UNIVERSITEIT GENT

FACULTEIT PSYCHOLOGIE EN PEDAGOGISCHE WETENSCHAPPEN

Language representation and processes in bilingual memory

Sofie Schoonbaert

Promotor: Prof. Dr. Robert J. Hartsuiker

Proefschrift ingediend tot het behalen van de academische graad
van Doctor in de Psychologische Wetenschappen

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-- to my grandmother for fighting to stay. I would like to dedicate this modest contribution to science to her.

Ghent, April 6th 2008

CHAPTER 1
FACTS AND FINDINGS ON BILINGUALISM

Hello,

Hallo,

Haai,

Hola,

Ahoj,

Bonjour,

Bună,

Szia,

Salve,

Powitanie,

Здравствуй,

こんにちは,

ביי,

안녕하세요

Many of you will have recognized more than one of these expressions to greet one another. This illustrates **Fact #1: Bilingualism is a very widespread phenomenon**. More than half of the world's population is considered to have a least some notion of a language that is different from the native language (Grosjean, 1982).

When studying these multilingual greetings, it is clear that some languages appear to be more closely related than others. This clearly shows **Fact #2: Languages vary.** They not only vary lexically (different words to express one meaning, e.g., *Hello* and *Bonjour*), but can also vary semantically (meanings in one language that are hard to express in other languages; e.g., the English word *serendipity*: the accidental discovery of something fortunate, especially when looking for something intirely different, or so-called false friends, e.g. the English word *room*, meaning *cream* in Dutch), as well as syntactically (not all structures are legal in all languages, e.g. the passive structure *De kerk is door de bliksem getroffen* [*The church is by the lightning hit*] is illegal in English).

Most of you probably understood two of the above greetings, while some have understood more than two. This brings up **Fact #3: The bilinguals themselves vary.** Bilinguals differ in the number of languages they use, in how proficient they are, in their age of acquisition, and in how frequently they use each language; they also differ in native language, and in what language setting they live in (e.g., natives vs. immigrants).

Unfortunately, research on bilingualism (and on the human mind in general) seldomly leads to waterproof facts. Instead, it can lead to challenging theories. What follows in this dissertation are data and interpretations on how certain types of bilinguals mentally organize their languages, and how these languages interact. We will be speaking in terms of evidence *in favor of (or against) bilingual theories*, rather than in terms of *facts.*

In the last decade, the study of bilingualism has been a hot topic in psycholinguistics. It has become clear, as Grosjean already warned in a 1989-paper, that '*the bilingual is not just two monolinguals in one person*'. This realisation has intruiged many researchers into exploring how to adjust models of language processing, which were at that time mostly monolingual. In this introduction, bilingual theories based on a wide range of relatively recent studies will be presented, and it is with respect to these theories and previous findings on bilingualism, that we developed our research questions. Different models of bilingualism make different assumptions regarding these questions. Testing the hypotheses of these models with be the leitmotiv throughout this dissertation. This introduction will take off at the word level, discussing both lexical and semantic representations in bilinguals, and will eventually evolve to the sentence level, discussing syntactic representations in bilinguals.

LEXICO-SEMANTIC REPRESENTATIONS ACROSS LANGUAGES

Bilingual Word Processing Theories.

Traditionally, experimental research on bilingualism has focussed on how both languages of a bilingual are represented in memory at a lexical level (i.e., their word forms in a lexicon) and at a semantic level (i.e., their meanings in a conceptual system). With regards to this, reseachers have debated whether bilinguals have two separate memory systems, or whether they share one common system (Snodgrass, 1984).

One of the most influencial models on bilingualism is the Revised Hierarchical model [RHM] of Kroll and Stewart (1994). Figure 1 presents how, according to this model, bilinguals represent both of their languages, the first, native language being labelled as L1, and the second language labelled as L2. It assumes two separate lexicons (the upper boxes), and one shared conceptual system (the lower box). Note that the L2 lexicon is smaller than the L1 lexicon, reflecting the smaller L2 vocabulary (even for fairly proficient bilinguals).

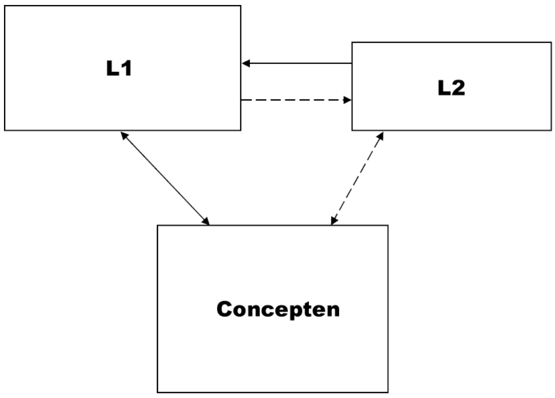

Figure 1. Kroll & Stewart's (1994) revised hierarchical model of lexical and conceptual representation in bilingual memory.

Not only does the RHM provide a theory about the basic architecture of bilingual memory, it also makes assumptions regarding the interactions between its constituents (both lexicons and their shared conceptual system). Although the model proposes separate lexicons for L1 and L2, both lexicons are interconnected and can therefore interact. More specifically, Kroll and Stewart assumed asymmetric connections between both lexicons. The connection from L2 to L1 is stronger than vice versa, reflecting the way a second language is traditionally learned at school, i.e. through word-word associations without neccesarily accessing semantics. This is supported by (overt) translation studies, showing that bilinguals translate faster from L2 to L1 than vice versa (e.g., Kroll & Curley, 1988), because according to the RHM translation occurs via strong direct lexical links. The model also assumes that while L1 lexical representations can benefit from strong connections from and to the conceptual system, this so called lexico-semantic mapping is much weaker in L2. This is again supported by production studies, namely picture naming studies showing faster naming latencies of pictures (concepts) in L1 than in L2 (e.g., Potter, So, Von Eckardt, & Feldman, 1984). To account for proficiency differences across bilinguals, the RHM included the following developmental hypothesis: 'As a bilingual becomes more proficient in L2, the lexico-semantic mapping for L2 will slowly become stronger'. Although there is quite some evidence in favor of this model (see Kroll & de Groot, 1997; Kroll & Tokowicz, 2005), more recent studies indicate that the lexico-semantic mappings from L2 might be stronger than traditionally assumed, even at early stages of L2 proficiency (e.g., Altaribba & Mathis, 1997; Duyck & Brysbaert, 2004; Duyck & Warlop, 2008). It is generally accepted though that both languages map onto the same conceptual system.

A second model of bilingual word processing is the Distributed Representation Model [DRM], proposed by de Groot and colleagues (de Groot, 1992a-b; de Groot, 1993; de Groot, Dannenburg, & Van Hell, 1994; Van Hell & de Groot, 1998a-b). This model, presented in Figure 2, assumes that L1 and L2 are represented in a shared conceptual system (like the RHM) and a shared lexicon (unlike the RHM), and where the degree of overlap between L1 and L2 representations is dependent on word type. So, while the RHM assumes rather qualitatively different representations across languages, the DRM assumes more quantitatively different representations for L1 and L2. According to this model, translation times depend on the number of semantic features shared by the L1 and L2 words: When two words share many semantic features, translation is easier than when they only share a few semantic features. This is the reason why concrete words (which have many overlapping features in L1 and L2) are translated faster than abstract words (which more often have meanings and senses that are not shared in the other language). Figure 2 displays the major assumption of the model: Concrete words (e.g., *skirt*) activate very much the same conceptual nodes in L1 as in L2, whereas abstract words (e.g., *revenge*) have more diffuse meanings across languages (see two upper panels, for an example in Dutch-English bilinguals). In addition to a shared meaning, words can also share their form (i.e., so-called cognates: *appel – apple*; see lower panel). These words will not only show a large overlap in their form-related lexical representations, but also in their conceptual representations.

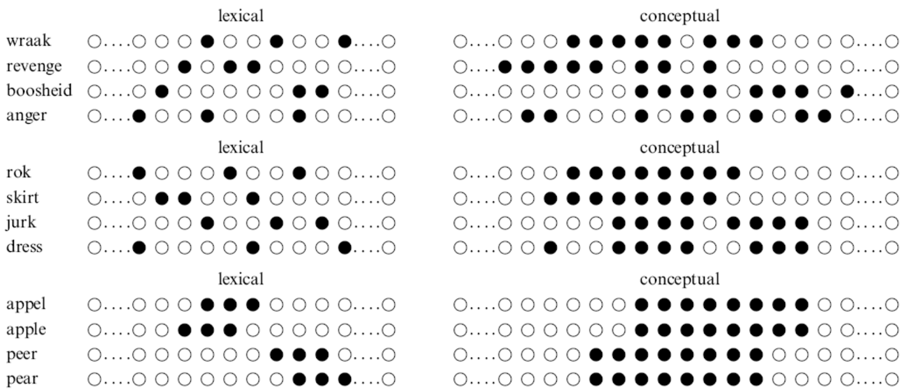

Figure 2. Van Hell & de Groot's (1998) distributed representation model.

The DRM has been very successful at predicting translation times of words. For example, de Groot (1992a) and de Groot et al. (1994) showed that concrete word are translated faster than abstract words (both from L1 to L2 and vice versa). Similarly, Van Hell and de Groot (1998a) reported faster response times in a word association task (both within and across languages) with concrete words than with abstract words. The model is also supported by the significant correlation that has been found between ratings of semantic similarity of translation pairs and the concreteness ratings of those words (Tokowicz, Kroll, de Groot, & Van Hell, 2002). Furthermore, basic concreteness effects have been repeatedly observed in monolingual studies as well, where concrete words are typically processed faster and more accurately than abstract words (Bleasdale, 1987; Kroll & Merves, 1986; Paivio, 1971; Shibahara, Zorzi, Hill, Wydell, & Butterworth, 2003; Tyler, Moss, Galpin, & Voice, 2002; Van Hell & Candia Mahn, 1997).

Cross-language priming as a tool to investigate word representations in bilingual memory.

A very useful and popular research method to investigate effects across languages is the masked priming method. Priming occurs when a given target word (e.g., *boy*) is processed faster when briefly preceded by that same word (*boy*) or even a semantic or associative related prime word (e.g., *girl*) than when preceded by an unrelated prime word (e.g., *tree*). The first paradigm is referred to as repetition or identity priming, while the latter is referred to as semantic or associative priming. A pioneer study in this respect is that of Meyer & Schvaneveldt (1971), although at that time primes were presented at very long stimulus onset asynchronies (SOAs). Many studies showing repetition and semantic priming in the monolingual reseach tradition were performed following the study of these pioniers (e.g., Chen & Ng, 1989; Bleasdale, 1987; Keatley, Spinks & De Gelder, 1994; Neely, Keefe, & Ross, 1989; Schwanenflugel & Rey, 1986; see Hutchison, 2003, and Lucas, 2000, for reviews).

However, most recent priming studies investigating automatic word processing have now adopted the masked priming procedure (see Forster & Davis, 1984), where primes are usually presented very briefly to prevent participants from adopting strategies while responding to target words in a priming experiment (Neely, Keefe, & Ross, 1989). As will appear from this introduction, there are many other variants to the classic priming paradigm, including some bilingual variations. In the present doctoral dissertation, priming across languages is our primary research tool.

In *Chapter 2*, we will employ the bilingual variants of masked repetition priming and semantic priming, namely translation priming and cross-language semantic priming. Our goal is to gather further evidence to distinguish between models assuming qualitatively different L1 and L2 representations (e.g., RHM; regarding the translation asymmetry reflecting the strength of lexico-semantic mappings for L2) versus models assuming quantitatively differences representations (e.g., DRM; regarding the degree of semantic overlap between L1 and L2 representations in bilingual memory, possibly as a function of word concreteness). We will test a population of unbalanced Dutch-English bilinguals in a lexical decision task. Previous masked priming studies have shown that there is a translation priming asymmetry in lexical decision times of bilinguals, i.e. bilinguals consistently respond faster to L2 targets (e.g., *GIRL*) when these are preceded by their L1 translation (*meisje* [girl], for a Dutch-English bilingual) then when preceded by an unrelated L1 word prime (e.g. *boom* [tree]), while the reverse translation priming effect is not as consistent and is either weaker or not found (e.g., Grainger & Frenck-Mestre, 1998; Gollan, Forster, & Frost, 1997; Jiang, 1999; Jiang & Forster, 2001; for an overview, see *Chapter 2*). The finding that L1 primes can speed up processing in L2 but not (or weaker) vice versa has been in favor of the RHM's assumption of weak lexico-semantic connections for L2. However, the mixed data pattern with regards to this critical L2 to L1 priming condition, may reflect differences between studies, such as the concreteness of the used stimuli. Most studies did not control their stimuli for concreteness. Therefore, it seems appropriate to test the assumption of the DRM by manipulating the semantic word variable Concreteness in a set of masked priming experiments.

First, we will investigate translation priming from L1 to L2, as well as from L2 to L1 for both abstract and concrete pairs. Second, semantic cross-language priming will be tested in both priming directions (e.g. *jongen* [boy] - *GIRL* vs. *boy* - *MEISJE* [girl]), and for both abstract and concrete pairs (*jongen* [boy] - *GIRL* vs. *leugen* [lie] - *TRUTH*). Although a cross-language semantic related word shares less semantic features with the target than its translation, finding priming in this paradigm is a more solid test for semantic activation across languages, especially in the L2 to L1 priming condition.

Based on a quantitative model of bilingual word representations (like the DRM), we would predict that the strength of the priming effect would be dependent on the amount of semantic features activated by the prime and shared by the target. Activation would then spread most for translation primes as opposed to semantically related cross-language primes, from L1 to L2 as opposed to the reverse priming direction, without necessarily excluding the possibility of L2 to L1 priming, and possibly from concrete word pairs as opposed to abstract word pairs.

In *Chapter 3*, we will use more sensitive electrophysiological measures to study our previous research questions more thoroughly in four translation priming experiments tested with unbalanced English-French bilinguals. These measures are the so-called Event Related Potentials (ERPs). They represent the electrical activity of the brain (measurable at the scalp) related to the processing of a particular stimulus category. Peaks in the ERP signal provide information about different perceptual and cognitive processes. None of the published ERP studies to date investigated masked translation priming in lexical decision (cf. *Chapter 2*). Nonetheless, some recent electrophysiological studies have proposed a range of ERP components that are picked up in language repetition priming paradigms in monolinguals (Grainger, Kiyonaga, & Holcomb, 2006; Holcomb & Grainger, 2006, 2007). One of these components could be particularly interesting for our study of semantic representations across languages. This component is the N400, which is a negative-going component that peaks between 400 and 600 ms after target onset and is typically larger at middle and posterior brain regions. Masked priming causes this component to be reduced (less negative) for targets preceded by repeated items, as opposed to targets preceded by unrelated items. Finding this N400 modulation in masked priming from L2 to L1, would clearly indicate the use lexico-semantic mappings from L2 to L1, because the semantic representation of the target is then pre-activated by its L2 translation prime. Therefore, *Chapter 3* reports four experiments investigating masked translation priming from L1 to L2 (Experiment 1a and 2a), and from L2 to L1 (Experiments 1b and 2b), while gathering both behavioral measures from a lexical decision task and electrophysiological recordings.

