexical decision task or translated target words in forward (from L1 to L2) or in backward direction (from L2 to L1). Sentence contexts, in which the location of the target word was marked with three dashes, were presented on a computer screen (e.g., *The best cabin of the ship belongs to the* ---; target *captain*). The target word was presented immediately after the sentence disappeared from the screen. After reading a high-constraint sentence context, cognate facilitation was no longer observed in lexical decision and strongly diminished in both translation tasks. In low-constraint sentences, cognate effects were still present. This suggests that cross-lingual activations can be restricted by a semantically constraining sentence.

Schwartz and Kroll (2006) reported similar results for word naming by Spanish-English bilinguals. They presented cognates and interlingual homographs appearing in low- and high-constraint sentences. The participants were divided in groups of more and less proficient bilinguals. Sentences were presented word by word using rapid serial visual presentation and the target (printed in red) had to be named. In both groups of bilinguals, cognate facilitation was observed in low-constraint sentences, but not in high-constraint ones. Again, this suggests that the top-down effect of sentence constraint can modulate cross-lingual activations in the bilingual lexicon. No reaction time differences were found for homographs and controls in low- and high-constraint sentences, for both groups of bilinguals. However, less proficient bilinguals showed increasing naming error scores, particularly in low-constraint sentences. In this regard, the authors considered their results to be somewhat inconclusive: "Although the present study provided evidence of interactions between the top-down processes of sentence comprehension and the bottom-up processes of lexical access, we could not definitively conclude that actual selective access had taken place." (Schwartz & Kroll, 2006) [pp. 209].

The mixed results for homograph processing were somewhat clarified by Libben and Titone (2009) who recorded eye movements from highly proficient French-English bilinguals reading English sentences containing form-identical cognates and interlingual homographs. Low-constraint and somewhat more constraining sentence contexts preceded the targets. They observed cognate facilitation and homograph interference on both early (e.g., first fixation duration, gaze duration) and late (e.g., go-past time, total reading time) comprehension measures in low-constraint sentences. However, in the more constraining sentences, cross-lingual activations were only present on early comprehension measures. The late stage comprehension measures showed no cognate facilitation or homograph interference, consistent with the naming results of Schwartz and Kroll (2006) and the lexical decision and translation results of Van Hell and De Groot (2008). It therefore seems that only the registration of eye movements is sensitive enough to uncover early cross-lingual activations during the reading of semantically constraining sentences.

However, an important point to emphasize here concerns the fact that only early eyetracking measures showed cognate facilitation in Libben and Titone (2009). This suggests that lexical representations from both languages may become active during early stages of word recognition, but also that this dual-language activation is rapidly inhibited by semantic factors, given that the late measure effect only disappeared for the more constraining sentences. This is consistent with the BIA+ model (see above), which assumes that a semantic linguistic context may impose constraints on the degree of non-selectivity through boosted semantics which feed back to the orthographic level. As such, Libben and Titone's study converges with Schwartz and Kroll (2006) and Van Hell and De Groot (2008), because all these studies are consistent with the idea that top-down factors may indeed annul cross-lingual lexical activation (albeit only in later stages of word recognition in the case of Libben and Titone).

In addition, even though the recent above results of Libben and Titone (2009) seem to suggest that top-down semantic influences do not have a large impact on cross-lingual lexical interactions during early stages of word recognition, there are also a number of reasons why this issue seems not yet resolved even for the very early lexical stages of word recognition. First, it should be pointed out that these earlier studies operationalized the concept of semantic constraint in a different way. In particular, the semantic constraint manipulation in the Libben and Titone study is much weaker than in the earlier studies (Schwartz & Kroll, 2006; Van Hell & De Groot, 2008). Libben and Titone's 'high-constraint' sentences were semantically coherent sentences, but actually rather medium-constraint with cloze probabilities of .48 for cognates and .49 for controls. So, target words in Libben and Titone were always plausible within their sentence contexts, but the sentence did not really constrain towards a specific lexical representation. Let's consider for instance the sentence "Since he liked to compose songs, he made an extended TUNE that was very catchy". Indeed, the target TUNE (this is an example of a control) matches the meaning of the sentence, but for a majority of participants, the sentence constraint may rather preactivate the lexical representations of RECORD, or ALBUM instead. Importantly, the cloze probabilities in earlier studies of Schwartz and Kroll (2006; .67 for cognates and .67 for controls) and Van Hell and De Groot (2008; .72 for concrete cognates and .71 for concrete controls) were higher and as a result, their sentences provided a stronger semantic context. Of course, this difference might explain why Libben and Titone on the one hand did report effects in 'high'-constraint sentences, whereas on the other hand Van Hell and De Groot and Schwartz and Kroll did not. The present study will use a much stronger semantic constraint manipulation (with cloze probabilities of .89 for cognates and .86 for controls) in order to find out whether these divergent results may be due to this difference across studies.

Second, it is also important to explore this issue in bilingual populations different than those of Libben and Titone (2009). In this study, bilinguals were living in a truly bilingual environment (Montreal, Canada). This is reflected in the percentage of language use for these participants, which was about 50% for both languages. In fact, although English was considered as the L2 in Libben and Titone, participants even reported somewhat more use of English (50.10%, Libben & Titone, pp. 382) than of French (i.e., L1) (47.24%). This is different from the present study: the present bilinguals are able to communicate quite fluently in their L2 (English), but their language environment is L1 (Dutch) dominant, and estimates of daily usage of English does not exceed 10%. Also, for the Belgian bilinguals, age of acquisition for English (formal education starts in high school, around age 14) is later than for Canadians (around age 7). So, the present paper constitutes a much more conservative test of cross-lingual interactions in sentence reading, investigating cognate effects in late, unbalanced bilinguals, living in a L1 dominant environment.

Third, unlike the Libben and Titone (2009) study, the present study will consider non-identical cognates. This is not a trivial issue because some authors (e.g., Gollan, Forster & Frost, 1997) have suggested that identical cognates may share the same lexical representation in the bilingual lexicon. Within this view, the observation of facilitation solely for identical cognates may still be explained within a cumulative frequency account, with cognates behaving as more frequent words than their controls because their lexical representation is strengthened by encounters with the same word in both languages. For non-identical cognates, because of the form differences between languages, lexical representations are by definition not shared. As such, in order to attribute cognate effects to interactions between lexical representations of different languages, it is important to also show such effects with non-identical cognates

Fourth, it is important to note that Libben and Titone (2009) presented no filler-target sentences so that the number of language-ambiguous targets (identical cognates and interlingual homographs) in the experiment was quite high (50%) compared to earlier studies (e.g., Duyck et al., 2007; Van Hell & De Groot, 2008). This might have boosted the activation of the non-target language, and therefore also the observed cognate effects.

The present study

The goal of this study is to provide a comprehensive view on how semantic constraint influences cross-lingual activation by testing cognates with varying degrees of cross-lingual overlap in highly constraining sentences. This study therefore constitutes an important extension of Duyck et al. (2007) and Libben and Titone (2009) and can provide answers about two main issues in bilingual research. First, it should provide clear insights regarding the influence of semantic constraint on lexical access, and the time course of such top-down influences. If sentence constraint inhibits co-language activation already during early or rather at late stages of word recognition, no cross-lingual interaction effects should appear in respectively early or late eyetracking measures. If however, both early and late comprehension measures would show cross-lingual interactions under the strict conditions of high semantic constraint and with cognates with varying degrees of overlap, a limited role should be assigned for semantic top-down influences on the profoundly nonselective bilingual language system. Second, the use of a continuous measure of cognate status, based on cross-lingual similarity between translation equivalents, allows a more sensitive analysis of possible gradual effects on word processing. Moreover, they can provide new insights regarding the representation of cognates and noncognates in bilingual memory, as finding continuous effects of cross-lingual overlap would be more in line with computational interactive activation models proposing a similar representation for cognates and noncognates (e.g., Dijkstra & Van Heuven, 2002; Thomas & Van Heuven, 2005; Van Hell & De Groot, 1998) than with models assuming qualitatively different representations for cognates and noncognates (e.g., De Groot & Nas, 1991; Sánchez-Casas & García-Albea, 2005).