To date, there is one ERP-study investigating cross-language translation priming, (Alvarez, Grainger, & Holcomb, 2003). This study observed a modulation of the N400 as a result of priming both from L1 to L2 and from L2 to L1, but it also showed a surprising reversed translation priming asymmetry: Priming was stronger from L2 to L1 than vice versa. However, due to the very long SOA of 2700 ms and the fact that primes were unmasked in this study, strategic rather than automatic effects could not be excluded (Neely, Keefe, & Ross, 1989). In the experiments of *Chapter 3*, we will use much shorter SOAs (120ms, Experiment 1a-b; 200 ms, Experiment 2a-b). The four studies presented in *Chapter 3* were also aimed at examining whether the difference between abstract and concrete words would modulate N400-priming effects (following predictions of the DRM). An N400-concreteness effect entails that ERPs to concrete words elicit a more negative polarity waveform than the ERPs to abstract words,and has an atypical N400-distribution: the effect is seen only at anterior scalp sites (Holcomb, Kounios, Anderson, & West, 1999; Kounios & Holcomb, 1992, 1994; West & Holcomb, 2000).

So far, we have only considered the question of how a bilingual's languages are represented at word and meaning levels. Of course, being a bilingual is more than just understanding and producing words in another language: it also entails having knowledge of the second language's syntax and being able to construct sentences using the appropriate syntactic rules. The next paragraph will discuss recent research starting to focus on the syntactical aspect of being a bilingual.

LEXICO-SYNTACTIC REPRESENTATIONS ACROSS LANGUAGES

It is only recently that researchers began to wonder whether syntactic representations can be shared across languages as well. In this respect, we mention the model of Hartsuiker, Pickering, and Veltkamp (2004), as the first bilingual model to take into account the representation of syntax across languages. The model is an extension to bilingualism of the lexicalist model of Pickering and Branigan (1998) that accounts for syntactic priming in monolinguals, as the tendency to repeat a recently encountered syntactic structure. Bock (1986) was the first to demonstrate that syntactic structures such as actives vs. passives (e.g., *The building manager was mugged by a gang of teenagers* vs. *A gang of teenagers was mugged the building manager*), and prepositional object (PO) vs. double object (DO) dative constructions (e.g., *The governess made a pot of tea for the princess* vs. *The governess made the princess a pot of tea*) can be primed in English. For instance, she showed that participants, after reading a passive sentence, were more likely to describe a picture with a passive sentence structure than with an active sentence structure. In the two decades since this study, syntactic priming has been widely adopted as a very useful research method to investigate syntactic representations. Countless studies have shown that the effect generalizes to many different situations (different tasks, structures, and populations; e.g., Branigan, Pickering, Stewart, & Mclean, 2000; Brooks & Tomasello, 1999; Ferreira, 2003; Hartsuiker & Kolk, 1998a-b; Hartsuiker, Kolk, & Huiskamp, 1999; Hartsuiker & Westenberg, 2000; Huttenlocher, Vasileyva, & Shimpi, 2004; Pcikering & Branigan, 1998; Potter & Lombardi, 1998; Saffran & Martin, 1997; Scheepers, 2003).

Syntactic priming is also observed in language comprehension, in language production and more importantly between comprehension and production (i.e., in dialogue; Branigan, Pickering, & Cleland, 2000).

Pickering and Branigan (1998) developed a lexicalist model to account for syntactic priming effects in monolinguals, which is largely based on the lexical production model of Levelt, Roelofs and Meyer (1999). In the model, priming results from residual activation of syntactic representations, which are connected to the lexical representations of nouns and verbs (more specifically, to their lemmas). They introduce *combinatorial nodes* which specify the kinds of grammatical construction in which a lemma can be used (e.g., different nodes for the passive construction and the active construction). It is assumed that connections between lemma nodes and the combinatorial nodes are strengthened whenever a lemma is used with a that particular syntactic structure. As a consequence, this model also predicts a so-called *lexical boost* to syntactic priming when the same verb or noun is repeated between prime and target, a finding that was reported in several studies (Branigan et al., 2000; Cleland & Pickering, 2003; Corley & Scheepers, 2002; Hartsuiker et al., 2008; Pickering & Branigan, 1998).

The lexical-syntactic model of Hartsuiker et al. (2004) is supported by the observation that syntactic structures can also be primed across languages, provided that similar structures exist between two given languages. Hartsuiker et al. (2004) found syntactic priming for Spanish-English bilinguals, in dialogue. In this study, a bilingual variant of the paradigm introduced by Branigan et al. (2000) was used, in which a naïve participant and a confederate alternately described pictures to each other. When the confederate produced a Spanish (L1) active sentence, the naïve bilingual tended to respond more frequently with an English (L2) active as opposed to an English passive. This suggested that some syntactic representations can be shared between languages, as is shown in the model in Figure 3 for active and passive structures across Spanish and English (Hartsuiker et al., 2004).

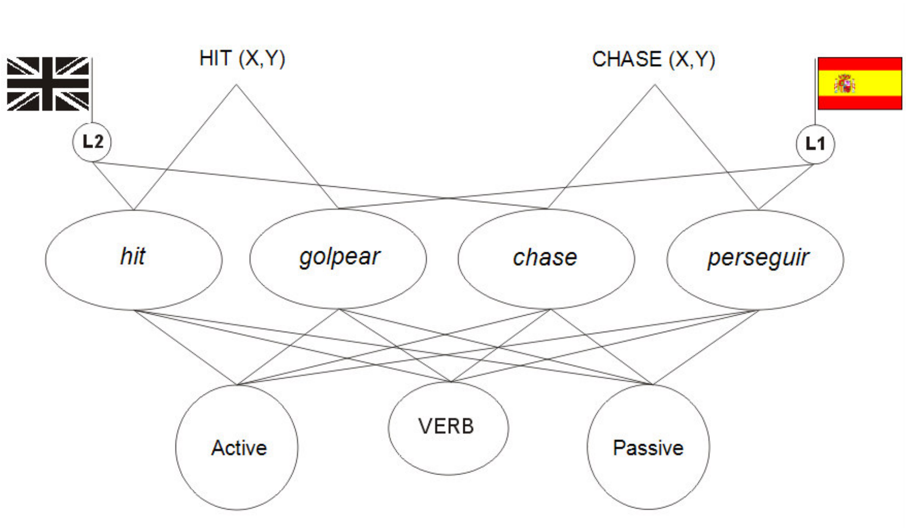

Figure 3. Hartsuiker et al.'s (2004) lexical-syntactic model of bilingual sentence production

Cross-language syntactic priming as a tool to investigate syntactic representations in bilingual memory

Although Hartsuiker et al. (2004) were not the only ones to investigate syntactic representations across languages, still only few studies have focused on syntactic processes in bilinguals. Interestingly, all these studies have employed the syntactic priming paradigm (e.g., Desmet & Declercq, 2006; Hartsuiker et al., 2004; Loebell & Bock, 2003; Meijer & Fox Tree, 2003; for a review, see Hartsuiker & Pickering, in press). However, it remains to be seen whether robust syntactic priming occurs within a second language and from a second language to a first. Previous studies also did not investigate whether syntactic priming between two sentence structures of different languages can be enhanced by a cross-language verb repetition between prime and target sentences (e.g. geven

[give] – GIVE; cf. the lexical boost in monolingual studies), a prediction that directly follows from the model of Hartsuiker et al. (2004).

Chapter 4 presents a series of four experiments investigating syntactic priming of dative structures in unbalanced Dutch-English bilinguals. Given that the DO and PO dative structure occurs in both Dutch and English (e.g., *De kok geeft een hoed aan de zwemmer* vs. *De kok geeft de zwemmer een hoed* (L1)*; The chef gives a hat to the swimmer* vs. *The chef gives the swimmer a hat* (L2)), the representation of this structures might as well be shared across languages. Four priming directions will be tested. Experiment 1 will test whether the robust syntactic priming effect for monolinguals can be replicated in English as a second language (L2 to L2); Experiment 2 will then investigate whether syntactic priming between languages, from L1 to L2. Futhermore, Experiment 3 will try to replicate the robust syntactic priming effects within Dutch (L1 to L1), to then compare these effects with syntactic priming effect from L2 to L1, as investigated in Experiment 4. Additionally, we will test whether a cross-language repetition of verbs between prime and target (e.g*., geven*[give] – *GIVE* from L1 to L2, and *give* – *GEVEN* [GIVE] from L2 to L1) can cause a boost to syntactic priming, how it relates to the lexical boost (Experiment 1 and 3), and if this boost is equally large when priming from L1 to L2 than vice versa (Experiment 2 vs. 4). We believe that these experiments will contribute to the question regarding 'shared or separate syntactic representations' for bilinguals, and will further test the assumptions of the lexical-syntactic memory system, proposed by Hartsuiker et al. (2004).

IN SHORT

The presented work in this dissertation focusses on different kinds of representations in bilingual memory, using the priming method as a promising tool to investigate cross-linguistic interactions. The first two empirical chapters (*Chapter 2* and *3*) mainly investigate semantic representations across languages, but also investigate how a word's lexical representation in the first or the second language (in this case, its orthographic code in the lexicon) accesses its/their meaning. *Chapter 2* will solely rely on behavioral measures of bilingual word recognition, whereas in *Chapter 3* also electrophysiological measures will be included. The third empirical chapter (*Chapter 4*) has its main focus on how syntactic structures are represented across languages. In this last chapter, we also explored if and how lexical and syntactic representations interact across languages, in bilingual dialogue.

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CHAPTER 2
SEMANTIC AND TRANSLATION PRIMING FROM A FIRST LANGUAGE TO A SECOND AND BACK: MAKING SENSE OF THE FINDINGS

Manuscript submitted for publication[1]

The present study investigates cross-language priming effects. Unbalanced Dutch (L1)-English (L2) bilinguals performed a lexical decision task in a masked priming paradigm. Two experiments showed significant translation priming from L1 to L2 (meisje – GIRL) and from L2 to L1 (girl – MEISJE), using unique noncognate translation pairs. Translation priming from L1 to L2 was significantly stronger than priming from L2 to L1, replicating a well-known asymmetry. Two further experiments with the same word targets showed significant cross-language semantic priming in both directions (jongen [boy] – GIRL; boy – MEISJE [GIRL]). Semantic priming did not differ reliably between directions. These data suggest that L1 and L2 are represented by means of a similar lexico-semantic architecture, in which L2 words are also able to rapidly activate semantic information, although to a lesser extent than L1 words. This is consistent with models assuming quantitative rather than qualitative differences between L1 and L2 representations.

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[1] This paper was co-authored by Wouter Duyck, Marc Brysbaert, & Robert Hartsuiker.

During the last decade, bilingual word processing has received increasing attention in the field of visual word recognition. A basic feature of being bilingual is that one often has multiple lexical representations (one in each language) to represent a particular meaning (e.g., *dog* and *hond* are the English and Dutch words for the same animal). If these lexical representations are connected to the same or overlapping semantic representations (or directly to each other) one might expect interactions between a bilinguals' languages during word recognition. Indeed, there is a plethora of evidence for influences from bilinguals' first language (L1) on processing a second language (L2) (see below; for instance, Duyck, 2005 ; Keatley, Spinks & De Gelder, 1994; Kim & Davis, 2003; Schoonbaert, Hartsuiker, & Pickering, 2007; Weber & Cutler, 2004). Depending on the organization of bilingual memory, a non-dominant language may also influence the dominant language. This article asks whether such influences from L2 on L1 processing exist, and if so, whether they are equally strong as L1 on L2 influences.

A number of studies have observed effects from L2 on native language processing. For example, Van Hell and Dijkstra (2002) showed that L1 (Dutch) targets having an L2 (English) and L3 (French) near-cognate translation equivalent (e.g. *banaan – banana – banane*) yielded faster lexical decision responses than control words. However, despite the fact that these cross-language influences apparently seem to exist in both directions, it is a recurrent finding that L1 typically has more impact on L2 processing, than vice versa. This well-known asymmetry has been reported in a number of studies using a wide range of paradigms (e.g., Duyck, 2005; Gollan, Forster, & Frost, 1997; Grainger & Frenck-Mestre, 1998; Marian & Spivey, 2003; Schoonbaert, Hartsuiker, & Pickering, 2007; Weber & Cutler, 2004). For instance, in a lexical decision task with translation primes there are clear effects from L1 to L2, but no, or unreliable effects from L2 to L1 (Gollan, Forster, & Frost, 1997; Jiang, 1999; Jiang & Forster, 2001).

A possible theoretical explanation is that words in L2 are represented and accessed in a qualitatively different way than words in L1. For instance, in Jiang and Forster's (2001) episodic model, only L1 words are represented in semantic memory. L2 words, in contrast, are only represented as a trace (together with their L1 translation) in episodic memory. A second example of such a theory is offered by Kroll and Stewart's (1994) Revised Hierarchical model [RHM]. They state that both L1 and L2 words are represented in semantic memory, but also that they differ with respect to the way in which the lexical representations are mapped onto underlying semantics. A very strict interpretation of this model implies that L2 words (unlike L1 words) are not mapped directly onto semantics, but primarily access meaning through their L1 translation equivalent (for a different view, see for example Duyck & Brysbaert, 2004, 2008). Hence, in such a model, L2 representations are qualitatively different from L1. This ‘qualitative’ hypothesis is in line with the lack of consistent translation priming effects from L2 to L1 (assuming that the locus of such priming is semantic, see discussion).

However, an alternative hypothesis would be that the representational differences between L1 and L2, and the way in which these are activated, are not qualitative but quantitative. That is, an L2 word might activate only some of the semantic features activated by its L1 translation (e.g., the Distributed Representation model [DRM] proposed by Van Hell and De Groot, 1998), cause weaker activation in these features (e.g. the model of Duyck & Brysbaert, 2004) or the activation in L2 representations may develop more slowly than in L1 (e.g., the ‘temporal delay hypothesis’ proposed by Dijkstra & Van Heuven, 2002). This ‘quantitative’ hypothesis could explain why L2 to L1 priming may be weaker than vice versa, without a priori excluding reliable priming effects from L2 to L1.

The present study was designed to test under which conditions two types of cross-language priming (namely translation priming and cross-language semantic priming) occur in the lexical decision task. This allows to differentiate between models proposing qualitatively versus quantitatively different L1 and L2 representations. To this end, we investigated how the effect of second language knowledge on native language processing is compared to the reverse effect. Before we go into more details about the present study, we will discuss the current state of affairs with respect to this issue.

The 'general' bilingual asymmetry

Many studies reported differential effects from L1 onto L2 and vice versa, across different modalities. When auditorally instructed to fixate the picture of a *desk,* Dutch-English bilinguals in Weber and Cutler's eye tracking study (2004) were significantly distracted by a picture of a *lid*, because their L1 lexical representation of the distractor item (*deksel [lid]*) has the same initial phonemes as the auditorily presented L2 word *desk*. However, when the participants heard the L1 word *deksel*, the picture of a *desk* was not significantly distracting participants' fixations of the target picture *lid*. This shows how the native language interferes with auditory word recognition in L2 (English) but not vice versa, providing evidence for asymmetric cross-language interactions in bilingual auditory word recognition.

Like the Van Hell and Dijkstra study (2002), Weber and Cutler (2004) investigated the influence of the other language without overt input in that language, and thus without directing participants' attention to that language. There is additional support for the bilingual asymmetry from studies explicitly bringing participants into a bilingual context. One of these studies is the study of Schoonbaert et al. (2007), which showed that there is an asymmetric translation-equivalence boost for syntactic priming across languages. Dutch-English bilinguals (from the same bilingual population tested in the present study) tended to re-use the dative structure that they previously heard in Dutch (e.g., *De kok toont een hoed aan de bokser [The cook shows a hat to the boxer];* prepositional dative) to describe a dative target picture in English (*The monk gives a book to the waitress*; prepositional dative), instead of using the alternative dative structure (*The cook shows the boxer the hat*; double object dative). More importantly, this L1 to L2 syntactic priming effect was boosted when the L2 translation of the L1 prime verb (e.g. *toont [show]*) was to be used in the description of the dative target picture (e.g. *The monk shows a book to the waitress*). Although the study also observed syntactic priming from L2 to L1, this effect was not boosted by using translation-equivalent verbs. This finding was again interpreted as a demonstration of the bilingual asymmetry.

Other studies overtly confronting bilinguals with both of their languages include unmasked priming studies (Chen & Ng, 1989; Jin, 1990; Keatley, Spinks & De Gelder, 1994; Schwanenflugel & Rey, 1986). Several of these have shown larger priming effects from L1 to L2 than vice versa. In the next section, we will further discuss the masked variant of the priming paradigm as an interesting way to test for cross-language effects.

Masked cross-language priming asymmetries in lexical decision

A widely adopted approach to investigate spreading activation across languages from non-target language representations without bilingual participants' awareness, involves the masked priming paradigm (Forster & Davis, 1984). The present study will adopt this popular paradigm to further investigate whether and to what extent activation of lexical and semantic representations in L1 influences L2 processing and vice versa. Translation priming occurs when the processing of a target is facilitated by a tachistoscopically presented translation prime (e.g., Dutch-English, *meisje – GIRL*), relative to an unrelated prime-target pair (e.g., *koffie [coffee] – GIRL*). We will briefly discuss the existing bilingual studies using this priming paradigm with a lexical decision task (Basnight-Brown & Altarriba, 2007; Duyck, 2005; Finkbeiner, Forster, Nicol, & Nakamura, 2004; Gollan, Forster & Frost, 1997; Grainger & Frenck-Mestre, 1998; Jiang, 1999; Jiang

& Forster, 2001; Kim & Davis, 2003; Voga & Grainger, 2007), as this is the task we focus on in the present paper. In general, L1 translation primes systematically speed up lexical decision times to L2 targets (Basnight-Brown & Altaribba, 2007; Gollan, et al., 1997; Jiang, 1999; Jiang & Forster, 2001; Kim & Davis, 2003; Voga & Grainger, 2007). In contrast, evidence for L2 to L1 translation priming (e.g., *girl – MEISJE*) is less unequivocal. This suggests that translation priming is asymmetrical in the lexical decision task. We summarized all the published data from masked translation priming studies (using the lexical decision task and noncognate stimuli) in Table 1. We did not include unmasked priming studies because these may induce strategic factors that influence non-target language activation (Neely, Keefe, & Ross, 1989), and because our focus is on the processing of automatic, cross-language activation spreading. The 10 studies (21 experiments) that meet these criteria are organized in Table 1, as a function of the type of script of the bilinguals' languages (*different vs. comparable*), of the specific languages used, and of the type of stimuli used (when available)[2].

[2] Note that we limited the current overview of cross-language priming to recognition studies (using a lexical decision task). We only mentioned priming studies using non-cognate translation pairs, because the special status of cognate stimuli is beyond the scope of this paper.

Table 1. Priming effects on lexical decision reaction times (in ms) for published masked cross-language priming studies using noncognate stimuli

Scripts	Bilinguals	Stimuli (Concreteness/Freq)	N	n	Authors	Prime	Blank	Mask	SOA	L1 to L2	L2 to L1
Translation Priming											
Different	Hebrew (L1) - English (L2)	-	40	16	Gollan, Forster, & Frost (1997, Exp. 1&3)	50	-	-	50	36*	9
	English (L1) - Hebrew (L2)	-	30	16	Gollan, Forster, & Frost (1997, Exp. 2&4)	50	-	-	50	52*	-4
	Chinese (L1) - English (L2)	abstract (high freq.)	52	16	Jiang (1999, Exp. 1)	50	-	-	50	45*	13*
		abstract	18/24	16	Jiang & Forster (2001, Exp. 3&4)	50	-	-	50	41*	4
		abstract	26	16	Jiang & Forster (2001, Exp. 1)	50	50	150	250	-	8
		concrete (low freq.)	44	16	Jiang (1999, Exp. 2)	50	-	-	50	68*	3
		concrete (high freq.)	16	16	Jiang (1999, Exp. 3)	50	50	-	100	-	4
		concrete (high freq.)	18	16	Jiang (1999, Exp. 4&5)	50	50	150	250	-	7/-2
	Korean (L1) - English (L2)	concrete	25	12	Kim & Davis (2003, Exp. 1)	50	-	-	50	40*	-
	Japanese (L1) - English (L2)	-	18	26	Finkbeiner, Forster, Nicol, & Nakamura (2004, Exp. 2)	50	-	150	200	-	-4
	Greek (L1) - English (L2)	-	30	10	Voga & Grainger (in press, Exp. 2)	50	-	-	50	23*	-
Comparable	French (L1) - English (L2)	concrete	12	60	Grainger & Frenck-Mestre (1998, Exp. 1)	0	-	14	14	-	-4
						14	-	14	28	-	-3
						29	-	14	43	-	2
						43	-	14	57	-	10a
	Spanish (L1) - English (L2)	-	26	16	Basnight-Brown & Altarriba (in press, Exp. 2)	100	-	-	100	33*	24*
	Dutch (L1) - English (L2)	-	17/19	15	De Groot & Nas (1991, Exp. 3&4)	40	20	-	60	35*/40*/22*	-
		abstract vs. concrete	20	26b	This study (Exp. 1&2)	50	50	150	250	90*	21*
Cross-lingual Semantic Priming											
Comparable	Spanish (L1) - English (L2)	-	26	16	Basnight-Brown & Altarriba (in press, Exp. 2)	100	-	-	100	-8	6
	Dutch (L1) - English (L2)	-	17/19	15	De Groot & Nas (1991, Exp. 3&4)	40	20	-	60	13/ 4/ -3	-
		-	20	17	Duyck (2005, Exp. 3&4)	57	-	57	114	33*	20
		abstract vs. concrete	20	26b	This study (Exp. 3&4)	50	50	150	240	21*	14*

Note – All priming effects were computed relative to an unrelated baseline condition.
N: Number of subjects per experiment
n: Number of observations per condition per subject
*: $p < .05$
a: F1: $p < .10$; F2: $p < .05$
b: collapsed across concreteness levels (to increase comparability with the other studies)

Gollan et al. (1997) tested both English-Hebrew and Hebrew-English bilinguals and reported significant translation priming from L1 to L2, but failed to observe translation priming from L2 to L1. These results were basically replicated by Jiang (1999), who tested Chinese-English bilinguals. The L2-L1 priming effect was absent in all but one experiment, in which a 13 ms effect was obtained with highly frequent stimuli (see Table 1). In a similar study using comparable bilinguals, Jiang and Forster (2001) failed to obtain significant priming effects from L2 to L1, whereas priming from L1 to L2 was significant. The existence of a translation priming asymmetry in the lexical decision task is further supported by studies of De Groot and Nas (1991), Kim and Davis (2003), Voga and Grainger (2007), and Finkbeiner et al. (2004). These studies respectively showed the existence of L1-L2 priming in Dutch-English bilinguals, Korean-English bilinguals, and in Greek-English bilinguals, and the absence of L2-L1 priming in Japanese-English bilinguals. However, although Grainger and Frenck-Mestre (1998) were unable to find L2 to L1 translation priming at very short SOAs (below 50 ms) testing French-English bilinguals, they did find a 'healthy trend' (Grainger & Frenck-Mestre, 1998, pp. 615) for L2 to L1 priming with a more commonly used (longer) SOA (57 ms). Another study by Basnight-Brown and Altarriba (2007) tested Spanish-English bilinguals in both the L1 to L2 and the L2 to L1 condition. Both priming effects proved to be significant. There was no interaction between priming and direction, providing evidence against the translation priming asymmetry.

A similar asymmetry might be observed in another variant of cross-language priming, namely cross-language semantic priming. Semantic priming is a well-documented effect in the monolingual domain (e.g., Bleasdale, 1987; Ferrand & New, 2003; Neely, Keefe, & Ross, 1989; Perea & Rosa, 2002; see Hutchison, 2003, Lucas, 2000, and Neely, 1991, for reviews). In this paradigm, responses to target words like *GIRL* are typically faster after being presented with a semantically related word like *boy* than after an unrelated word like *day*. The cross-language version of this paradigm, when testing Dutch-English bilinguals, uses prime-target pairs like *jongen* [boy] – *GIRL* (from L1 to L2), and *boy* – *MEISJE* [GIRL] (from L2 to L1). Using a lexical decision task, cross-language semantic priming has been found by Chen and Ng (1989), De Groot and Nas (1991), Jin (1990), Keatley et al., (1994), and Schwanenflugel and Rey (1986). However, all of these studies used unmasked priming techniques. As in translation priming, cross-language semantic priming effects are often larger from L1 to L2 than from L2 to L1 (e.g., Jin, 1990). Table 1 lists three studies that looked at cross-language semantic priming in a masked priming paradigm. The first study, by De Groot and Nas (1991), had failed to find cross-language semantic priming effects from L1 to L2, testing Dutch-English bilinguals. A more recent study showed that L2 targets (e.g. *CHURCH*) are primed by L1 pseudohomophones (e.g. *pous*) of semantically related words (e.g. *paus* [pope]) in Dutch-English bilinguals (Duyck, 2005). This effect was not replicated with L1 targets (e.g. *BEEN* [LEG]) and L2 pseudohomophone primes (e.g. *knea* [knee]), revealing an asymmetry in cross-language semantic priming. The third study again failed to find a significant cross-language semantic priming effect in either priming direction, using prime-target pairs like *dia* [day] – *NIGHT* in Spanish-English bilinguals (Basnight-Brown & Altaribba, 2007).

Taken together, most cross-language translation priming studies provide evidence for a priming asymmetry, with stronger priming from L1 to L2 than the reverse. What is less clear, is whether the asymmetry is a qualitative one (priming exists from L1 to L2, but not from L2 to L1) or a quantitative one (priming is stronger from L1 to L2 than from L2 to L1). In addition, although there are some indications for a similar asymmetry in cross-language semantic priming, the present evidence on the basis of masked priming does not allow us to draw any firm conclusions about this issue.

In the four experiments presented below, we compared translation and cross-language semantic priming for the exact same target words. This approach rules out stimulus differences as a confound of priming asymmetries observed across priming studies. The first two experiments were designed to test for masked translation priming. In Experiment 1, our aim was twofold: to replicate the L1 to L2 translation priming effect, and to show that this effect generalizes to a population of unbalanced Dutch-English bilinguals. Experiment 2 then tested the more debated L2 to L1 translation priming effect, using the exact same stimuli as in Experiment 1 (reversing translation primes and targets) in the same bilingual population. The last two experiments (Experiment 3 and 4) were designed to test for masked cross-language semantic priming from L1 to L2 and vice versa, using semantically related primes for the same targets used in Experiment 1 and 2. A comparison between the two sets of experiments allowed to test whether translation priming and cross-language semantic priming are both asymmetric to the same extent.

EXPERIMENT 1: TRANSLATION PRIMING FROM L1 TO L2

Method

Participants. Twenty Dutch-English bilinguals from Ghent University participated in the experiment and received course credit in exchange. Mean age was 22.97 years (SD = 2.14). Participants were all native speakers of Dutch and primarily used their mother tongue in daily life. All of them were regularly exposed to English through media such as textbooks, television, movies, music, etc. They had formal English education at school (starting around the age of 12). They all reported having normal or corrected-to-normal vision and only participated in Experiment 1 of the current study.

Stimuli and Design. One hundred Dutch-English translation pairs were selected. A group of 20 Dutch-English bilinguals (from the same population as the participants in the experiments) was asked to give a spontaneous

English translation for the Dutch items (L1-L2 translation), while a similar group of bilinguals was asked to translate the English items into Dutch (L2-L1 translation). The 52 word pairs that were translated identically by 80% of the participants, in both directions, served as unique (one-to-one) translation pairs in the following priming experiments. This is important, because a recent study by Tokowicz and Kroll (2007; Experiment 3) reports an interaction between concreteness and the number of word meanings in lexical decision: only one-meaning words showed the traditional concreteness effect (i.e., a processing advantage for concrete words relative to abstract words). The 52 English words with unique translation equivalents in Dutch were selected as critical targets in a masked priming lexical decision experiment. The English word targets could be preceded by their Dutch translation, or by an unrelated Dutch word (see Table 2 and Appendix A). In this and all subsequent experiments, the translation pairs consisted of 26 abstract words (mean imageability rating of 3.43 (SD = .71) on a seven-point Likert scale from low to high imageable) and 26 concrete words (mean imageability rating of 6.53 (SD = .26)), following Dutch imageability norms gathered by Van Loon-Vervoorn (1985). The imageability ratings for the two groups of words differed significantly on a two-tailed t-test (*p*< *.001*). This variable was included because the DRM model of bilingual memory (e,g, Van Hell & De Groot, 1998a) predicts stronger priming for concrete than abstract words (which may explain the diverging body of evidence reported in Table 1).