We decided to use a strong and reliable marker of nonselective activation: the cognate facilitation effect. In previous studies (e.g., Caramazza & Brones, 1979; Dijkstra, et al., 1999; Libben & Titone, 2009; Schwartz & Kroll, 2006; Van Hell & De Groot, 2008), each cognate was considered an item of a homogeneous group (the cognate group) that was compared to a group of items containing noncognate words (the control group). Libben and Titone (2009) only tested identical cognates, whereas the other studies made no explicit distinction between effects for identical and non-identical cognates. Here, we adopted a more fine-grained approach by using a continuous measure of cognate status for analyses instead of a dichotomous cross-lingual overlap manipulation (identical vs. non-identical cognates, Duyck et al., 2007). We calculated cross-lingual similarity between (a) each cognate word and its translation (e.g., *pilot*-*piloot*: 0.89) and (b) between each control word and its translation (e.g., *habit*-*gewoonte*: 0.04) using the word similarity measure developed by Van Orden (1987).[1] In addition, several studies have shown the importance of phonological overlap in the cognate effect (e.g., Dijkstra et al., 1999; Schwartz et al., 2007). For instance, Schwartz et al. (2007) showed that English-Spanish bilinguals' naming times for cognates were a function of both the orthographic and phonological similarity in the two languages. As the Van Orden measure does not take into account phonological overlap, we also collected bilinguals' ratings for each target word and its translation with respect to phonological and orthographic overlap. We included only a limited number of identical cognates and no interlingual homographs to guarantee a strong unilingual language context. The tracking of eye movements was used to uncover the time-course of activations by dissociating several early (reflecting initial lexical access) and late reading time measures (reflecting higher-order processes such as semantic integration) (Rayner, 1998).

Experiment 1 used a standard L2 lexical decision task to replicate the cognate facilitation effect in isolation (e.g., Dijkstra et al., 1999; Duyck et al., 2007; Lemhöfer & Dijkstra, 2004) with a new set of stimuli. Experiment 2 presented cognates and control words in low-and high-constraint sentences while eye movements were monitored. The use of the eyetracking method allows assessing the time course of cross-lingual lexical interactions and is probably the closest experimental operationalization of natural reading. Experiment 3 was a monolingual control experiment with native English participants.

Experiment 1: Lexical decision

Method

Participants. Twenty-nine students from Ghent University participated in the experiment. They were all late Dutch-English bilinguals who started to learn English around age 14 at secondary school for about 3-4 hours a week. In Belgium, students are regularly exposed to their L2 through popular media or English university textbooks. The criteria for recruitment stipulated that the participants should have good knowledge of English. Participants did not know that their knowledge of Dutch would be of any relevance to the experiment. Participants were paid or received course credit for their participation. After the experiment was finished, they were asked to rate their L1 and L2 proficiency with respect to several skills (reading, writing, speaking, and general proficiency) on a seven-point Likert scale ranging from *very bad* to *very good*. Mean self-reported general L1 (M = 6.3) and L2 proficiency (M = 5.3) differed significantly (all dependent samples t-test ps < .001). Means are reported in Table 1.

< Insert Table 1 about here >

Stimulus materials. The original target stimuli consisted of 46 cognates of three to eight letters in length which varied in their degree of Dutch-English orthographic similarity. Using the WordGen stimulus generation program (Duyck, Desmet, Verbeke, & Brysbaert, 2004), we selected 46 English noncognate control words matched (on an item by item basis) to the cognates with respect to word length (identical), number of syllables, word frequency, neighborhood size (Coltheart, Davelaar, Jonasson, & Besner, 1977) and word class (all words were nouns). Paired samples t-tests showed no significant differences on any of these variables (all ps > .16). This matching ensured that there were no correlations between any of the matching variables and degree of cross-lingual overlap (cognate status). Based on Van Orden's (1987) measure, we defined cognates as words with an orthographic overlap score of 0.40 or more. This resulted in the removal of 4 word pairs because these targets' orthographic overlap in both languages was too low for a cognate (*sea - zee*: 0.08) or too high for a noncognate (*king – koning*: 0.74; *liar – leugenaar*: 0.55; *walk – wandeling*: 0.40).

Additionally, 46 English filler words were randomly selected from the CELEX lexical database (Baayen, Piepenbrock, & Van Rijn, 1993). They were matched to the target words on the criteria mentioned above. Using the WordGen program (Duyck et al., 2004), 138 orthographically regular and pronounceable nonwords were selected that were matched to the target words on word length, neighborhood size, and bigram frequency.

Procedure. Participants were tested in groups of four persons. Participants received oral and written instructions to decide on each trial if the presented letter string was a real English word or not by pressing one of two response buttons. They were instructed to press the right button for a word response and the left button for a nonword. It was emphasized to make this decision as quickly and accurately as possible. Every participant saw a different randomized order of the 276 trials. Each target word was presented only once and 10 practice trials preceded the experiment.

Each trial started with the presentation of a centered fixation point for 800 ms. After a 300 ms interstimulus interval, the letter string was presented in the middle of the screen. It remained there until the participant's response or until the maximum response time of 2500 ms was exceeded. The intertrial interval was 700 ms. After the experiment, participants completed a questionnaire assessing their self-reported L1 and L2 reading, speaking, writing, and general skills on a seven-point Likert scale.

Results

Analyses were run on 32 cognate-noncognate pairs because of the above-mentioned exclusion of 4 pairs based on their overlap scores and because the cloze probability study of Experiment 2 (see below) indicated that 10 pairs were not usable for the sentence study (i.e., because the cognate or control word was generated too often in the low-constraint sentence or not often enough in the high-constraint sentence). The selection of these 32 word pairs for the analyses did not affect the matching between cognates and controls on word length, number of syllables, word frequency, neighborhood size, and bigram frequency (*p*s > .12). Means on these matching variables are presented in Table 2. The target words and their Van Orden's (1987) overlap scores are presented in Appendix A.

< Insert Table 2 about here >

We conducted mixed-effects models analyses on the reaction time (RT) and accuracy data. Incorrect responses (5.8% of the data) and RTs that were more than 2.5 standard deviations below or above the participant's mean RT for cognates and controls were excluded from analyses (2.7% of the data). RT data were inverse transformed (i.e., -1/RT) to reduce the skewness of the distribution. We applied the Markov Chain Monte Carlo (MCMC) sampling method (with a sample size of 10.000) to obtain *p*-values for the coefficients in the RT analysis (Baayen, Davidson, & Bates, 2008). We first present the analyses based on the discrete manipulation of cognates vs. controls (cf. Dijkstra et al., 1999; Lemhöfer et al., 2004; Van Hell & De Groot, 2008). Then, we provide the continuous analyses of orthographic overlap based on (a) the Van Orden (1987) orthographic similarity measure and (b) on the combined orthographic and phonological ratings for each target. Word frequency (i.e., logarithm of word frequency per million words according to the CELEX lexical database, Baayen et al., 1993) of the targets was included as a (continuous) control variable. Random intercepts were included for subjects and items (Baayen et al., 2008). Logistic models were used for the binomially distributed error data.

Analyses including the factor Word type (cognate vs. control) showed that RTs to cognates (M = 512 ms) were faster than RTs to controls (M = 543 ms) [$F(1,1696) = 19.17$, $p < .001$]. Also, we observed a significant effect of Frequency [$F(1,1696) = 25.34$, $p < .001$], indicating that more frequent words were recognized faster. The error analysis showed no significant differences in error percentages for cognates (M = 4.8%) and controls (M = 6.8%) [$z = 1.27$, $p = .21$], but fewer errors for more frequent words [$z = 4.67$, $p < .001$].

The results of the analyses on the continuous measure of cognate status using Van Orden's (1987) measure indicated that the recognition of English words was facilitated when they had higher degrees of orthographic similarity with Dutch [$F(1,1696) = 24.69$, $p < .001$]. And again, more frequent words were recognized faster [$F(1,1696) = 25.80$, $p < .001$]. The error analysis yielded no significant effect of Overlap [$z = 1.61$, $p = .11$] and a significant effect of Frequency [$z = 4.71$, $p < .001$], showing more errors for low frequent words. The analyses on the combined measure of orthographic and phonological overlap yielded the same pattern of results: a continuous effect of Overlap [$F(1,1696) = 23.80$, $p < .001$] and an effect of Frequency [$F(1, 1696) = 24.93$]. The error analysis indicated no significant effect of Overlap [$z = 1.37$, $p = .17$] and a significant effect of

Frequency [$z = 4.64$, $p < .001$]. A graph of the RT results on Van Orden's overlap measure presented in Figure 1.[2]

< Insert Figure 1 about here >

Discussion

Consistent with previous studies (e.g., Dijkstra et al., 1999; Duyck et al., 2007; Lemhöfer & Dijkstra, 2004), this lexical decision task showed that cognates were processed faster than controls. Interestingly, analyses also showed that this cognate facilitation effect becomes gradually stronger as a continuous function of cross-lingual overlap. As such, this experiment on targets presented out-of-context provided a validation of the materials for use in sentences in the following experiments.