Table 2. Examples of the four different kinds of experimental trials, as used in the experiments

Experiment	Direction	**Concrete**			**Abstract**		
		Prime Relation		Target	Prime Relation		Target
		Translation	Semantic		Translation	Semantic	
1 & 3	L1/L2	*meisje*	*jongen*	*GIRL*	*smaak*	*geur*	*TASTE*
2 & 4	L2/L1	*girl*	*boy*	*MEISJE*	*taste*	*smell*	*SMAAK*

Fifty-two Dutch words, matched closely and item-by-item to the translation primes, were selected as unrelated primes for the English word targets. The Dutch translation primes and their respective controls were matched on length, number of syllables, frequency, and number of orthographic neighbors (all *ps*> .25, two-tailed t-tests; see Table 3, for an overview). The measure used for this last variable was Coltheart's N, defined as the number of words differing by a single letter from the stimulus, preserving letter positions (e.g., *worse*, and *house* are both orthographic neighbors of *horse*; Coltheart, Davelaar, Jonasson, & Besner, 1977). Neighborhood size and frequency measures for both Dutch and English were calculated using the WordGen stimulus generation program (Duyck, Desmet, Verbeke, & Brysbaert, 2004), based on the CELEX lexical database of Baayen et al. (1993). The mean printed frequency for all English word targets was 2.01 log10 per million, and ranged from 0.85 to 3.04. To avoid confounded priming effects of orthographical overlap, translation and control primes had the same number of shared letters with the target, in the same positions. Also, cognate or interlingual homograph prime-target pairs were excluded from our stimulus lists (as suggested by Altarriba & Basnight-Brown, 2007). This constitutes a conservative test of non-target language activation during language processing.

Table 3. Matched variables & summary of stimuli used in all experiments

Prime	Freq	Length	Syll	BigramFreq	Nb	Relatedness	Target	Freq	Length	Syll	BigramFreq	Nb
L1							**L2**					
Experiment 1												
Translation	1,92	6,04	1,75	46246,75	4,21	-	Concrete	1,85	5,69	1,69	10551,19	2,92
Unrelated	1,84	6,06	1,85	53485,13	4,31	-	Abstract	1,99	5,46	1,65	9845,35	3,38
Experiment 3												
Semantic	1,62	5,58	1,65	50766,98	3,67	0,29	Word	2,01	5,58	1,67	10198,27	3,15
Unrelated	1,60	5,60	1,67	56395,25	3,52	-	Non word	-	5,62	1,67	9897,96	2,92
L2							**L1**					
Experiment 2												
Translation	2,01	6,15	1,83	10198,27	3,15	-	Concrete	1,85	6,04	1,85	47325,31	4,23
Unrelated	1,99	6,13	1,85	11184,04	3,15	-	Abstract	1,99	6,12	1,73	45168,19	4,19
Experiment 4												
Semantic	1,82	5,35	1,52	9454,73	4,85	0,29	Word	1,92	6,08	1,79	46246,75	4,21
Unrelated	1,73	5,35	1,54	9738,96	4,63	-	Non word	-	5,81	1,77	44680,50	4,56

Freq: Mean printed frequency in LogInl, i.e. the logaritm of frequency per million words

Syll.: Mean number of syllables

BigramFreq: Mean bigramfrequency

Nb: Mean number of orthografic neighbours (neighbourhood size e.g. Coltheart et al., 1977)

Relatedness: Mean association strength between translation primes/targets & semantically related primes

The experiment involved a 2 (Prime type : *translation vs. unrelated*) x 2 (Concreteness: *abstract vs. concrete*) design. Both variables were repeated measures. Additionally, 52 non-words were created that followed the English GPC-rules, serving as English filler targets for the lexical decision task. These non-word targets were matched with the English word targets on number of letters, number of syllables, bigram frequency, and number of orthographic neighbors (all *ps*> .60, two-tailed t-tests), in order to ensure their wordlikeness and pronouncability. All non-words were preceded by unrelated Dutch words. Prime-target pairing was counterbalanced using a Latin-square design, thus creating two presentation lists. Each participant was assigned to one list, and consequently saw each target only once, either with the translation prime or its control. The relatedness proportion within each list was 0.5 (in accordance with recent suggestions made by Altarriba & Basnight-Brown, 2007, to avoid that participants create expectancy sets).

Procedure. Each trial consisted of a sequence of four visual events. First, a row of ten hash marks (##########), serving as a forward mask and as a fixation mark, was presented for 500 ms. Second, the prime was displayed on the screen for 50 ms (3 refresh cycles at a 60 Hz monitor), immediately followed by a blank interval of 50 ms. Third, a backward mask (##########) was presented for 150 ms. Fourth, the target was presented for 500 ms, or until the participants' response. The blank interval and backward mask were adopted from the masked priming procedure of Jiang and Forster (2001), and meant to increase the processing time for the prime, without increasing its visibility. This identical paradigm was also used by Finkbeiner et al. (2004). The stimulus onset asynchrony (SOA) in this study was kept relatively short (250 ms), in order to avoid expectancy strategies (see also Altarriba & Basnight-Brown, 2007, p. 2-3)[3]. Stimulus presentation

[3] Note that Altarriba and Basnight-Brown (2007; p.8) suggest to use SOAs below 200 ms when examining automatic processing. Although, the present study used a somewhat longer SOA of 250 ms, it should be noted that the translation priming effects in this study were replicated in a study with Dutch-English bilinguals by

and response registration were controlled by ERTS software Version 3.28 (Berisoft Cooperation). All stimuli were presented centered on a standard 15" VGA color monitor in standard DOS-font, as yellow characters on a black background. Primes appeared in lowercase (font size 12), whereas targets were presented in uppercase (font size 14), to minimize visual feature overlap between primes and targets. For the masks, the same font size as for the primes was used. Order of trials was randomized for each participant. Participants were asked to fixate the center of the screen and to decide as quickly and accurately as possible if the target stimulus was an English word or not. The two possible response buttons were the right key (for a 'Yes' response) and the left key (for a 'No' response) of a millisecond accurate response box, connected to the printer port of a PC. The assignment of responses was reversed for half of the participants. None of the participants were informed about the presence of the primes. Instructions were given in Dutch (L1) by the experimenter (before the experiment), and visually presented (on the screen). At the end, participants were asked to complete a short questionnaire about their L1 and L2 language proficiency and L2 learning age (see Table 4).

Duyck & Warlop (submitted), employing an SOA of 112 ms. Moreover, in a recent RT- and ERP-study with English-French bilinguals by Schoonbaert, Holcomb, & Hartsuiker (in preparation), identical translation priming results were found at SOAs of 120 ms and 200 ms.

Table 4. Self-ratings on language proficiency measures for subjects in all four experiments

	L1 (Dutch)	L2 (English)	Relative L2 Proficiency
Measure	*Mean (sd)*	*Mean (sd)*	*Mean (sd)*
Experiment 1 (L1 to L2 translation priming)			
Writing	5.9 (1.0)	4.5 (1.3)	5.4 (1.7)
Speaking	5.7 (1.3)	4.7 (1.3)	5.9 (1.8)
Reading	5.9 (0.9)	5.0 (1.3)	**5.9 (1.4)**
Overall Proficiency	5.8 (0.9)	4.7 (1.1)	5.7 (1.6)
Experiment 2 (L2 to L1 translation priming)			
Writing	5.1 (1.1)	4.2 (1.1)	6.0 (1.5)
Speaking	5.8 (0.9)	4.9 (1.0)	6.0 (1.1)
Reading	5.5 (0.9)	4.9 (0.8)	**6.4 (1.0)**
Overall Proficiency	5.4 (0.7)	4.7 (0.8)	6.1 (1.2)
Experiment 3 (L1 to L2 cross-language semantic priming)			
Writing	5.6 (0.8)	4.3 (1.3)	5.3 (1.4)
Speaking	5.5 (1.0)	4.7 (1.5)	5.9 (1.7)
Reading	5.6 (1.1)	4.8 (1.0)	**6.1 (1.0)**
Overall Proficiency	5.6 (0.8)	4.6 (1.1)	5.8 (1.4)
Experiment 4 (L2 to L1 cross-language semantic priming)			
Writing	5.4 (0.8)	4.3 (1.0)	5.6 (1.1)
Speaking	5.7 (0.8)	4.5 (1.2)	5.5 (1.5)
Reading	5.6 (0.9)	5.0 (1.3)	**6.2 (1.3)**
Overall Proficiency	5.6 (0.7)	4.6 (1.1)	5.8 (1.3)

Note — 7-point Likert scale ratings (1= very poor; 7= excellent)

Results

Mean response times are presented in Table 5 by Prime Type and Concreteness. Only correct responses of word trials (93%) were analyzed. All participants had error rates below 25%. Outlier data (RTs less than 200 ms and 2 SD below or above the subject's mean word RT) were removed from the analyses, excluding less than 1% of all data. ANOVAs were carried out with participants (F_1) and items (F_2) as random variables, and mean RTs and the percentage of errors as the dependent variables. The factor Stimulus List was included as a between-participants variable

(Pollatsek & Well, 1993). This analysis procedure was used in all experiments reported in this paper.

Table 5. Mean reaction times (in ms), mean error rates, and priming effects in the participants analysis of Experiment 1

L1 to L2			Concreteness			
	Overall		Abstract		Concrete	
	RT	Error %	RT	Error %	RT	Error %
Translation	565	6.9	570	9.5	559	4.3
Unrelated	655	6.5	649	7.1	661	5.8
Priming	+90***		+79***		+102***	

***: p <.001

An ANOVA was performed with Prime type (*translation vs. unrelated*) and Concreteness (*abstract vs. concrete*) as repeated measures factors. English targets preceded by their Dutch translation (565 ms) were recognized faster than those preceded by an unrelated Dutch word (655 ms). This 90 ms priming effect was significant, $F_1(1,18) = 104.53, p< .001,$ and $F_2(1,48) = 147.58, p< .001.$ The effect of Concreteness was not significant (both $Fs< 1$). Mean response time was identical (M = 609 ms) for both abstract and concrete targets. The priming effect also did not interact with Concreteness (both $Fs< 1$). Planned comparisons showed that both the priming effects for abstract and concrete targets were significant, respectively $F_1(1,18) = 44.29, p< .001,$ and $F_2(1,48) = 62.23, p< .001,$ and $F_1(1,18) = 68.79, p< .001,$ and $F_2(1,48) = 86.33, p< .001.$

There was no effect of Prime type on the percentage of errors to words (both $Fs< 1$), although the Concreteness effect did reach significance ($F_1(1,18) = 13.71, p< .01,$ and $F_2(1,48) = 4.42, p< .05$). The overall percentage of errors was higher for abstract words than for concrete words (8% versus 5%). Their interaction was not significant ($F_1(1,18) = 2.67, p < .12$, and $F_2(1,48) = 1.43, p < .24$).

Discussion

Experiment 1 showed a significant translation priming effect from L1 to L2. This finding is consistent with earlier studies, showing that L1-L2 translation priming is a robust finding in bilingual word recognition (e.g., Gollan, et al., 1997; Jiang, 1999; Jiang & Forster, 2001; Kim & Davis, 2003). The next experiment tested whether translation priming from L2 to L1 can be obtained using the same stimuli. The L2 targets from Experiment 1 were now L2 primes, whereas the L1 primes from Experiment 1 were now L1 targets (see Table 2).

EXPERIMENT 2: TRANSLATION PRIMING FROM L2 TO L1

Method

Participants. Twenty Dutch-English bilinguals from Ghent University took part in this experiment for course credit. Mean age was 19.25 years old (SD = 2.97). They belonged to the same population and had a similar L2 history as the participants in Experiment 1.

Stimuli. The 52 English word targets of Experiment 1 and their respective Dutch translation primes were used again, but now, respectively, as English (L2) translation primes and corresponding Dutch (L1) word targets (see Table 2 and Appendix B). The average log10 of the printed frequency (per million) for these targets was 1.92 (ranged from .60 to 3.14). The 52 Dutch non-word targets satisfied the criteria mentioned in Experiment 1 (all *ps*>*.60*, two-tailed t-tests). English unrelated primes and Dutch non-words (following Dutch GPC-rules) were selected, also following the same criteria described in Experiment 1 (all *ps*> *.25;* see Table 3) .

Design and Procedure. The design and procedure of the present experiment were identical to those of Experiment 1. Only the languages of primes and targets were reversed.

Results

Mean response times are presented in Table 6 by Prime Type and Concreteness. Less than 1% of all correct (97%) word trials were outliers and therefore excluded from all analyses. Because of a malfunctioning response box, the data of one participant could not be analyzed and were discarded from all analyses.

Table 6. Mean reaction times (in ms), mean error rates, and priming effects in the participants analysis of Experiment 2

L2 to L1			Concreteness			
	Overall		Abstract		Concrete	
	RT	Error %	RT	Error %	RT	Error %
Translation	544	1.3	546	1.5	542	1.0
Unrelated	565	4.1	564	4.6	566	3.5
Priming	+21*		+18 ~		+24*	

~: p <.10

*: p <.05

Dutch targets preceded by their English translation (544 ms) were recognized faster than those preceded by an unrelated English word (565 ms).This 21 ms priming effect was significant, $F_1(1,18) = 8.31, p< .05$ and $F_2(1,48) = 6.37, p< .05$. The Concreteness factor did not lead to significant main or interaction effects *(all Fs< 1).* Planned comparisons showed that the priming effects for abstract targets only tended to be significant by participants, $F_1(1,18) = 3.17, p< .10$ and $F_2(1,48) = 2.73, p< .11$, while the priming effect for concrete targets was significant by participants, and tended to be significant by items, $F_1(1,18) = 7.38, p< .05$ *and* $F_2(1,48) = 3.68, p< .07$.

In the ANOVA on mean error percentages, the main effect of Prime Type tended towards significance in the participants analysis, $F_1 (1,17) = 3.50, p< .08$, and was significant in the item analysis, $F_2(1,48) = 10.08, p< .01$. Participants recognized Dutch targets preceded by their English translation more accurately than those preceded by an unrelated English word (1% vs. 4%). The effect of Concreteness was not significant, and neither was the interaction between Prime type and Concreteness (all Fs< 1).

Combined analysis for Experiment 1 and 2. To test for a translation priming asymmetry, we analyzed the data from Experiments 1 and 2 in one design. A t-test indicated that participant's relative L2 proficiency (see Table 4) in both translation priming experiments (from L1 to L2 and vice versa) was comparable ($p> .25$), and thus ensured comparable groups of participants. Hence, a three-way ANOVA was run with Direction (*L1-L2 vs. L2-L1*) as an additional between-participants factor, again treating mean RT on correct trials as the dependent variable. As expected, the overall translation priming effect was significant (56 ms), $F_1(1,35) =92.02, p< .001$ and $F_2(1,100) = 39.39, p< .001$. Additionally, responses were slower to L2 targets (610 ms) than to L1 targets (555 ms). This 55 ms difference, however, was only significant in the item analysis, $F_1(1,35) = 2.92, p< .10$

and $F_2(1,100) = 51.91$, $p < .001$. More interestingly, the priming effect interacted significantly with Direction, $F_1(1,35) = 33.57$, $p < .001$ and $F_2(1,100) = 18.07$, $p < .001$. The effect of L1 primes on their L2 translations (90 ms; see Table 5) was larger (69 ms) than the effect of L2 primes on their L1 translations (21 ms; see Table 6). There were no other significant effects.