Experiment 2: Eyetracking bilinguals

Method

Participants. Sixty-two further students from Ghent University participated in the experiment. They were paid for their participation or received course credit. Mean self-reported general L1 ($M = 6.2$) and L2 ($M = 5.3$) proficiency differed significantly (all dependent samples t-tests yielded *p*s < .001) (see also Table 1). There was no difference in mean general L1 and L2 proficiency for the participants of Experiments 1 and 2 (independent samples t-test yielded $p > .73$).

Stimulus materials. For each target word of the original set, a low- and high-constraint sentence context was constructed, resulting in 184 sentences. Sentences for cognates and noncognates were matched in terms of number of words, syntactic structure, and the length of the word preceding the target. Critical words were never in the final position of the sentence. A minimum of five words preceded the target and a minimum of two words followed the target. A native speaker of English checked that all stimuli were correct English sentences. The sentences were divided across two presentation lists so that no participant would see the same cognate or control word twice. Additionally, 36 filler sentences and 10 practice sentences, all of a syntactic complexity comparable to the target sentences, were added to each list.

Pretest 1. To verify the context manipulation of the cognate and noncognate sentences, a cloze probability study was conducted with 35 additional Ghent University students. Each participant was presented with the 184 sentence frames up to the target word. They were instructed to type in the first word of the sentence completion that came to mind when reading the sentence frame. Based on these results, 4 cognate-noncognate pairs were removed because cloze probability in the high-constraint condition did not reach 60% or because there was an alternative completion with a high cloze probability. Additionally, we removed 6 pairs because the cloze probabilities between the cognate and control differed more than 20%. The above-mentioned exclusion of 4 pairs based on the overlap scores and the removal of these 10 pairs based on the cloze probability test resulted in a set of 32 cognate-control pairs that entered analyses. Dependent samples t-tests on cloze probabilities for the remaining 32 pairs of targets in low- and high-constraint sentences showed no significant differences between cognates and noncognates (all *p*s > .16). Also, cloze probabilities in high-constraint sentences were significantly higher than in low-constraint sentences ($p < .001$) (see Table 3), showing that our constraint manipulation was effective. The low- and high-constraint sentences for each cognate-control pair are shown in Appendix B.

< Insert Table 3 about here >

Pretests 2 and 3. In order to provide a measure of orthographic and phonological overlap for each target word and its translation, we conducted two rating studies. In the first rating study, 19 bilingual participants from the same population as those of the actual experiment had to rate the orthographic similarity of the translation pairs on a seven-point Likert scale (1 indicating an unequal spelling and 7 an equal spelling). We created four lists in which word pairs were presented in a different order. Each list contained all the word pairs and subjects wrote down their answers. In the second rating study, 21 further subjects rated the phonological similarity of the translation pairs on a seven-point Likert scale (1 indicating an unequal pronunciation and 7 an equal pronunciation). Subjects listened to each word pair and wrote down their answers. Again, we used 4 different orders for presenting the word pairs. Each rating study started with three practice items. Mean orthographic and phonological rating scores of the 32 target pairs are presented in Appendix A. As expected, there was a significant correlation between Van Orden's (1987) overlap measure and the orthographic ratings ($r = .97$). Similarly, the correlations between Van Orden's measure and the phonological ratings ($r = .91$) and between the orthographic and phonological ratings ($r = .94$) were significant. In the analyses, we combined the orthographic and phonological ratings by calculating their mean value and we presented it as the variable combined orthographic and phonological ratings.

Apparatus. Eye movements were recorded using an SR Research Eyelink 1000 eye tracking device. Viewing was binocular, but eye movements were recorded from the right eye only. The tracker monitored participants' gaze locations every millisecond. All sentences were displayed on no more than two lines with a maximum length of 85 characters per line and all letters were lowercase (except when capitals were appropriate) and in mono-spaced Courier font. Targets were never the final word of a line, nor the first word of the second line. The sentences were presented in black on a white background.

Procedure. Before the start of the experiment, participants were informed that the experiment was about the comprehension of sentences presented on a screen. We emphasized that it was important to read the sentences as naturally as possible for comprehension (as if one was reading a book or a newspaper). Sentences were presented as a whole on the screen. Participants pressed a button indicating they had finished reading the sentences, after which a new sentence appeared on the screen or a comprehension question followed. Comprehension questions appeared on the screen in 36 trials and needed a yes- or no-response by pressing one of two response buttons. Overall accuracy on these questions was 96%, indicating that participants read the sentences attentively.

The 126 sentences were presented in a random order to each participant and were preceded by 10 practice sentences. Calibration consisted of a standard 9-point grid. The whole session including camera setup and calibration lasted about half an hour.

Data analysis. Mixed-effects models, as implemented in the *Lme4* library (Bates, 2007) in *R* (R Development Core Team), were fitted to four eye movement measures. We examined both early, first-pass measures and a late eye tracking measure (Rayner, 1998). First-pass measures included *first fixation duration* (FFD), *gaze duration* (GD), and *percentage of skipped targets*. The FFD is the duration of the first fixation during the first passage through the region of the target. The GD is the sum of fixations from the moment the eyes land on the target (for the first time) until the moment they move off again. The decision to skip a word occurs very early in processing the target based on parafoveal processing during preceding fixations. If the reader skipped the word, this was coded as a missing value for the FFD, GD, and GPT measures. These early measures are typically assumed to reflect lexical access and word identification processes. The later stage measure, *go-past time* (GPT) is assumed to reflect higher-order processes such as semantic integration. The GPT is the sum of all fixations from the first fixation on the target until a word to the right of the target is fixated. Regressions originating from a particular region are added to the GPT of that region, but they are not added to the GD. Assuming that cognate effects arise from nonselective lexical access to the bilingual lexicon, we predicted cognate effects to show up in the first-pass early reading time measures. GPT is supposed to reflect higher-order processes and we therefore did not assume this measure to reflect cognate processing. However, if readers do not make many regressions from the target word, GD and GPT will be similar because GD is completely included in GPT.

Prior to analyses, fixations shorter than 100ms (for justification, see Morrison, 1984; Rayner, Sereno, Morris, Schmauder, & Clifton, 1989) or longer than 800 ms were removed. Removing trials in which calibration was inadequate resulted in 0.1% of the trials being deleted. Analyses were run on the 32 cognate-noncognate pairs included in the analyses of the lexical decision task (Experiment 1). We will first report the analyses on the discrete variable Word type (cognate vs. control). Then, we present the analyses on the continuous variable Overlap defined by the Van Orden (1987) similarity measure and the overlap measure defined by the combined orthographic and phonological ratings. Each analysis considered the effect of Constraint as a discrete variable. Random intercepts were included for subjects and items for the four eye movement measures and random slopes regarding the constraint factor for items were included for FFD, GD, and GPT.[3] Logistic models were used for the binomially distributed skipping data. To control for effects of parafoveal preview, we also included the distance of the prior fixation from target word as the control variable Prior fixation distance (cf. Van Assche et al., 2009; see e.g., Vitu, McConkie, Kerr, & O'Regan, 2001). The possibility of a non-linear effect of this factor was considered. As in the lexical decision task, frequency of the targets was included as a control variable. Outliers on Prior fixation distance (exceeding a distance of more than 20 character spaces) were removed (0.1% of the data for FFD, GD, GPT, and skipping). After calculation of the skipping percentages on the target word, we removed the trials in which the target was skipped (17.8% in the high-constraint condition; 14.4% in the low-constraint condition) from the analyses of FFD, GD, and GPT. We applied the MCMC sampling method (with a sample size of 10.000) to obtain *p*-values for the coefficients in the RT analysis. Prior to analyses, the reading times on FFD, GD, and GPT were log-transformed to reduce the skewness of the distribution.