Discussion

Experiment 2 showed a significant, but much smaller translation priming effect from L2 to L1. Numerically, there was a 69 ms difference between the priming effect in the L1-L2 condition (Experiment 1) and that of the L2-L1 condition (Experiment 2). The combined analysis of Experiment 1 and 2 confirmed that this difference was significant. Hence, the expected translation priming asymmetry in the lexical decision task was observed. Important to note, however, is that the L2-L1 translation priming effect was still strong enough to be significant.

EXPERIMENT 3: CROSS-LANGUAGE SEMANTIC PRIMING FROM L1 TO L2

To gain further insight into the language asymmetry in the masked cross-language priming paradigm, we ran two more experiments using cross-language semantic priming. As shown in Table 1, the evidence for a language asymmetry is much less clear for this particular paradigm. Basnight-Brown and Altarriba (2007) found no priming in either direction, whereas in a similar cross-language semantic priming paradigm, Duyck (2005) observed asymmetric priming (from L1 to L2 but not vice versa) with pseudohomophones of semantically related words in the prime position. Thus, it remains to be seen whether the cross-language semantic priming effect can be replicated, and if so, whether the effects are asymmetrical or not.

Experiment 3 examines cross-language semantic priming from L1 to L2, using the same target words as in Experiment 1. The primes were semantic associates of the targets, as was the case in the previously reported cross-language semantic priming studies by Basnight-Brown & Altarriba (2007) and Duyck (2005). As before, half of the stimuli were abstract words, while the other half were concrete words (see Table 2).

Method

Participants. Twenty Dutch-English bilinguals from Ghent University took part in the experiment for course credit. Mean age was 19.02 years old (SD = 0.54). They were selected from the same population and had a similar L2 history as the participants in Experiment 1 and 2.

Stimuli and Design. All target stimuli were identical to Experiment 1. Fifty-two Dutch words were selected as semantically related primes, replacing the translation primes of Experiment 1 (see Table 2 and Appendix A). These related primes were selected from the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 1998). The mean "Forward Cue-to-Target Strength" (FSG) of English target words and their respective semantically related primes (translated to Dutch) was 0.27 for abstract words and 0.31 for concrete words ($p > .55$, two-tailed t-test). Primes for semantically related concrete words were also concrete, whereas primes for semantically related abstract words were also abstract. In addition, 52 Dutch words were selected as unrelated primes, again closely matched item by item to the semantically related primes, following the same criteria as in Experiments 1 and 2 (all $ps > .25$, two-tailed t-tests; see Table 3). Two matched presentation lists were constructed (counterbalanced over participants). This resulted in a 2 (Prime type: *semantically related vs.*

unrelated) x 2 (Concreteness: *abstract vs. concrete*) design. Both of these factors were manipulated within participants.

Procedure. The same procedure as in Experiments 1 and 2 was used for stimulus presentation and data collection.

Results

Mean response times are presented in Table 7 by Prime Type and Concreteness. Less than 1% of all correct (96%) word trials were outliers and therefore excluded from analyses. One participant responded incorrectly to more than 25% of the word trials, and was discarded from the analyses. Additionally, one abstract target word was misjudged by more than 30% of all participants, and one concrete target word seemed to have an unforeseen semantic relationship with its unrelated prime. These items were also discarded from the analyses (see Appendix A).

Table 7. Mean reaction times (in ms), mean error rates, and priming effects in the participants analysis of Experiment 3

L1 to L2			Concreteness			
	Overall		Abstract		Concrete	
	RT	Error %	RT	Error %	RT	Error %
Cross-language semantic	600	3.7	603	2.8	597	4.6
Unrelated	621	5.0	620	4.2	622	5.7
Priming	+21**		+17		+25*	

*: p <.05

**: p <.01

An ANOVA was conducted with Prime type (semantically related vs. unrelated) and Concreteness (abstract vs. concrete) as repeated measures factors, treating mean RT and percentage of errors as dependent variables. English targets preceded by a Dutch semantically related word (600 ms) were recognized significantly faster than those preceded by an unrelated Dutch word (621 ms). This 21 ms priming effect was significant, $F1(1,17) = 9.72$, $p < .01$ and $F2(1,46) = 5.95$, $p < .05$. The Concreteness factor did not lead to significant main or interaction effects (all $Fs < 1$). Planned comparisons showed that the priming effect for abstract targets was not significant, $F1(1,17) = 2.85$, $p < .11$ and $F2(1,46) = 1.52$, $p < .23$, although the priming effect for concrete targets was significant, $F1(1,17) = 5.15$, $p < .05$ and $F2(1,46) = 4.92$, $p < .05$.

An ANOVA on the mean error percentages did not reveal significant effects.

Discussion

We found a cross-language semantic priming effect from L1 to L2. This finding is consistent with the data observed in a recent semantic priming study by Duyck (2005), but contrasts with the findings of Basnight-Brown and Altaribba (2007). Before discussing these observations further, we will first present the data of Experiment 4.

EXPERIMENT 4: CROSS-LANGUAGE SEMANTIC PRIMING FROM L2 TO L1

Experiment 4 used L2 primes and L1 targets. In order to preserve the same association strength from prime to target as in Experiment 3, we translate the L1 prime (to L2) and the L2 target (to L1) from Experiment 3, instead of swapping them. Examples for abstract and concrete conditions are shown in Table 2.

Method

Participants. Eighteen Dutch-English bilingual volunteers participated in this experiment. Mean age was 22.75 years (SD = 3.32). They were drawn from the same population and had a similar L2 history as the participants in Experiments 1 to 3.

Stimuli. The 52 L1 word targets were the Dutch translations of the English primes in Experiment 3. The L2 semantically related primes were the English translations of the Dutch targets in Experiment 3 (see Table 2 and Appendix B). This approach ensured that the same concepts were used across both cross-language semantic priming experiments. English unrelated primes and Dutch non-words were selected and controlled as in the previous experiments.

Design & Procedure. The design and procedure were identical to those of Experiment 3.

Results

Mean response times are presented in Table 8 by Prime Type and Concreteness. Less than 1% of all correct (96%) word trials were outliers and therefore excluded. We also excluded the translation of the excluded abstract and concrete targets in Experiment 3 (see Appendix B).

Table 8. Mean reaction times (in ms), mean error rates, and priming effects in the participants analysis of Experiment 4

L2 to L1			Concreteness			
	Overall		Abstract		Concrete	
	RT	Error %	RT	Error %	RT	Error %
Cross-language semantic	563	4.9	563	5.0	562	4.7
Unrelated	577	3.1	570	3.1	584	3.0
Priming	+14*		+7		+22 ~	

~: p <.10

*: p <.05

A repeated measures ANOVA similar to that in Experiment 3 was performed. Dutch targets preceded by an English semantically related word (563 ms) were recognized faster than those preceded by an unrelated English word (577 ms). This 14 ms priming effect was significant, $F_1(1,16) = 7.77, p< .05$ and $F_2(1,46) = 4.54, p< .05$. The Concreteness factor did not lead to significant main effects, $F_1<1$ and $F_2(1,46)= 2.14, p< .16$, or interaction effects (both $Fs<1$). Planned comparisons showed that the priming effect for abstract targets was not significant, both $Fs<1$, although the priming effect for concrete targets tended to be significnant in the participants' analysis, $F_1(1,16) = 4.28, p< .06,$ *and* was significant in the item analysis, $F_2(1,46) = 4.32, p< .05$.

An ANOVA on the mean error percentages did not reveal significant effects.

Combined analysis for Experiment 3 and 4. To test for differences between cross-language semantic priming in both directions, we analyzed the data from Experiment 3 and 4 in one design. A t-test again indicated that participants' relative L2 proficiency (see Table 4) in both cross-language semantic priming experiments (from L1 to L2 and vice versa) was comparable (*p*> *.63*), and thus ensured comparable groups of participants. Therefore, a three-way ANOVA was run with Direction (*L1-L2 vs. L2-L1*) as an additional between-participants factor and mean RTs to correct trials as the dependent variable. The overall cross-language semantic priming effect (18 ms) was significant, $F_1(1,33) = 13.65$, $p < .01$ and $F_2(1,96) = 8.51$, $p < .01$. As in translation priming (Experiments 1 and 2), responses to L2 targets (611 ms) were slower than to L1 targets (570 ms), but this 41 ms effect was only significant in the item analysis, $F_1(1,33) = 1.20$, $p < .17$ and $F_2(1,96) = 17.00$, $p < .001$. Although a comparison of Table 7 and 9 suggests that the semantically related priming effect of L1 primes on L2 targets (21 ms) was larger (7 ms) than the effect of L2 primes on L1 targets (14 ms), this interaction was not significant (both *Fs <1*).

Discussion

Experiment 4 showed an L2 to L1 cross-language semantic priming effect. The combined analysis of Experiments 3 and 4 further showed that the overall cross-language priming effect did not interact with the direction of priming (from L1 to L2, or vice versa). In other words, cross-language semantic priming did not seem to be asymmetric (only a 7 ms difference).

GENERAL DISCUSSION

The present study tested translation priming and cross-language semantic priming from L1 to L2 and vice versa in unbalanced Dutch-English bilinguals. We used a lexical decision task with noncognate prime-target pairs. Experiment 1 replicated the translation priming effect from L1 to L2 with Dutch-English bilinguals (e.g., *meisje* – *GIRL*). Experiment 2 showed a reliable translation priming effect from L2 to L1 (e.g., *girl – MEISJE*), in contrast with a number of previous studies that failed to find such effects (Table 1). Experiment 3 and Experiment 4 added to the very small literature on cross-language semantic priming. These experiments showed that such priming can be observed both from L1 to L2 (e.g., *jongen [boy] – GIRL*; Experiment 3), and from L2 to L1 (e.g., *boy –MEISJE [GIRL];* Experiment 4*).* None of these cross-language priming effects interacted significantly with concreteness.

The data of our experiments, together with the overview of previous studies in Table 1, reveal some of the factors that affect masked cross-language priming. One conclusion that clearly stands out is that none of the factors involves a qualitative difference. It is *not* the case that cross-language priming is possible from L1 on L2, but not from L2 on L1. Similarly, it is *not* the case that cross-language priming is limited to translation primes and can not be observed for semantic primes. Finally, it is *not* the case either that priming is limited to words referring to concrete objects or persons. Rather, the pattern of results that emerges is one of quantitative differences: the priming effect is larger from L1 on L2 than vice versa, larger for translation priming than for semantic priming, and slightly larger (but not significantly) for concrete words than for abstract words.

In this view, to understand cross-language priming, it is not a good idea to start from a model with different mechanisms for different types/languages of targets and primes. What we need is a model that makes use of a single mechanism for all types of stimuli. In what follows, we argue that the Distributed Representation model (DRM) proposed by De Groot and colleagues (De Groot, 1992a-b; De Groot, 1993; De Groot, et al., 1994; Van Hell & De Groot, 1998a-b) may account for this set of data through such a single, parsimonious mechanism of gradual spreading of activation. The DRM assumes that word translation times and priming effects depend on the number of semantic features shared by the L1 word and the L2 word. This idea has already been picked up by Duyck and Brysbaert (2004), who proposed a reformulation of the classical RHM to explain a consistent pattern of semantic effects in the translation of L1 and L2 number words (which have almost maximal semantic similarity across languages). A similar idea was also proposed in the Sense model of Finkbeiner and colleagues (2004), in which they assume that cross-language priming effects depend on the proportion of senses shared by the L1 and L2 word.

Our account in terms of the DRM builds upon several additional assumptions that have been made in other studies or that can be defended. First, for unbalanced bilinguals, we assume that the semantic representation is richer for the dominant language than for the secondary language (for a similar view, see Tokowicz, Kroll, De Groot, & Van Hell, 2002, pp. 439; see also Duyck & Brysbaert, 2004). This means that in general more conceptual nodes will be activated by L1 words than by L2 words. A similar idea can again be found in the Sense model, where it is assumed that the proportion of (shared) senses activated by a L1 prime is much higher than the proportion of senses activated by an L2 prime. This was supported by evidence that showed within-language semantic priming from many to few sense words, but not from few to many sense words (see Finkbeiner et al., 2004). Second, the semantic overlap is assumed to be larger for translations than for semantically related and associated words (e.g. De Groot & Nas, 1991). This means that more shared conceptual nodes will be activated by a translation prime than by a semantically related prime. Third, there is more overlap in the semantic representations of L1 and L2 translations for concrete words than for abstract words. This means that more shared conceptual nodes will be activated by concrete primes than by abstract primes (De Groot, 1992; De Groot, 1993; De Groot, et al., 1994; De Groot, 1995; Van Hell & De Groot, 1998a-b). This assumption is supported by the significant correlation that has been found between ratings of semantic similarity of translation pairs and the concreteness ratings of those words (Tokowicz et al., 2002).