Results

Word type (cognate vs. control). There was no significant interaction between Word type and Constraint for FFD, GD, and GPT [all *F*s < 1], and therefore this interaction was removed from the model and the model was tested again. Results showed significantly faster reading times for cognates than for controls on FFD [$F(1,3311) = 5.80$, $p < .01$], GD [$F(1,3311) = 4.97$, $p < .01$], and GPT $F(1,3311) = 5.32$, $p < .01$]. Also, reading times in high-constraint sentences were faster than in low-constraint sentences on all measures [FFD: $F(1,3311) = 12.81$, $p < .001$; GD: $F(1,3311) = 27.37$, $p < .001$; GPT: $F(1,3311) = 21.93$, $p < .001$], illustrating the successful manipulation of sentence constraint. Means are presented in Table 4.

< Insert Table 4 about here >

The effect of Frequency was significant on FFD [$F(1,3311) = 6.87$, $p < .05$] and GD [$F(1,3311) = 9.19$, $p < .01$], indicating shorter reading times for more frequent words. This effect was not significant on GPT [$F(1,3311) = 2.74$, $p = .11$]. Significant non-linear effects of Prior fixation distance were observed for all dependent measures [FFD-linear, FFD-quadratic, GD-linear, GD-quadratic, GPT-linear, and GPT-quadratic: all *p*s < .001]. Fixations on the target were shorter when the previous fixation was close to the target word. However, the slope of this effect decreased with distance.

As in the reading time analyses, the results for skipping showed no significant interaction between Word type and Constraint [$z < 1$] and, as a result, it was removed from the model and the model was tested again. Cognates were skipped more often than controls [$z = 3.00$, $p < .01$]. Words in high-constraint sentences were skipped more than in low-constraint sentences [$z = 3.65$, $p < .001$]. Also, there was a marginally significant effect of frequency, with increased skipping rates for more frequent words [$z = 1.78$, $p = .08$] and significant non-linear effects of Prior fixation distance were observed [all *p*s < .001].

We tested contrasts to investigate if the cognate effect was present in low- and high-constraint sentences separately. The mixed-effects models analyses with MCMC sampling adjustment of the degrees of freedom for the test statistic showed (marginally significant) faster reading times for cognates than for controls in low-constraint sentences [FFD: $t = 1.81$, $p = .07$; GD: $t = 1.69$, $p = .10$; GPT: $t = 1.92$, $p = .06$] and significant cognate facilitation in high-constraint sentences [FFD: $t = 2.52$, $p < .05$; GD: $t = 2.66$, $p < .05$; GPT: $t = 2.36$, $p < .05$]. Results on skipping yielded more word skipping on cognates than on controls in both low [$z = 2.43$, $p < .05$] and high-constraint sentences [$z = 2.11$, $p < .05$].

Orthographic overlap (Van Orden). Analyses on this continuous measure of cognate status showed no significant interaction of Overlap and Constraint on FFD, GD, and GPT [all *F*s < 1], and so we tested a model without the interaction. This showed faster reading times for words with more cross-lingual orthographic overlap [FFD: $F(1,3311) = 5.17$, $p < .05$; GD: $F(1,3311) = 5.52$, $p < .01$; GPT: $F(1,3311) = 7.92$, $p < .01$]. As in the previous models including the factor Word type, we observed significant effects of Constraint [all *p*s < .001] and Prior fixation distance [all *p*s < .001] on all three reading time measures. The effect of Frequency was significant for FFD [$p < .05$] and GD [$p < .01$], but not for GPT [$p = .10$].

In the analyses on skipping percentages, we first removed the nonsignificant interaction between Overlap and Constraint from the model [$z < 1$]. The model was tested again and showed that words with higher degrees of cross-lingual overlap were skipped more often [$z = 2.49$, $p < .05$]. Similar to the previous analyses on Word type, the results yielded significant effects of Constraint [$p < .001$], Prior fixation distance [*p*s < .001], and a marginally significant effect of Frequency [$p = .08$].

Separate contrasts showed significant facilitation for words with increasing orthographic overlap in low [FFD: $t = 1.82$, $p = .07$; GD: $t = 2.34$, $p < .05$; GPT: $t = 2.91$, $p < .01$] and high-constraint sentences [FFD: $t = 2.33$, $p < .05$; GD: $t = 2.45$, $p < .05$; GPT: $t = 2.50$, $p < .05$]. Results on skipping percentages showed significant effects of Overlap in low-constraint sentences [$z = 2.22$, $p < .05$], but not in high-constraint sentences [$z = 1.56$, $p = .12$]. Graphs of these effects on reading times and skipping rates are presented in Figures 2 and 3, respectively.

< Insert Figures 2 and 3 about here >

Orthographic and phonological overlap (ratings). The results of this continuous measure of cognate status showed no significant interaction of Overlap and Constraint [all *F*s < 1]. Consequently, this interaction was removed from the model and the model was tested again. Target words were processed faster with increasing cross-lingual overlap on all three reading time measures [FFD: $F(1,3311) = 5.44$, $p < .01$; GD: $F(1,3311) = 5.97$, $p < .01$; GPT: $F(1,3311) = 6.11$, $p < .01$]. As in the analyses on Word type and Overlap defined by Van Orden's (1987) measure, we observed significant effects of Constraint [all *p*s < .001] and Prior fixation distance [all *p*s < .001] on FFD, GD, and GPT. The effect of Frequency was significant for FFD and GD [*p*s < .05], but not for GPT [$p = .12$].

After removing the nonsignificant interaction of Overlap and Constraint from the skipping analysis, the results showed that target words were more likely to be skipped if they had higher degrees of orthographic and phonological overlap [$z = 3.53$, $p < .001$].

Furthermore, words in high-constraint sentences were skipped more often than in low-constraint sentences [$z = 3.65$, $p < .001$]. We observed significant effects of Prior fixation distance [ps < .001] and no significant effect of Frequency [$z = 1.66$, $p = .10$].

We tested contrasts to check if the effect of Overlap was significant in both low- and high-constraint sentences. In general, there were significant effects of Overlap in both low [FFD: $t = 1.62$, $p = .10$; GD: $t = 2.22$, $p < .05$; GPT: $t = 2.61$, $p < .05$] and high-constraint sentences [FFD: $t = 2.52$, $p < .05$; GD: $t = 2.57$, $p < .05$; GPT: $t = 2.17$, $p < .05$], although the effect of FFD in low-constraint sentences did not reach significance. Significantly more skipping was observed with increasing cross-lingual overlap in low [$z = 2.82$, $p < .01$] and high-constraint sentences [$z = 2.51$, $p < .05$].

Discussion

The present eye movement experiment clearly showed a cognate facilitation effect on both early *and* late eye movement measures for a set of cognates with varying degrees of cross-lingual overlap in highly semantically constraining sentences. Cognate effects were not modulated by sentence constraint and this was shown in three separate analyses, each using a different measure of cognate status. The first analysis tested the discrete effect of cognates versus controls (cf. the analyses in Libben & Titone, 2009; Schwartz & Kroll, 2006; Van Hell & De Groot, 2008). Reading times on FFD, GD, and GPT were faster for cognates than for controls, both in low- and high-constraint sentences. Also, cognates were skipped more often than controls, and this effect occurred in both low- and high-constraint sentences.[4]

The second analysis examined whether cognate facilitation is a continuous process, based on the degree of cross-lingual orthographic overlap. To this end, each cognate and control received an orthographic overlap score based on Van Orden's (1987) word similarity measure. Based on models that assume a similar representation for cognates and noncognates with varying degrees of orthographic, phonological and semantic overlap (e.g., Dijkstra & Van Heuven, 2002; Thomas & Van Heuven, 2005), we predicted faster reading times for words with higher degrees of cross-lingual overlap. The results showed that this was indeed the case: word reading was faster as cross-lingual overlap of the targets increased. This was true for FFD, GD, and GPT in both low- and high-constraint sentences. Skipping percentages were higher with increased cross-lingual overlap, but only in low-constraint sentences.

The third analysis tested the continuous effect of combined phonological and orthographic overlap based on ratings of each target and its translation equivalent. Although this continuous effect failed to reach significance on FFD in low-constraint sentences, it was significant on FFD in high-constraint sentences and on GD, GPT, and skipping, in both low- and high-constraint sentences.

To summarize, clear-cut cognate facilitation effects were observed in highly semantically constraining sentences using discrete and continuous measures of cognate status and this has important repercussions for the conceptualization of the influence of semantic constraint on lexical access in bilinguals. Specifically, the results indicate that there is only a very limited influence of semantic constraint on nonselective lexical activation, both during early and late stages of word processing because the semantic constraint imposed by a sentence did not nullify cross-lingual interaction effects on any eyetracking measure. Experiment 3 tested the same stimuli in a group of participants who had no knowledge of Dutch, and so should not be influenced by cognate status.