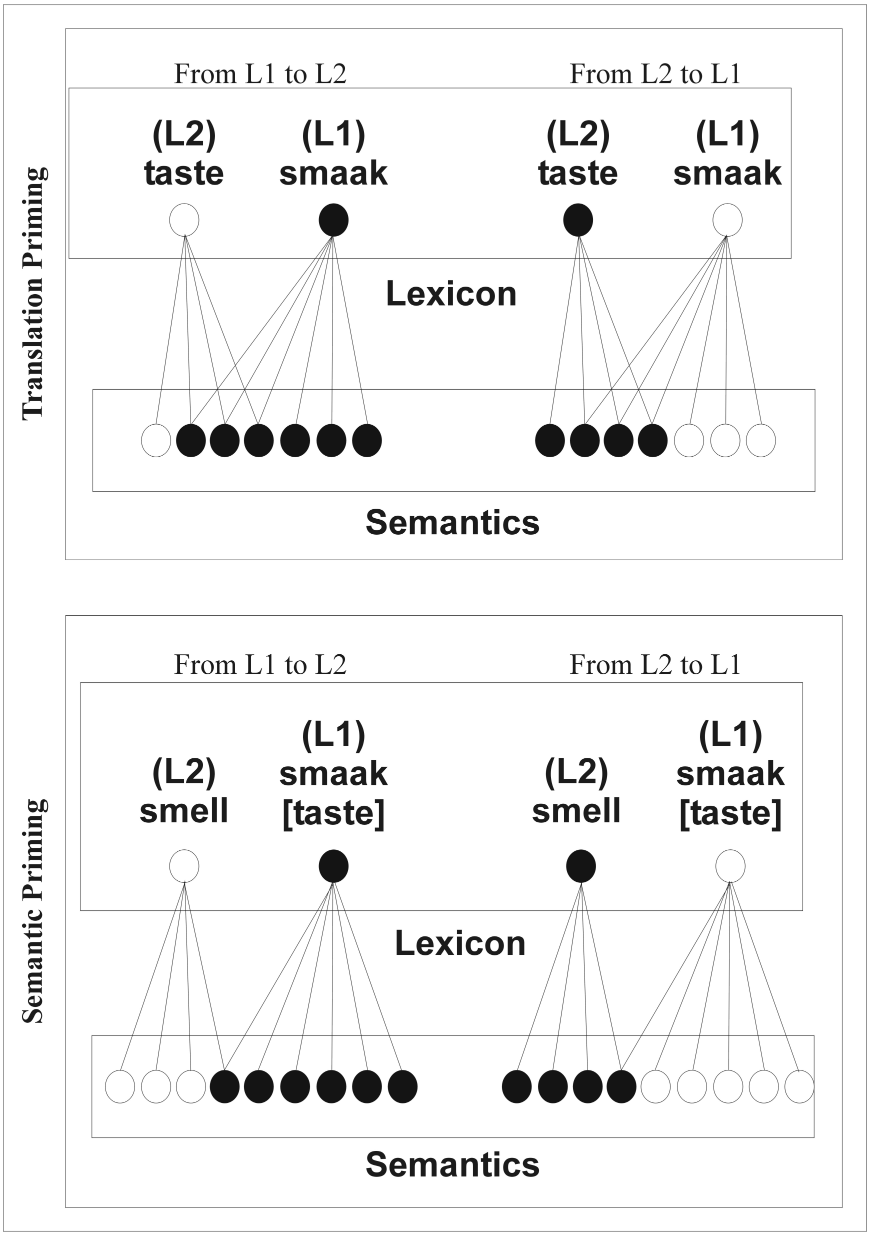

Figure 1. A refined version of the distributed representation model of bilingual conceptual memory

Figure 1 shows how the Distributed Representation model can explain the different findings by assuming that the magnitude of the priming effect depends on the proportion of the target's conceptual nodes that are activated by the prime. First, it easily explains why translation priming is stronger than semantic priming, as a translation prime shares more conceptual nodes with the target than a semantically related prime (compare the upper panel of Figure 1 with the lower panel).

Second, it also accounts for the finding that priming from L1 to L2 is stronger than priming from L2 to L1. As long as an L2 prime only activates a subset of L1 target's conceptual nodes, the percentage of activated conceptual nodes will be lower than 100% (compare the right figure in each panel of Figure 1 with the left figure). An objection against this interpretation might be that the absolute number of shared activated conceptual nodes is the same from L1 to L2 as from L2 to L1 (e.g., five in the upper panel of Figure 1, and two in the lower panel). However, it is common practice in connectionist modeling to correct the connection weights for the number of connections, so that a node that is connected to 100 other nodes does not change the activation of all 100 nodes to the same extent as a node that is only connected to 10 other nodes (Cohen & Grossberg, 1987). Similarly, a node that receives input from 20 other nodes does not receive the same amount of activation from each node as a node that only receives input from 2 other nodes. Otherwise, the former node would always dominate the latter. More fundamentally, this normalization prohibits that a word or concept is activated by only a few of its features and thus attempts to minize the amount of false positives. Our data also showed a translation priming asymmetry (Experiment 1-2), as opposed to more symmetric results in cross-language semantic priming (Experiments 3-4). A joint analysis of the four experiments further confirmed this by a three-way interaction. This finding can also be accounted for by the model in Figure 1: the difference of activated shared features between both directions of translation priming is bigger than the same difference in cross-language semantic priming, explaining the bigger asymmetry in translation priming versus cross-language semantic priming (compare the difference in activated shared features by an L1 translation prime versus an L2 translation prime in the upper panel, versus the difference in shared features activated by both the L1 and the L2 cross-language semantically related prime in the lower panel).

Finally, the degree of priming will also differ as a function of the percentage of conceptual nodes that are shared by the L1 and the L2 node. Priming will be stronger for two translations that share a lot of their features than for translations that share only a few of their nodes (e.g., because they have several meanings and senses that are not present in the other language; see also Finkbeiner et al., 2004). Assuming that the overlap is greater for concrete words than for abstract words, this predicts more cross-language priming for the former than for the latter. This assumption is more tentative, since our results suggest that the average difference between both types of words probably is not very large (and thus not significant). The major selling point of the DRM here is that it can explain the gradual, quantitative (and not qualitative) differences observed in the present cross-language priming experiments. The cross-language semantic priming experiment from L2 to L1 may have taken this quantitative difference near the limit, meaning that it provided the weakest, but yet still significant, priming effect. In other studies, using bilinguals with different proficiency levels, other stimuli, this threshold for observing significant priming may be different, resulting for example in a null effect for L2 tot L1 translation priming.

A final element that may contribute to the differences between L1 and L2 priming concerns the speed with which L1 and L2 words can activate the conceptual features. Several authors assume that form and meaning activation may take more time in L2 than in L1 (e.g., the BIA+ model by Dijkstra & Van Heuven, 2002; Grainger & Frenck-Mestre, 1998). Table 1 shows that the translation priming effect from L1 to L2 increased with increasing SOA, as might the translation priming from L2 to L1, but with some delay. Interestingly, this delay may explain why L2 to L1 priming seems to be less strong when the scripts of the languages differ (see Table 1). An advantage of a shared script is that many of the early processes in word recognition (e.g., letter identification, phonological coding) can be shared between L2 and L1, so that L2 word recognition can profit from the already well-established and fast operating L1 machinery (see Brysbaert & Van Wijnendaele, 2002, and MacWhinney, 1997, for evidence along these lines). In contrast, the processing of words in a different script relies on other processes that are not as well practiced as the processes of L1, so they take more time to complete. Considering this delay, it looks like we have made a wise choice to follow Jiang and Forster's (2001) lead by increasing the SOA with the use of a backward mask between the prime and the target.

The idea that translation priming predominantly relies on shared meaning has been presented before (Finkbeiner et al., 2004; Grainger & Frenck-Mestre, 1998), on the basis of the finding that translation priming (both from L1 on L2 and from L2 on L1) is considerably stronger in a semantic decision task than in a lexical decision task. This idea is also in line with recent evidence from our laboratory showing large semantic activation in the translation of numbers (De Brauwer, Duyck, & Brysbaert, 2008; Duyck & Brysbaert, 2002, 2004, 2008). However, it should be noted that many models of bilingual language representation assume direct word-word connections between L1 and L2 translations, in addition to semantically mediated connections (e.g., the RHM; Kroll & Stewart, 1994).

It should also be noted that finding more symmetric priming with cross-language semantic associates might be in line with the assumption that semantic priming depends less on the semantic overlap between prime and target and more on word-word associations. There is indeed a discussion in monolingual language research to what extent the priming effect of *girl* on *boy* depends on the similarity in meaning, and to what extent it depends on the fact that both words often co-occur in texts (see Hutchison, 2003, and Lucas, 2000, for meta-analyses of the semantic and associative contributions to semantic priming). Given the idea of quantitative rather than qualitative differences in L1 and L2 representations, we argue that not finding a significant asymmetry in the present semantic cross-language experiments (cross-experiment comparisons) is likely to be due to a floor effect in weak semantic cross-language priming (in both directions) than to reflect a genuine, structurally defined, symmetry.

To conclude, the present experiments first of all showed that translation priming and semantic cross-language priming can be generalized to a new population, namely unbalanced Dutch-English bilinguals. We also showed that the much debated priming effect from L2 to L1 does exist but that it is weaker than the reverse effect, using the exact same stimuli and type of bilinguals. This asymmetry was however not as reliable in the case of cross-language semantic priming. Finally, we believe that the overall data pattern indicates that the difference between processing of L1 and L2, translation and cross-language semantic associates and maybe even concrete and abstract words, is a quantitative difference rather than a qualitative one.

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APPENDIX A. Word targets and corresponding primes used in Experiment 1 and 3

English (L2) Target	Dutch (L1) Translation	Dutch (L1) Control for Translation	Dutch (L1) Related	Dutch (L1) Control for Related
Abstract				
AREA	gebied	helpen	streek	moreel
TRUTH	waarheid	zekerheid	leugen	keuken
FUTURE	toekomst	toestand	verleden	herhalen
HONOR	eer	bar	hulde	harem
FEELING	gevoel	geheel	stemming	bewering
MARRIAGE	huwelijk	zedelijk	scheiding	socioloog
AGE	leeftijd	bezoeker	jaren	laten
WEAKNESS	zwakte	vlakte	sterkte	spreker
SPACE	ruimte	eerste	komeet	ruiter
RUMOR*	gerucht	kruisen	roddel	roepen
PEACE	vrede	feit	oorlog	minuut
SOUL	ziel	geel	geest	tekst
QUESTION	vraag	hoofd	antwoord	concreet
DISTANCE	afstand	verstand	mijl	film
STORY	verhaal	periode	sprookje	schroom
LANGUAGE	taal	hals	spaans	staand
LIFE	leven	lopen	dood	arts
DANGER	gevaar	gebaar	risico	crisis
CRIME	misdaad	kermis	getuige	functie
TASTE	smaak	blaas	geur	werk
LAW	wet	wip	regel	kerel
HABIT	gewoonte	behoefte	ritueel	titelen
CHOICE	keuze	derde	optie	notie
LOSS	verlies	telkens	winst	angst
ABUSE	misbruik	bestaand	gebruik	gebouwd
DOUBT	twijfel	terrein	schaamte	patiente
Concrete				
COLOR	kleur	blaar	verf	grof
SUNSHINE	zonneschijn	clandestien	straal	stroom
CEILING	plafond	plagend	vloer	bloem
RAIN	regen	roman	paraplu	paradox
CURTAIN	gordijn	verstaan	douche	schuld
FATHER	vader	kamer	moeder	verder
FIRE	vuur	haar	draak	grond
BULLET	kogel	gevel	geweer	dekker
QUEEN	koningin	kapitein	koning	mening
EARTH	aarde	aardig	hemel	heling
MOUNTAIN	berg	kerk	heuvel	geheim
GIRL	meisje	koffie	jongen	voegen
RABBIT	konijn	muziek	wortel	gordel
ANIMAL	dier	hier	boerderij	spoorlijn
CHILD	kind	eind	ouder	baden
CASTLE	kasteel	voorstel	paleis	dansen
BODY*	lichaam	reactie	lijk	hals*
HUMAN	mens	mond	wezen	groen
SNAKE	slang	staal	hagedis	dateren
CHAIR	stoel	geest	zitplaats	diagonaal
KEY	sleutel	ongeluk	slot	dank
BUILDING	gebouw	gebrek	kantoor	venster
BRACELET	armband	wasbak	halssnoer	samenstel
PLANE	vliegtuig	vloedgolf	vlucht	sluis
TRIANGLE	driehoek	vrijheid	vierkant	ledikant
BEACH	strand	middag	schelp	scherm

*: removed out of Experiment 3

APPENDIX B. Word targets and corresponding primes used in Experiment 2 and 4

Dutch (L1) Target	English (L2) Translation	English (L2) Control for Translation	English (L2) Related	English (L2) Control for Related
Abstract				
GEBIED	area	fuel	region	regime
WAARHEID	truth	north	lie	pie
TOEKOMST	future	little	past	cast
EER	honor	labor	tribute	crackle
GEVOEL	feeling	reality	mood	whom
HUWELIJK	marriage	continue	divorce	dispose
LEEFTIJD	age	she	years	sense
ZWAKTE	weakness	awakening	strength	eyesight
RUIMTE	space	force	comet	comer
GERUCHT*	rumor	rural	gossip	glance
VREDE	peace	sense	war	far
ZIEL	soul	goal	spirit	poison
VRAAG	question	business	answer	appear
AFSTAND	distance	instance	mile	hope
VERHAAL	story	yours	fairytale	rationale
TAAL	language	landlord	spanish	measure
LEVEN	life	like	death	reach
GEVAAR	danger	badger	risk	rich
MISDAAD	crime	prime	witness	vicious
SMAAK	taste	basic	smell	smile
WET	law	how	rule	hide
GEWOONTE	habit	visit	ritual	attain
KEUZE	choice	anyone	option	hardly
VERLIES	loss	lass	profit	tragic
MISBRUIK	abuse	bushy	use	ask
TWIJFEL	doubt	short	shame	pause
Concrete				
KLEUR	color	solar	paint	month
ZONNESCHIJN	sunshine	crushing	ray	hay
PLAFOND	ceiling	decline	floor	clock
REGEN	rain	ruin	umbrella	wherever
GORDIJN	curtain	surgeon	shower	supper
VADER	father	matter	mother	number
VUUR	fire	work	dragon	tricky
KOGEL	bullet	valley	gun	gap
KONINGIN	queen	learn	king	sing
AARDE	earth	early	heaven	chapel
BERG	mountain	position	hill	hall
MEISJE	girl	high	boy	day
KONIJN	rabbit	credit	carrot	mellow
DIER	animal	origin	farm	burn
KIND	child	which	parent	amount
KASTEEL	castle	vastly	palace	malice
LICHAAM*	body	very	corpse	corner
MENS	human	woman	being	penny
SLANG	snake	snack	lizard	lethal
STOEL	chair	night	seat	sort
SLEUTEL	key	new	lock	loan
GEBOUW	building	bulletin	office	others
ARMBAND	bracelet	brandish	necklace	navigate
VLIEGTUIG	plane	close	flight	slight
DRIEHOEK	triangle	printing	square	nature
STRAND	beach	black	shell	soup

*: removed out of Experiment 4

CHAPTER 3
CROSS-LANGUAGE EFFECTS OF PRIMING AND CONCRETENESS: EVIDENCE FROM RTS AND ERPS

Manuscript in preparation [1]

In this study English-French bilinguals performed a lexical decision task while reaction times (RTs) and event related potentials (ERPs) were measured to L2 targets, preceded by non-cognate L1 translation primes versus L1 unrelated primes (Experiment 1a), and vice versa (Experiment 1b). Significant masked translation priming was observed, indicated by faster reaction times and a decreased N400 for translation pairs as opposed to unrelated pairs, both from L1 to L2 (1a) and from L2 to L1 (1b), the latter effect being weaker (RTs) and less longer lasting (RTs, ERPs). N250 effects were present, more strongly and earlier in the L2 to L1 condition. We also observed ERP-concreteness effects for L1 targets, indicated by an increased N400 for concrete words as oppossed to abstract words, and a similar but delayed N400 concreteness effect in L2. However, there was no interaction between priming and concreteness in either direction (L1-L2 or L2-L1), a conclusion that was also supported by the different distribution of priming effects (typically more posterior) and concreteness effects (typically more anterior). These effects were replicated in a second set of experiments (Experiments 2a-b) employing a longer SOA (120ms vs 200ms).