Experiment 3: Eyetracking English monolinguals

A monolingual control experiment was carried out to ensure that the observed cognate effects were indeed due to non-target language activation, and thus to the bilingual nature of the participants. Although we carefully controlled our stimulus materials, it cannot be completely excluded with absolute certainty that other factors inherent to the materials that were not taken into account may have influenced the results. For this reason, an eyetracking experiment was run with a group of English monolinguals who had no knowledge of Dutch. They saw the same low- and high-constraint cognate and noncognate sentences as the bilinguals. If the observed cognate facilitation in low- and high-constraint sentences is a result of cross-lingual interactions in the bilingual lexicon, this effect should disappear for participants without knowledge of Dutch.

Method

Participants. Twenty-four members of the University of Massachusetts community participated. All were native speakers of English and indicated that they did not have any knowledge of the Dutch language or any exposure to the Dutch language worth mentioning. The participants had normal or corrected-to-normal vision and were either paid or were given course credits to participate in the experiment.

Stimulus materials, Apparatus, and Procedure. The materials and procedure were identical to those used in Experiment 2, and the apparatus was comparable to that used in Experiment 2. Accuracy on the comprehension questions was 97%.

Results

We excluded 1.1% of the trials on the basis of the same criteria that were used in Experiment 2. Mixed-effects models were fit to the four dependent eye movement measures and the same variables were included. Analyses were run on the 32 cognate-noncognate pairs included in the analyses of the previous experiment. Participants and items were included as random effects for analyses on FFD, GD, and GPT and random slopes regarding the constraint factor for items in the analyses on skipping rate.[5] After calculation of the skipping percentages on the target word, we removed the trials in which the target was skipped (26.4% of the trials) from the analyses of FFD, GD, and GPT. We log-transformed the reading times on FFD, GD, and GPT to reduce the skewness of the distribution. We will first report the analyses on the discrete variable Word type (cognate vs. control). Then, we present the analyses on the continuous variable Overlap defined by Van Orden's (1987) measure. Finally, we report the analyses on Overlap defined by the combined orthographic and phonological ratings.

Word type (cognate vs. control). After removing the non-significant interaction of Word type and Constraint [all Fs < 1] from the model, results showed a main effect of

Constraint for FFD, GD, GPT [all *p*s < .001], and skipping percentages [*z* = 1.79, *p* = .07], just as in the bilingual experiment. Target words in high-constraint sentences (FFD *M* = 210; GD *M* = 224; GPT *M* = 260; skip *M* = 29.8) were read faster and were skipped more often than in low-constraint sentences (FFD *M* = 222; GD *M* = 240; GPT *M* = 294; skip *M* = 23.1). However, in these monolinguals, there was no main effect of Word type on FFD, GD, GPT [all *F*s < 1] and skipping [*z* < 1]. As in the bilinguals, there were non-linear effects of Prior fixation distance on all dependent measures [all *p*s < .001]. The effect of Frequency was not significant [6] [all *F*s < 2.50, all *p*s > .12; *z* = 1.18, *p* = .23]. Contrasts yielded no significant effect of Word type tested in low [all *t*s < 1; *z* < 1] and high-constraint sentences [all *t*s < 1; *z* < 1]. Means are presented in Table 5.

< Insert Table 5 about here >

Orthographic overlap (Van Orden). The nonsignificant interaction of Overlap and Constraint was removed from the model and the model was tested again. Results showed no main effect of Overlap on FFD, GD, GPT [all *F*s < 1], and skipping [*z* < 1] and no effect in both low [all *t*s < 1; *z* < 1] and high-constraint sentences [all *t*s < 1; *z* < 1]. As in the analyses on Word type, there were significant effects of Constraint [all *p*s < .001] and Prior fixation distance [all *p*s < .05]. The effect of Frequency was not significant [all *F*s < 2.50, *p*s > .12; *z* = 1.16, *p* = .25].

Orthographic and phonological overlap (ratings). After removing the nonsignificant interaction of Overlap and Constraint from the model, results showed no main effect of Overlap on FFD, GD, GPT [all *F*s < 1], and skipping [*z* < 1] and no effect in both low [all *t*s < 1; *z* < 1] and high-constraint sentences [all *t*s < 1; *z* < 1]. As in the bilingual experiment, there were significant effects of Constraint [all *p*s < .01] and Prior fixation distance [all *p*s < .05]. The effect of Frequency was not significant [all *F*s < 2.57, *p*s > .11; z =1.15, p = .25].

Discussion

Monolingual English readers with no knowledge of Dutch read the cognate and noncognate words equally fast, even though exactly the same materials were presented as in the previous experiment with bilinguals. Consistent with other studies, and similar to Experiment 2, there was a significant effect of constraint on all eye-movement measures. This demonstrates that the current control experiment had sufficient power to detect significant effects on each of these measures. More importantly, the absence of cognate facilitation in this monolingual group shows that the cognate effects in Experiment 2 indeed resulted from lexical activations in the Dutch language when bilinguals read English sentences.

General Discussion

In the present study, we examined how a strong semantic context modulates lexical activation spreading between languages in the bilingual lexicon. In Experiment 1, the cognate facilitation effect for words presented in isolation was replicated with a new set of stimuli. In Experiment 2, the set of cognates and noncognates with varying degrees of cross-linguistic overlap was presented in low- and high-constraint sentences while eye movements were monitored. As expected, we observed main effects of semantic constraint, demonstrating that our constraint manipulation was effective. More importantly, the results revealed clear cognate facilitation effects on early *and* late eyetracking measures in both low- and high-constraint sentences. These effects were shown in three different analyses on (a) the discrete effect of cognate status (cognate vs. control), (b) the continuous effect of orthographic overlap between translation equivalents (Van Orden, 1987), and (c) the continuous effect of orthographic and phonological overlap between translation equivalents (ratings). Cognates were read faster than controls in both low- and high-constraint sentences on FFD, GD, and GPT. Also, cognates were skipped more often than controls. The continuous analyses based on Van Orden's (1987) orthographic overlap measure showed that this cognate facilitation was a continuous and gradual effect: reading times were faster for words with more cross-lingual orthographic overlap on FFD, GD, and GPT, in both low- and high-constraint sentences. The continuous effect on skipping rates was significant in low-constraint sentences only. The other continuous analyses on the combined orthographic and phonological ratings yielded shorter reading times with increasing overlap on GD, GPT, and skipping rates, in both low- and high-constraint sentences. Results on FFD were only significant for high-constraint sentences, although there was a clear trend in the low-constraint sentences. In sum, the analyses convincingly show the existence of discrete and continuous cognate facilitation on several early (skipping, FFD, GD) and late reading time measures (GPT) in both low *and* highly semantically constraining sentences.

Our interpretation is corroborated by a control experiment with English monolinguals (Experiment 3) in which no cognate effects were observed for any reading time measure, even though this experiment again showed the same main effect of our sentence constraint manipulation. We therefore conclude that cognate facilitation in the bilinguals partaking in Experiment 2 is indeed due to their knowledge of Dutch and cannot be due to confounds in stimulus selection.

The pattern of results for high-constraint sentences provides important new insights regarding the influence of semantic constraint on nonselective lexical activation. Cognate facilitation was observed on early (skipping, FFD, and GD) *and* late (GPT) reading time measures, indicating that semantic constraint does not affect the co-activation of representations from both languages in the bilingual language system at any stage of word recognition. This contrasts with Libben and Titone (2009) who found cognate facilitation only in early comprehension measures. Based on this finding, they suggested that between-language effects occur during the initial processing stages, but also that dual-language activation is rapidly resolved by top-down factors (e.g., semantics) at later stages of comprehension. Instead, our results suggest that the influence of such factors on the language-selectivity of lexical access is rather limited. Note that the late effects in the high-constraint condition of the present study were obtained despite the fact that the present study also used non-identical cognates and more constraining sentences (i.e., cloze probabilities of .48 for cognates and .49 for controls in Libben and Titone, compared to .89 and .86 in the current study).

Importantly, because the study of Libben and Titone (2009) used a much weaker semantic constraint manipulation than the earlier studies of Schwartz and Kroll (2006) and Van Hell and De Groot (2008), the present cognate effects rule out the hypothesis that this difference across studies may explain why Libben and Titone *did* observe effects in more constraining sentences, whereas Schwartz and Kroll and Van Hell and De Groot dit not. Still, the fact that the present eyetracking results differ from these latter studies remains. For instance, Van Hell and De Groot (2008) obtained no cognate facilitation in a lexical decision task for targets that were primed by a high-constraint sentence context (e.g., *The best cabin of the ship belongs to the* ---; target *captain*). Similarly, Schwartz and Kroll (2006) presented sentences word by word using rapid serial visual presentation. They observed no cognate facilitation on target naming times in high-constraint sentences. To test whether the differences between the current study and these previous studies might be a result of the different methodology used, we conducted an additional experiment with 52 further subjects (manipulating constraint within participants), in which we presented the stimulus materials of Experiment 2 using the paradigm of Van Hell and De Groot. The results showed cognate facilitation in low- and high-constraint sentences, but the latter effect was weak, and only emerged after running many more participants than Van Hell and De Groot (20 per condition). So, although this new experiment hinted towards a cognate effect in the high-constraint condition (similar to the non-significant 17 ms effect in the Van Hell & De Groot paper), this paradigm did also not yield a very robust cognate effect in our lab. This illustrates the importance of using the more sensitive eyetracking technique, like the experiments reported in the paper.

As opposed to the results for high-constraint sentences, the pattern for low-constraint sentences is consistent with the few earlier studies on bilingual word processing discussed in the above. Schwartz and Kroll (2006) and Van Hell and De Groot (2008) found that the mere presence of a sentence context did not modulate cross-lingual interactions because cognate facilitation was observed in low-constraint sentences. In a more natural reading task without the need of an overt response (as in lexical decision or naming), Duyck et al. (2007) also reported cognate facilitation in low-constraint sentences for identical cognates (e.g., *ring* – *ring*), but not for non-identical cognates (e.g., *schip* –*ship*). This result highlights the importance of cross-lingual overlap. Similarly, Libben and Titone (2009) observed cognate facilitation in low-constraint sentences for identical cognates. The inclusion of a continuous measure of cross-lingual overlap in the current study extends these previous results of Duyck et al. (2007) and Libben and Titone (2009) by revealing that there is probably not a strict qualitative difference between cognate effects of identical and non-identical translation equivalent pairs. Instead, we show that cognate facilitation increases as a gradual and continuous function of cross-lingual overlap.

The present new findings of cognate effects in high-constraint sentences have a number of theoretical implications. First, the results show that a strong (high-constraint) semantic context does not affect selectivity of lexical access in the bilingual language system. It seems that the presentation of a semantic context effectively restricts conceptual information, as shown by the main effects of semantic constraint, but it does *not* restrict activation of lexical entries to the sentence. Instead, lexical representations from both languages are preactivated as fitting the semantic constraint imposed by the sentence. This indicates that the bilingual language system is profoundly nonselective both during early and late stages of word recognition, with a very limited influence of top-down semantic restrictions on lexical activations. Second, the gradual and continuous cognate effects we observed provide new insights in the representation of cognates. Some models propose a similar representation for cognates and noncognates, with varying degrees of orthographic, phonological, and semantic overlap (e.g., Dijkstra & Van Heuven, 2002; Thomas & Van Heuven, 2005; Van Hell & De Groot, 1998), while others assume qualitatively different representations for cognates and noncognates (e.g., De Groot & Nas, 1991; Sánchez-Casas & García-Albea, 2005). Finding continuous effects of cross-lingual overlap is more in line with the former group of models than with the latter, as there is no reason to expect graded effects of cognate status if cognates are assumed to have qualitatively different representations from noncognates. Also, finding graded effects of cognate status is important for further modeling of the bilingual lexicon. Within the logic of interactive activation models of visual word recognition (e.g., the BIA+ model of Dijkstra and Van Heuven, 2002), the cognate effect, originating from activation spreading between lexical representations, should indeed be a function of the degree of similarity (overlap) of lexical representations.

Finally, the results of the present study have important implications for the future development of models of bilingual language processing. We discuss this in the context of the BIA+ model (Dijkstra & Van Heuven, 2002). With regard to linguistic context effects, Dijkstra and Van Heuven propose that the word identification system is part of a much larger Language User system that also includes sentence parsing and language production. They suggest that linguistic context information may exert constraints on the degree of cross-lingual activation transfer. Indeed, the modulation of cognate effects in high-constraint sentences in previous studies (e.g., Schwartz & Kroll, 2006; Van Hell & De Groot, 2008) is typically explained by assuming that a high-constraint sentence activates a set of semantic (cf. Schwanenflugel & LaCount, 1988) and lexical restrictions and thereby reduces the number of lexical candidates (see also Altarriba et al., 1996). According to Libben and Titone (2009), such a top-down modulation of dual-language activation by semantic factors only occurs during later stages of word recognition, after initial non-selective lexical access, given that their high-constraint cognate effects only emerged in early, but no late, eyetracking measures. In contrast, the present results show that even a very strong semantic context does not necessarily eliminate cross-lingual activation effects, even not at later stages of word recognition. Therefore, the present findings constrain the importance of top-down influences of semantic activation on lexical access in future developments of the BIA+ model.

In conclusion, the present study on natural reading in semantically highly constraining sentences provides important insights in the bilingual language system. We obtained cognate facilitation effects in high-constraint sentences. Moreover, cognate facilitation was shown to be a continuous effect as larger degrees of cross-lingual overlap speeded up word recognition. The results offer strong evidence for a bilingual language system that is profoundly nonselective, and with a very limited role for top-down effects from semantic context to the nonselective activation of words.

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Appendix A

Dutch-English target words of Experiments 1, 2 and 3.

L2 cognate	**Overlap Van Orden (1987)**	**Orth overlap rating**	**Phon overlap rating**	**Fre-quency[a]**	**L2 noncognate**	**Overlap Van Orden (1987)**	**Orth overlap rating**	**Phon overlap rating**	**Fre-quency[a]**
book [boek]	0.72	5.16	6.52	2.62	face [gezicht]	0.06	1.00	1.14	2.79
bride [bruid]	0.60	4.37	4.38	1.11	scarf [sjaal]	0.34	2.11	1.67	1.11
captain [kapitein]	0.41	4.47	4.95	1.87	chicken [kip]	0.07	1.37	1.95	1.63
circle [cirkel]	0.61	4.89	5.57	1.90	church [kerk]	0.05	1.32	1.90	2.27
coffee [koffie]	0.48	3.89	6.62	1.97	bottle [fles]	0.18	1.00	1.00	2.11
dance [dans]	0.61	5.11	5.76	2.02	queen [koningin]	0.17	1.42	2.24	1.72
dream [droom]	0.62	5.11	4.76	2.09	cloud [wolk]	0.15	1.26	1.38	1.81
finger [vinger]	0.64	5.95	5.05	2.13	corner [hoek]	0.08	1.00	1.10	2.11
flag [vlag]	0.57	5.84	5.10	1.46	cage [kooi]	0.05	1.58	2.95	1.28
fruit [fruit]	1.00	7.00	5.14	1.85	knife [mes]	0.06	1.05	1.10	1.69
hair [haar]	0.67	5.00	4.71	2.32	size [maat]	0.20	1.00	1.00	2.11
hotel [hotel]	1.00	7.00	6.43	2.16	money [geld]	0.06	1.00	1.00	2.59
lip [lip]	1.00	7.00	7.00	1.92	law [wet]	0.09	1.37	1.10	2.33
model [model]	1.00	7.00	5.81	1.92	delay [vertraging]	0.05	1.05	1.10	1.65
nail [nagel]	0.67	3.16	3.14	1.49	tail [staart]	0.16	1.26	1.29	1.63
news [nieuws]	0.65	4.37	5.52	2.07	farm [boerderij]	0.03	1.00	1.00	1.99
nose [neus]	0.41	4.21	4.43	1.93	wife [vrouw]	0.06	1.74	1.67	2.41
pepper [peper]	0.94	5.68	4.67	1.08	shower [douche]	0.10	1.21	1.14	1.45
pilot [piloot]	0.89	5.68	5.29	1.43	habit [gewoonte]	0.04	1.05	1.19	1.81
police [politie]	0.72	4.68	4.14	2.34	secret [geheim]	0.07	1.58	1.00	2.05
ring [ring]	1.00	7.00	6.38	2.18	wing [vleugel]	0.04	1.11	1.10	1.80
school [school]	1.00	7.00	5.38	2.68	future [toekomst]	0.06	1.00	1.05	2.30
sheep [schaap]	0.51	4.42	4.29	1.62	witch [heks]	0.06	1.00	1.62	1.53
shoulder [schouder]	0.81	4.84	4.00	2.15	mountain [berg]	0.03	1.00	1.05	1.95
sock [sok]	0.77	5.47	6.29	1.30	duck [eend]	0.07	1.05	1.00	1.32
soup [soep]	0.72	5.05	6.38	1.32	frog [kikker]	0.05	1.00	1.05	0.95
sport [sport]	1.00	7.00	5.76	1.62	shark [haai]	0.19	1.37	1.14	1.32
station [station]	1.00	7.00	5.24	2.11	teacher [leraar]	0.30	1.28	1.10	2.17
storm [storm]	1.00	7.00	6.29	1.61	giant [reus]	0.04	1.05	1.00	1.67
student [student]	1.00	7.00	5.81	2.44	country [land]	0.05	1.00	1.00	2.75
thunder [donder]	0.51	3.21	3.95	1.23	witness [getuige]	0.08	1.00	1.00	1.70
tunnel [tunnel]	1.00	7.00	6.05	1.28	lawyer [advocaat]	0.05	1.00	1.05	1.72
MEAN	**0.77**	**5.55**	**5.34**	**1.85**	**MEAN**	**0.10**	**1.19**	**1.28**	**1.87**