[1] This paper was co-authored by Phillip Holcomb and Robert Hartsuiker

Although bilinguals have been the focus of study for years now, there is still much debate on how bilinguals mentally organise two languages. While many researchers agree that a bilingual's first language (L1) might influence their second language (L2) processing, there is less consensus about L2 influences on L1. For instance, conflicting data have been obtained using the masked translation priming paradigm to study L2 to L1 influences. The fact that most studies failed to find faster lexical decision times to L1 targets (e.g. *BOY*) when preceded by masked non-cognate L2 translation primes (L2 translation of *boy*) than when preceded by an unrelated L2 word (e.g. Finkbeiner, Forster, Nicol, & Nakamura, 2004; Gollan, Forster, & Frost, 1997; Jiang, 1999; Jiang & Forster, 2001), has been taken as evidence for the revised hierarchical model of Kroll & Stewart (1994). This model suggests that L2 accesses L1 only through direct links in the lexicon, instead of via their shared concept (except for highly proficient bilinguals). Since it is generally assumed that translation priming originates at the semantic level (Finkbeiner, Forster, Nicol, & Nakamura, 2004; Grainger & Frenck-Mestre, 1998), it seems logical, according to the RHM, that L2 to L1 priming effects have not been observed.

However, some recent studies did find significant L2 to L1 priming effects (Basnight-Brown & Altarriba, 2007; Duyck & Warlop, in press; Schoonbaert, Duyck, Brysbaert, & Hartsuiker, 2008; we refer to the latter study for a recent review of masked translation priming studies, using lexical decision), and therefore argue against a qualitatively different lexico-semantic organisation in both languages. It is interesting to find out where these studies differ and which factors can strengthen the lexico-semantic connections in L2. Some might argue that it is the specific languages of the bilinguals that might cause different effects or null-effects. For instance, languages with different scripts (e.g. Japanese and English) might interact differently than two same-script languages (e.g. French and English). In their 1997-study, Gollan, Forster, and Frost (1997) mentioned that cross-script priming with non-cognates should be easier to obtain, because the different script of the prime functions as a cue for the lexical processor and thus primes are easier to access. However, none of the studies (except Experiment 1, by Jiang, 1999) testing translation priming with different scripts observed L2 to L1 priming effects, while the recent studies that did show a significant effect (or a trend to significance) were all same-script translation priming studies, testing Spanish-English, French-English, Dutch-French, and Dutch-English bilinguals (Basnight-Brown & Altarriba, 2007; Duyck & Warlop, in press; Grainger & Frenck-Mestre, 1998; Schoonbaert et al, 2008, respectively). Additionally, proficiency of the bilinguals needs to be considered. Note that Basnight-Brown and Altarriba (2007) not only used same-script languages, but they also tested participants living in their L2 environment (as well as Grainger & Frenck-Mestre, 1998), and thus these bilinguals can be considered as highly proficient. Although this might have contributed to the significance of the L2 to L1 priming effect, the two most recent studies showing clear translation priming from L2 to L1 did test unbalanced bilinguals living in their L1 environment (Duyck & Warlop, in press; Schoonbaert, et al., 2008). According to the RHM, unbalanced bilinguals did not yet develop strong lexico-semantic links, and thus these effects cannot be accounted for by this model.

Differences in priming procedure, in statistical power, in characteristics of the materials, etc. are all factors that may or may not have contributed to the different priming effects obtained in the reported studies. At this point, it would be fair to say that L2 can facilitate L1, even in a masked priming paradigm, but only under certain conditions and possibly not for every bilingual. The present study further explores what some of these conditions might be, for instance by manipulating stimulus materials (word concreteness). Theoretically, we also wanted to more precisely track the time-course of word processing in translation priming as well as explicitly collect evidence for a semantic locus of both L1 to L2 and L2 to L1 translation priming effects, in order to explore lexico-semantic organisation in L2. Therefore, this study, aside from behavioral measures, will also include ERP measures which have excellent temporal resolution (Rugg & Coles, 1995). Another advantage of ERPs is that one specific ERP component, the N400, is thought to reflect semantic integration during language processing use (Kutas & Federmeier, 2000; Kutas & Hillyard, 1980, 1984; Kounios & Holcomb, 1992, 1994). We wanted to investigate if the different priming conditions resulted in a modulation of the N400.

In a previous behavioral study (Schoonbaert, et al., 2008; see Chapter 1, Experiments 1 & 2), with Dutch-English bilinguals, masked translation priming effects were shown from L1 to L2, as well as from L2 to L1, the latter being the weaker effect. So, it entails on the one hand a replication of the well-known translation priming asymmetry, but on the other hand a significant though controversial L2 to L1 priming effect. There are no published ERP studies to date investigating masked translation priming. Nonetheless, some recent electrophysiological studies have proposed a range of ERP components that are picked up in within language repetition priming paradigms (Grainger, Kiyonaga, & Holcomb, 2006; Holcomb & Grainger, 2006, 2007). One of these components will be the focus of our study, namely the N400, which is a negative-going component that peaks between 400 and 600 ms after target onset and is typically larger at middle and posterior brain regions. In masked priming, this component is known to be reduced for targets preceded by repeated items, as opposed to targets preceded by unrelated items. Because the semantic representation of the target (e.g. *BOY*) is pre-activated by an identity or repetition prime (*boy*), the N400 component, reflecting semantic activation, is less negative and thus reduced. Finding this N400 modulation in masked priming from L2 to L1, would clearly indicate the use of a semantic route to transfer activation from L2 to L1, in other words: conceptual mediation. Note that there is one ERP-study testing translation priming, under unmasked conditions. Alvarez, Grainger and Holcomb (2003) indeed observed a modulation of the N400 as a result of priming. Interestingly, they found a reversed translation priming asymmetry: significant L1 to L2 priming effects, but stronger and earlier L2 to L1 effects. However, due to the very long stimulus onset asynchrony (SOA of 2700 ms) and the unmasked primes in this study, strategic effects could not be excluded (Neely, 1977). In fact, it seems likely that with such a long SOA that subjects in the Alvarez study were explicitly translating all L2 words into L1 so that when an L1 translation equivalent was presented on the next trial priming occurred not between languages but within L1 itself. So, it is yet to be determined whether L2 to L1 N400 (i.e., semantic) effects would occur when subjects cannot use such strategic processes.

Recently, another ERP component, the N250, has been found in masked repetition priming studies. This negative-going wave peaks around 250 ms. Its amplitude is reduced most (less negative) to targets that were preceded by identity primes, and becomes more negative the less targets lexically overlap with the preceded primes (Holcomb and Grainger, 2006). Holcomb and Grainger proposed that the N250 reflects a process whereby orthographic features are mapped on to lexical representations. It remains to be seen if N250 effects will be observed across languages (using non-cognates word pairs). Following the RHM (Kroll & Stewart, 1994), it could be hypothized that L1 to L2 priming will show less evidence of N250-effects, than L2 to L1 priming, because the model posits that L2 has strong direct lexical connections with L1, while activation from L1 to L2 will heavily rely on semantic mediation.

The study by Schoonbaert et al. (2008) also tentatively suggested that the semantic overlap of L1 and L2 representations differed quantitatively for abstract and concrete translation pairs, with the latter having more overlap (i.e. more semantic features that can be primed). Although the concreteness manipulation did not significantly interact with the priming effect, the numerical priming effects for concrete words were larger than for abstract words. While abstract prime-target translation pairs still produced a 79-ms L1 to L2 priming effect, the reserve effect did not reach significance (unlike the concrete pairs).

In the present study, we specifically set out to examine whether this difference between abstract and concrete words would modulate N400 priming effects.

Although no main concreteness effects were observed in the behavioral study of Schoonbaert, et al. (2008), ERP measures might prove better sensitivity in this regard as well as N400 effects has been found in several ERP studies where concreteness was manipulated (Holcomb, Kounios, Anderson, & West, 1999; Kounios & Holcomb, 1994; West & Holcomb, 200). This effect takes the form of more negative-going N400s to concrete words than to abstract words. Moreover, the effect is larger at anterior scalp sites, which is an atypical N400-distribution (N400 effects are usually larger over more posterior scalp sites). In a recent study, Lee and Federmeier (2008) showed that the N400-concreteness effect also generalizes to verbs.

Many previous studies have shown robust behavioral concreteness effect in various tasks, including lexical decision tasks (e.g., de Groot, 1992; Schwanenflugel, Harnish & Stowe, 1988), in which concrete words typically generate faster RTs and less errors than abstract words. We would like to note that the behavioral study of Schoonbaert et al. (2008) failed to show main concreteness effects.

In short, this study will test non-cognate masked translation priming under several conditions. We will test both directions of priming (L1 to L2, and more critically, L2 to L1), while manipulating stimulus materials, i.e. the concreteness of primes and targets. This will provide a test of same-script priming effects, using English-French bilinguals living in an L1 environment. We are including more sensitive ERP-measures to have a better understanding of the processes underlying cross-language priming in bilinguals, and to provide a test of early semantic activation in L2.

EXPERIMENT 1A: TRANSLATION PRIMING FROM L1 TO L2, AT 120 MS SOA

Method

Participants. Twenty English-French bilinguals (16 female; mean age = 19.85; *SD* = .99) from Tufts University participated in the experiment and were monetarily compensated for the for their time. Participants were all English native speakers and primarily used their mother tongue in daily life. All of them learned French in school and were currently enrolled or recently finished advanced French classes. None of them had learned French or any other language before the age of four. Mean age of the beginning of acquisition for French was 11.85 years (SD = 2.67). The number of months of immersion in a French-speaking environment ranged from .25 to fifteen (mean = 4.39; *SD* = 3.62). Detailed measures of language proficiency based on participants' self-ratings are shown in Table 1. All participants were right-handed (Edinburgh Handedness Inventory; Oldfield, 1971), and all reported having normal or corrected-to-normal vision with no history of neurological insult or language disability.

Table 1. Mean (*SD*) self-ratings in L1 and L2

Measure	L1 (English) Mean (SD)	L2 (French) Mean (SD)
Experiment 1 (120ms SOA)		
Reading ability	7.00 (.00)	5.35 (.59)
Speaking ability	7.00 (.00)	5.33 (.77)
Auditory Comprehension	7.00 (.00)	5.83 (.85)
Overall Proficiency	**7.00 (.00)**	**5.50 (.76)**
Experiment 2 (200ms SOA)		
Reading ability	6.95 (.22)	5.55 (.76)
Speaking ability	7.00 (.00)	5.65 (.81)
Auditory Comprehension	7.00 (.00)	5.70 (.66)
Overall Proficiency	**6.98 (.13)**	**5.63 (.74)**

Note — 7-point Likert scale (1= very poor; 7= excellent)

Stimuli and Design. The critical stimuli in this experiment were 160 English-French translation pairs (all three to eight letter words; see Appendix), including 80 abstract pairs (mean concreteness rating of 2.49, *SD* = 0.81) and 80 concrete pairs (mean concreteness rating of 6.53, *SD* = 0.36). Concreteness ratings were obtained by asking 21 English monolinguals how easy each word could be represented in physical space on a seven-point Likert scale from very difficult (abstract) to very easy (concrete). The mean printed frequency for all French target words was 1.83 log10 per million, and ranged from 0.45 to 2.98 (Lexique database of New, Pallier, Brysbaert, & Ferrand, 2004). The mean printed frequency for all English translation primes (used as targets in Experiment 1a) was 1.94 log10 per million, and ranged from 0.30 to 3.04 (Celex lexical database of Baayen, Piepenbrock, & van Rijn, 1993). The concreteness ratings for the two groups of words differed significantly on a two-tailed t-test ($p < .001$), whereas the length, frequency, bigram frequency and number of orthographic neighbors were matched between both the abstract French and the concrete French targets and abstract English and the concrete English primes (all *ps*>.10, on two-tailed tests). The measure used for this last variable was Coltheart's N, defined as the number of words differing by a single letter from the stimulus, preserving letter positions (e.g., *worse*, and *house* are both orthographic neighbors of *horse*; Coltheart, Davelaar, Jonasson, & Besner, 1977). The WordGen stimulus generation program (Duyck, Desmet, Verbeke, & Brysbaert, 2004) was used for all matching purposes. Cognate or interlingual homograph/homophone prime-target pairs, as well as overly polysemous words, were excluded from our stimulus lists.

The French word targets could be preceded by their English translation, or by an unrelated English word. Prime-target pairing was counterbalanced using a Latin-square design, creating four different lists. Each participant was assigned to one list, and consequently saw each target only once, either with the translation prime or with its control. However, all stimuli occurred as both translations and unrelated an equal number of times across participants. The order of prime-target trials was pseudo-randomized. An important feature of this design is that the prime and targets ERPs in the different conditions are formed from exactly the same physical stimuli (across subjects) which should reduce the possibility of ERP effects across conditions due to differences in physical features or lexical properties. The experiment involved a 2 (Concreteness: *abstract vs. concrete*) x 2 (Prime type : *translation vs. unrelated*) repeated measures design.

Additionally, 160 non-words were created that followed the French GPC-rules, serving as French filler targets for the lexical decision task. These non-word targets were matched with the French word targets on number of letters, bigram frequency, and number of orthographic neighbors (all *ps*> .30, two-tailed t-tests), in order to ensure their word-likeness and pronouncability. All non-words were preceded by unrelated English word primes.

Procedure. Each trial consisted of a sequence of four visual events. First, a row of ten hash marks [##########], serving as a forward mask and as a fixation mark, was presented for 500 ms. Second, the prime was displayed on the screen for 100 ms (10 refresh rates at 100 Hz). Third, a backward mask [##########] was presented for 20 ms. Fourth, the target was presented for 500 ms. After each priming sequence, a blank interval of 1000 ms was presented and replaced by a 2000 ms blink stimulus [(- -)]. Participants were asked to blink only when the blink stimulus was displayed. Stimulus presentation and response registration were controlled by ERP-software StimPres (Version 3.0 – NeuroCognition Lab, 2007). All stimuli were presented in Verdana font type as centered white characters with a black background on a standard 19" monitor, located 143 cm directly in front of the participant. Primes appeared in lowercase (font width 15, font height 30), whereas targets were presented in uppercase (font width 20, font height 40), to minimize visual feature overlap between primes and targets. For the masks, the same font size as for the primes was used.