Note. L1 (Dutch) translation equivalents are indicated in brackets. [a] Mean log frequency per million words, according to the CELEX lemma database (Baayen et al., 1993).

Appendix B

Sentence contexts of Experiments 2 and 3. Target words are printed in bold.

Cognate / low-constraint	Control / low-constraint
1. He went to the shop to buy a **book** that he needed for school.	1. She did not want to look at her **face** while she was crying.
2. The person who is standing near Eveline is the **bride** in her white dress.	2. A present your mother likes very much is a **scarf** made of wool.
3. Someone who can tell you more about it is the **captain** and he has a huge responsibility.	3. The animal responsible for the funny noise was a **chicken** and we all had to laugh.
4. Your drawing will look much better when you draw this little **circle** with a sharp pencil.	4. Everyone is very quiet when the guide tells about the **church** in the city centre.
5. He wants to stop for moment because he wants to buy a pack of this **coffee** in the shop.	5. He wants to stop for a moment because he wants to buy a special type of **bottle** in this shop.
6. Ann has seen a popular **dance** in Belgium.	6. That proud lady is the most famous **queen** in Europe.
7. Her daughter goes to that therapist because he can analyze every **dream** she had.	7. The drawing is not yet finished because he is still working on the **cloud** in the sky.
8. The doctor disinfected the wound on his **finger** with some disinfectant.	8. The old chair used to stand in the **corner** until Marc threw it out.
9. If Els wants to participate in the tournament, she has to bring the famous **flag** in her suitcase.	9. If Eveline wants to see those animals, she has to find the special **cage** they are in.
10. If you are able to go to the supermarket, you have to buy a lot of **fruit** for me.	10. If you want to clean his desk, you have to be careful for the **knife** he uses to open letters.
11. He spilled wine on her **hair** but he cleaned it up in a few seconds.	11. Fanny realized that she had chosen the wrong **size** but she couldn’t return the dress to the store anymore.
12. When they are in Brussels, they always pass by a beautiful **hotel** with an impressive pool.	12. When John entered the room, he saw some **money** lying on the floor.
13. Kate removed the blood on her swollen **lip** after the game.	13. Politicians of the new party are talking about a **law** for their country.
14. Her sister tried becoming a successful **model** in many different ways.	14. Her colleague has told her about the long **delay** at that administration.
15. Her mother asked Lisa to fix the broken **nail** on her left foot.	15. Her mother completed the carnival costume by adding a small **tail** to it.
16. My husband always tapes the **news** in the evening.	16. My friend did not pay much for this **farm** in the south of France.
17. My girlfriend hates her **nose** and wants	17. Our new friend talked to his **wife** and

to have it changed.	told her the whole story.
18. It would taste even better, if you added some extra tomatoes and **pepper** to the meal.	18. We could place the order, if you could decide on a **shower** for the bathroom.
19. The man sitting over there is a **pilot** and is admired a lot.	19. This visit has become a **habit** and is much appreciated.
20. If you like to have a job nearby, you can join the **police** in our village.	20. If you see your boss next week, you have to tell him about the **secret** very carefully.
21. Olivia’s mother surprised her with a beautiful **ring** from the jeweler.	21. The new vet cannot take care of the wounded **wing** on the bird’s left side.
22. If Michael wants to know more about this topic, he has to go to **school** this weekend.	22. If you meet this man next week, you will be able to talk about the **future** of the company.
23. The animal she sees standing in the sand is a **sheep** living on that farm.	23. The girl standing in front of the class painted a **witch** on this canvas.
24. She wanted to help the victim of the crash and disinfected the wound on his **shoulder** very carefully.	24. The painter wanted to work at his own pace and painted the view on the **mountain** very precise.
25. After the crime, they looked for a hat and a **sock** to identify the poor victim.	25. When Gary was young, he kept a rabbit and a **duck** in his room.
26. A hot dish which mother likes is **soup** or consommé.	26. A small animal that lives in a garden is a **frog** or a toad.
27. Kelly has never seen that type of **sport** in Canada.	27. The group was surprised by a large **shark** in the sea.
28. My friend sometimes arrives too late at the **station** in Brussels.	28. The new group always sings a song for the **teacher** on an excursion.
29. The friendly boy and his girlfriend are telling about the **storm** of last year.	29. The boy who is standing over there is called the **giant** of his class.
30. The man who you just met was a **student** at that university.	30. Ben visited the beautiful **country** which attracts many tourists.
31. When she was standing outside, she could see the house and hear the **thunder** in the air.	31. If Maria arrives on time, we will contact the **witness** and bring him here.
32. The girl carrying the heavy bags approached the **tunnel** and was scared to go in it.	32. The woman who lives near you just contacted a **lawyer** and told him the whole story.

Cognate / high-constraint	Control / high-constraint
1. He went to the library to get a **book** that he needed for school.	1. She could tell from the look on his **face** that he was very mad.
2. The person who wears a white dress on her wedding day is usually the **bride** and nobody else.	2. Something to wear around your neck to keep warm is a **scarf** made of wool.
3. The person who is on charge on a ship is the **captain** and he has a huge responsibility.	3. The animal that lays eggs for our consumption is a **chicken** and it usually lives on a farm.
4. You can tell it is a full moon when its shape forms a perfect **circle** without any imperfections.	4. Everyone has to be quiet when the priest says prayers in his **church** at the altar.
5. He is not quite awake yet because he still needs to drink a cup of black **coffee** this morning.	5. He does not want a glass because he wants to drink out of the **bottle** this evening.
6. Salsa has become a popular **dance** in Belgium.	6. Elizabeth II of Great-Britain is the most famous **queen** in Europe.
7. Her daughter woke up screaming because she had a bad **dream** that night.	7. The sun is no longer shining because it disappeared behind a big **cloud** in the sky.
8. The happy bride put the ring on the **finger** of her husband.	8. The naughty child has to stand in the **corner** of the living room.
9. If Justine Henin wins in the Olympics, she gets to carry the Belgian **flag** around the stadium.	9. If Eveline wants to free the canary birds, she has to open the iron **cage** they are in.
10. If you want to stay in good health, you have to eat 5 pieces of **fruit** every day.	10. If you want to cut your meat, you have to take a **knife** from the drawer.
11. The exotic dancer wears a rose in her blonde **hair** but she will remove it later.	11. Fanny asks for the blue shoes in a larger **size** but the store no longer has them.
12. When they are on a holiday, they always sleep in a luxurious **hotel** with a beautiful pool.	12. When they win the lottery, the will have plenty of **money** for buying a house.
13. Kate stuck a moustache on her upper **lip** for Halloween.	13. Breaking and entering into a house is against the **law** in every country.
14. Naomi Campbell is a very famous **model** all over the world.	14. The train has been announced with a 5 minutes **delay** in the station.
15. She goes to the manicurist to fix the broken **nail** on her left hand.	15. The cow chases insects away by moving her long **tail** from left to right.
16. My husband always watches the seven o'clock **news** in the evening.	16. My uncle has more than a hundred cows on his organic **farm** in the south of France.
17. Every person smells with his **nose** and listens with his ears.	17. The unfaithful man cheated on his **wife** and had absolutely no regrets.
18. It would taste even better, if you added some extra salt and **pepper** to the meal.	18. It would be a lot easier, if you choose between a bath and a **shower** right now.
19. Someone who flies a plane is called a **pilot** and is admired a lot.	19. Something you do regularly is a **habit** and everyone has them.

20. If you see a robbery in the street, you have to call the **police** on this number.	20. If someone tells you confidential information, you have to keep this a **secret** very carefully.
21. Olivia's boyfriend proposed to her with an expensive **ring** from the jeweler.	21. The poor bird cannot fly away with its broken **wing** on its left side.
22. If a child wants to learn how to read and write, it has to go to **school** every day of the week.	22. If you dream about events that will happen, you are able to look into the **future** of your life.
23. The animal that is shaved for its wool is a **sheep** living on a farm.	23. A woman flying on a broom at night is a **witch** to most people.
24. He wanted to attract the attention of the blind man and tapped gently on the man's left **shoulder** with his finger.	24. The alpinist wanted to climb at his own pace and reached the top of the **mountain** around noon.
25. On each foot, we usually wear a shoe and a **sock** to keep our feet warm.	25. When Gary was young, he always confused a goose and a **duck** when naming animals.
26. A hot first course that is eaten with a spoon is **soup** or consommé.	26. A green animal that jumps around in a pond is a **frog** or a toad.
27. Volleyball has always been the favorite **sport** of Sandra and her sister.	27. The surfers were attacked by a dangerous **shark** in the sea.
28. That train always arrives on time at the **station** in Brussels.	28. All the children walk in line behind the **teacher** on excursions.
29. A weather condition with lots of wind and rain is called a **storm** in our language.	29. A person who is extremely tall is called a **giant** in our language.
30. A person enrolled in university is a **student** of that university.	30. France is a beautiful **country** that attracts many tourists.
31. When is storms outside, you can see the lightning and hear the **thunder** in the air.	31. When you see a crime happening, you are a **witness** and you can provide information.
32. An underground passageway for car traffic is called a **tunnel** and can be very long.	32. The person who defends you in court is called a **lawyer** and has to be tough.

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Footnotes

1. Van Orden (1987, p. 196) defines graphemic similarity (GS) between two letter strings as GS = 10([50F + 30V + 10C)/A] + 5T + 27B + 18E) with F = number of pairs of adjacent letters in the same order, shared by pairs, V = number of pairs of adjacent letters in reverse order, shared by pairs, C = number of single letters shared by word pairs, A = average number of letters in the two words, T = ratio of number of letters in the shorter word to the number of letters in the longer, B = if first two letters are the same B = 1 else B = 0, E = if last two letters are the same E = 1 else E = 0. Then, Van Orden calculates Orthographic Similarity by determining the ratio between the GS of word 1 with itself and the GS of word 1 and word 2. For more details concerning this measure, we refer to Van Orden (1987).

2. As the two continuous measures of cross-lingual overlap are strongly correlated, we only presented the graphs on Van Orden's orthographic overlap here and in the subsequent analyses.

3. Model comparisons showed that including random slopes regarding the factor Constraint for items significantly improved the fit of the models for FFD (χ^2s > 22.77, *p*s < .001), GD (χ^2s > 20.45, *p*s < .001), and GPT (χ^2s > 35.45, *p*s < .001), but not for skipping (χ^2s < 1) in the discrete and continuous analyses.

4. Traditional repeated measures analyses of variance (ANOVAs) on the discrete manipulation of cognate status (cognate vs. control) showed similar results. The results of these analyses can be consulted at

http://users.ugent.be/~wduyck/articles/vanassche-etal-anovas-exp2.pdf

5. Model comparisons showed that the estimated variance-covariance for the factor 'items' in the analyses on FFD, GD, and GPT was singular. Therefore, random slopes regarding the factor Constraint were not included in these analyses. Including random slopes regarding the factor Constraint for items did improve the fit of the model for skipping rates in the discrete and continuous analyses (χ^2s > 7.26, *p*s < .05).

6. In contrast to Experiment 2, there was no frequency effect. Although this may appear surprising, it is important to note that the present study tested only a very limited range of frequency (see Appendix A). It is likely that this range was insufficient to yield a L1 frequency effect in monolinguals, but sufficient to create such a L2 frequency effect in bilinguals. Indeed a recent lexical decision study by Duyck, Desmet, Vanderelst, and Hartsuiker (2008), also using Dutch-English bilinguals and a monolingual American control group, showed that the word frequency effect is about twice as large when reading in a second language compared to when reading in the native language (for similar results, see Gollan, Montoya, Cera, & Sandoval, 2008).

Table 1. Self-assessed ratings (seven-point Likert scale) of L1 and L2 proficiency in Experiments 1 and 2.

Language	Skill	Experiment 1	Experiment 2
L1 (Dutch)	Writing	6.0 (1.0)	6.3 (0.6)
	Speaking	6.4 (0.6)	6.2 (0.8)
	Reading	6.3 (0.6)	6.5 (0.6)
	General Proficiency	6.3 (0.7)	6.2 (0.6)
L2 (English)	Writing	5.0 (1.1)	5.0 (0.6)
	Speaking	5.2 (1.0)	5.2 (0.8)
	Reading	5.6 (0.7)	5.7 (0.8)
	General Proficiency	5.3 (0.9)	5.3 (0.7)

Note. Standard deviations are displayed in parentheses.

Table 2. Mean lexical characteristics of the 32 target words.

Word type	Number of letters	Number of syllables	Word frequency[a]	Neighborhood size[b]	Bigram frequency[c]
Cognates	5.22 (1.18)	1.43 (0.50)	1.85 (0.43)	4.41 (4.35)	9044.28 (5436.89)
Controls	5.22 (1.18)	1.43 (0.50)	1.87 (0.45)	4.69 (5.09)	8588.69 (4972.54)
p	identical	identical	> .76	> .36	>.12

Note. Standard deviations are indicated in parentheses. Reported *p*-values indicate significance levels of dependent samples t-tests between cognates and controls.

[a] Mean log frequency per million words, according to the CELEX lemma database (Baayen, Piepenbrock, & van Rijn, 1993).

[b]Neighborhood size (Coltheart et al., 1977) calculated using the WordGen program (Duyck et al., 2004) on the basis of the CELEX lexical database (Baayen et al., 1993).

[c] Mean summated bigram frequency (calculated using WordGen, Duyck et al., 2004)

Table 3. Cloze probabilities for cognates and controls presented in low- and high-constraint sentences.

	Sentence constraint	
Word type	Low	High
Cognate	.05 (.09)	.89 (.09)
Control	.04 (.08)	.86 (.09)

Note. Standard deviations are indicated in parentheses.

Table 4. First fixation duration (FFD), Gaze duration (GD), Go-past time (GPT) and skipping percentages on the target word in Experiment 2.

Constraint	Word type	FFD	GD	GPT	Skipping
Low	Cognate	230 (72)	263 (109)	298 (162)	16.3 (36.9)
	Control	239 (82)	275 (115)	321 (188)	12.5 (33.1)
Effect		*9*	*12*	*23*	*-3.8*
High	Cognate	219 (70)	240 (96)	270 (143)	19.2 (39.4)
	Control	228 (72)	253 (101)	287 (157)	16.4 (37.1)
Effect		*9*	*13*	*17*	*-2.8*

Note. Standard deviations are indicated in parentheses.

Table 5. First fixation duration (FFD), Gaze duration (GD), Go-past time (GPT) and skipping percentages on the target word in Experiment 3.

Constraint	Word type	FFD	GD	GPT	Skipping
Low	Cognate	224 (71)	242 (96)	303 (196)	23.7 (42.6)
	Control	221 (64)	238 (93)	286 (158)	23.7 (42.6)
Effect		*-3*	*-4*	*-17*	*0*
High	Cognate	210 (62)	223 (81)	263 (172)	28.5 (45.2)
	Control	210 (55)	226 (71)	257 (170)	30.3 (46.0)
Effect		*0*	*3*	*-6*	*1.8*

Note. Standard deviations are indicated in parentheses.