Participants were asked to fixate the center of the screen and to decide as quickly and accurately as possible if the target stimulus was a French word or not. The two possible response buttons were the right key (for a 'Yes' response) and the left key (for a 'No' response) of a millisecond accurate game pad. The assignment of responses was reversed for half of the participants. Participants were not informed about the presence of the primes. Instructions were given in English (L1) by the experimenter (before the experiment). During the setup, participants filled out a handedness questionnaire (Edinburgh Handedness Inventory, by Oldfield, 1971). After the experiment, participants were asked to complete a short questionnaire about their L2 learning age, and L1 and L2 language proficiency (including self-ratings, see Table 1). They were also given a list of all L2 words in the experiment, and were asked to type the L1 translation. Mean performance on this post-translation task was 88.39% correct (*SD* = 6.61, range 71.88% to 96.88%).

Event-related potential recording procedure. This study was run at the Neurocognition Lab at Tufts University, Medford, MA. Participants were seated in a comfortable chair in a sound attenuating room. The electroencephalogram (EEG) was recorded from 29 active tin electrodes mounted on an elastic cap that was fitted on the participant's scalp (Electro-cap International, Eaton, OH). Additional electrodes were attached below the left eye (LE -- to monitor for vertical eye movement or blinks), to the right of the right eye (HE -- to monitor horizontal eye movement), over the left mastoid bone (used as reference), and over the right mastoid bone (recorded actively to monitor for differential mastoid activity – see Figure 1 for the electrode montage). All EEG electrode impedances were maintained below 5 kΩ (except the impedance for eye electrodes, which was less than 10 kΩ). The EEG (200 Hz sampling rate, bandpass 0.01 and 40Hz) was recorded continuously.

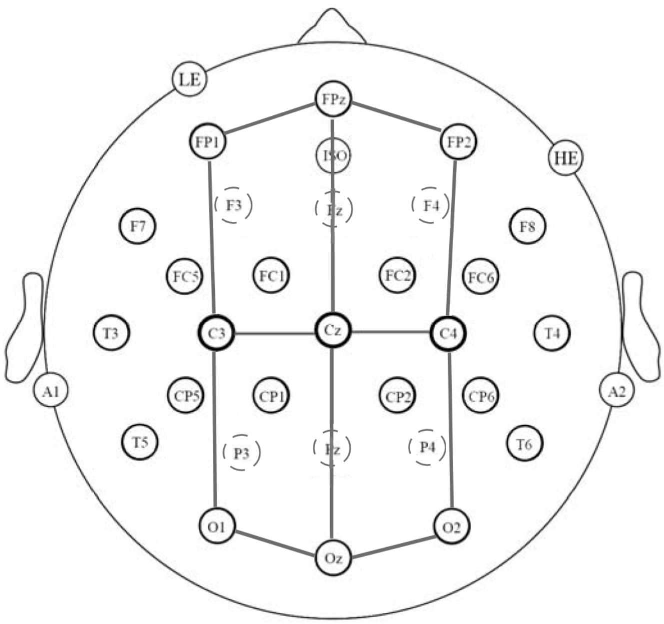

Figure 1. Electrode montage and nine sites used in analyses.

Data Analysis. Averaged ERPs time-locked to target onset were formed off-line, excluding trials with ocular and muscular artifact (< 0.57%). Trials with lexical decision errors, RTs below 200 ms and above 1500 ms, and post-translation errors were also excluded from both RT- and ERP-analyses (18.56% of all data). In order to carefully quantify the time course of the ERP effects, we measured mean amplitudes in five contiguous 100 ms time windows from 100 to 600 ms after target onset. For both behavioral (by subjects and by items) and ERP data (per time-window), an ANOVA was performed with Concreteness (*abstract vs. concrete*) and Prime type (*translation vs. unrelated*) as repeated measures factors, treating mean reaction time, mean error percentages and mean amplitude as respective dependent variables. The Greenhouse-Geisser (1959) correction was applied to all repeated measures in the ERP analyses with more than one degree of freedom. For ERP analysis the scalp distribution of effects was assessed at nine representative sites (FP1, FPz, FP2, C3, Cz, C4, O1, Oz and O2 – see Figure 1). These were divided into two three level factors of laterality (*left vs. center vs. right*) and front-to-back distribution (*anterior vs. middle vs. posterior*). To get a better picture of the scalp distribution across all electrodes scalp maps of ERP difference waves will be presented.

Results

Behavioral. French targets preceded by their English translation (583 ms) were recognized faster than those preceded by an unrelated English word (653 ms). This 70 ms priming effect was significant by subjects, $F_1(1,19) = 103.48, p < .001,$ and by items, $F_2(1,155) = 86.45, p < .001$. The main effect of Concreteness was not significant (both $Fs < 1$). Mean response time was 615 ms for abstract French targets, and 620 ms for concrete French targets. The priming effect did not interact with Concreteness (both $Fs < 1$; 69 ms priming for abstract pairs vs. 72 ms priming for concrete pairs).

There was a significant effect of Prime type on the *percentage of errors* to words (8%), $F_1(1,19) = 45.92, p < .001,$ and $F_2(1,158) = 36.36, p < .001$. French targets preceded by their English translation yielded fewer errors (5%) than those preceded by English unrelated primes (13%). No other significant effects were observed (all *Fs* <1).

ERPs. In this and all following experiments, there are no Prime type x Concreteness interactions. For this reason and for simplicity, ERPs for Prime type and Concreteness conditions are plotted separately for the nine electrodes used in the analyses. For this experiment, ERPs can be found in the left panel of Figures 2 and 3. Figures 4 and 5 present the voltage maps (formed from all 29 scalp sites), per effect and across different time windows. Significant effects are reported below, per 100 ms timewindow (from 100 ms to 600 ms after target onset) in order to best capture our results.

100- to 200-ms Target Epoch. Inspecting Figures 2 and 4, between 100 and 200 ms, clearly shows no effect of the priming manipulation. However, as can be seen in Figures 3 and 5 (at 150ms), a concreteness effect appears and seems to be somewhat larger at more anterior electrode sites. The ANOVAs were consistent with this observation: There was a significant Concreteness effect, $F(1,19) = 16.30$, p = .001, which marginally interacted with Front-to-back distribution, $F(2,38) = 2.56$, p = .098.

200- to 300-ms Target Epoch. Inspecting Figures 2 and 4, between 200 and 300ms, shows a small L1 to L2 priming effect at about 250 ms, but only seen at anterior sites. This observation is supported by a significant Prime type x Front-to-back distribution interaction, $F(2,38) = 7.60$, p = .003. In Figures 3 and 5, it can be seen that while the concreteness effect is still apparent at 200 ms, it fades away towards 250 and 300 ms. ANOVAs confirmed that there is a marginal effect of Concreteness in this window, $F(1,19) = 3.17$, p = .091.

300- to 400-ms Target Epoch. By inspecting Figures 2 and 4, a clear effect of priming is seen at 350 ms, most strongly at frontal electrode sites. ANOVAs confirmed that this L1 to L2 priming effect was significant, $F(1,19) = 21.11$, $p = .0002$. In Figures 3 and 5, an effect of concreteness can be seen around 350 ms. ANOVAs confirmed that the main Concreteness effect was significant, $F(1,19) = 7.32$, $p = .014$, although its interaction with Front-to-back distribution was not, $F(2,38) = 2.28$, $p = .120$.

400- to 500-ms Target Epoch. Figures 2 and 4 show very strong effects of priming at about 450 ms, over the more posterior electrode sites. ANOVAs confirmed that the L2 to L1 priming effect was significant, $F(1,19) = 27.19$, $p < .001$, as well as its interaction with Front-to-back distribution, $F(2,38) = 22.33$, $p < .001$. As can be seen in Figures 3 and 5, the concreteness manipulation is nearing its largest effect. The effect seems to be widely distributed, although somewhat stronger at frontal sites. ANOVAs supported this observation: There was a significant Concreteness effect, $F(1,19) = 16.16$, $p < .001$, while the interaction between Concreteness, Front-to-back distribution and Laterality nearly reached significance, $F(4,76) = 2.81$, $p = .052$.

500- to 600-ms Target Epoch. Figures 2 and 4 still show a clear L1 to L2 priming effect around 500-550 ms, although only visible at posterior electrode sites. ANOVAs confirmed that there was a significant interaction between Prime type x Front-to-back distribution, $F(2,38) = 6.54$, $p = .011$. Inspection of Figures 3 and 5, shows that there still is evidence for a concreteness effect in this late epoch. ANOVAs confirmed the presence of this late Concreteness effect, $F(1,19) = 7.78$, $p = .012$, although it did not interact with front-to-back in this window.

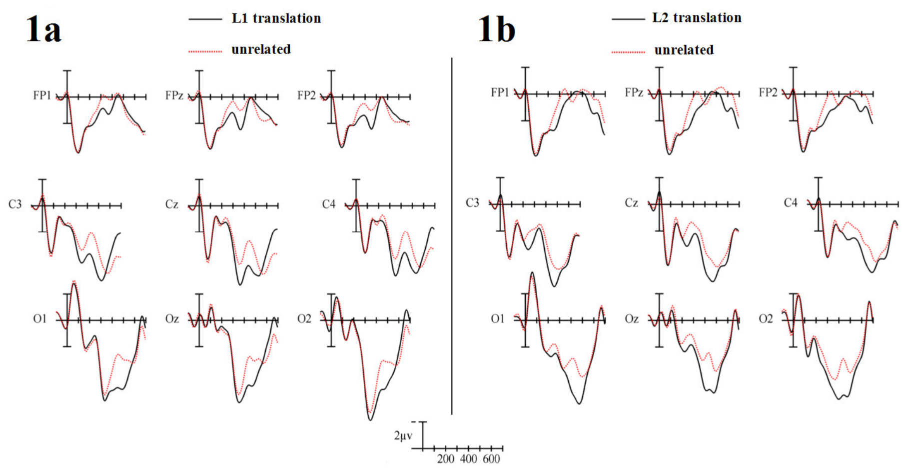

Figure 2. Event-related potentials time-locked to target onset in L1 to L2 translation priming conditions (1a) and L2 to L1 translation priming conditions (1b), plotted with the waveforms for their respective control conditions (Experiment 1).

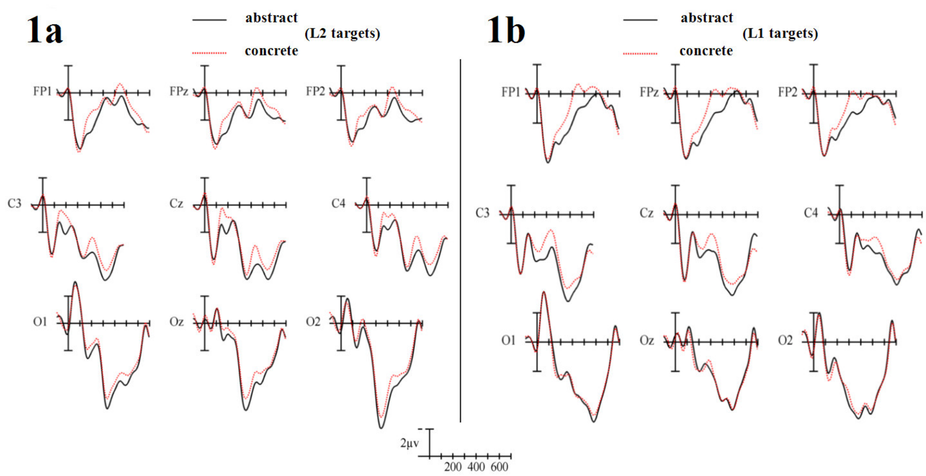

Figure 3. Event-related potentials time-locked to target onset for abstract and concrete L2 targets (1a) and L1 targets (1b) (Experiment 1).

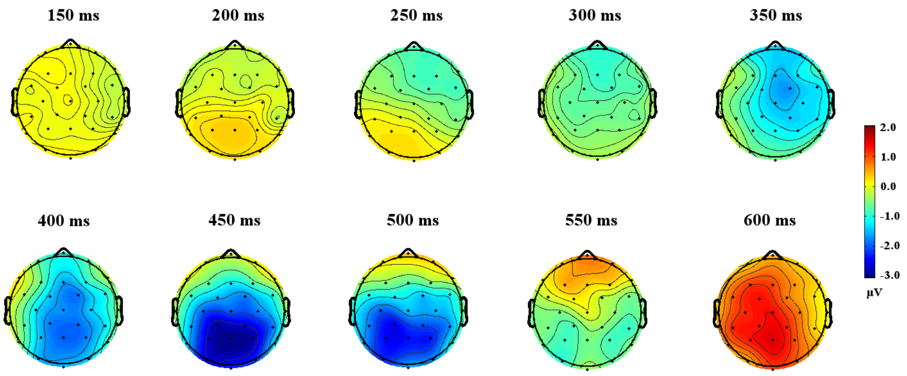

Figure 4. Voltage maps calculated from difference waves (*unrelated* - *translation*) in Experiment 1a (L1 to L2 priming), at each of nine time points encompassing the N250 and N400 epochs.

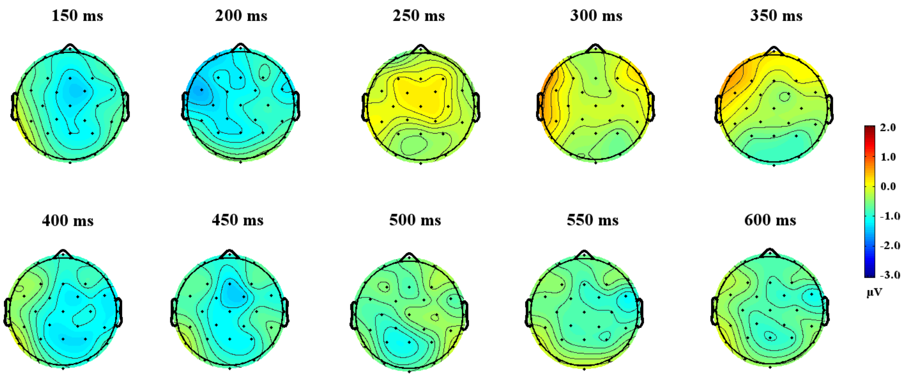

Figure 5. Voltage maps calculated from difference waves (*concrete* - *abstract*) in Experiment 1a (L1 primes and L2 targets), at each of nine time points encompassing the N400 epochs for primes and targets.

Before we provide a detailed discussion on the above mentioned data, we will present the data of the reverse priming direction, L2 to L1 (Experiment 1b). Experiment 1b used the same stimuli (by swapping primes and target) and participants as in Experiment 1a. Both experiments will then be discussed as one data-set.

EXPERIMENT 1B: TRANSLATION PRIMING FROM L2 TO L1, AT 120 MS SOA

Method

Participants. The same twenty English-French bilinguals who participated in Experiment 1a also participated in Experiment 1b.

Stimuli. Experiment 1b used the exact same critical stimuli as in Experiment 1a, except that the primes and targets were swapped. The L1 translation primes of Experiment 1a now served as L1 target words, preceded by L2 translation primes (the L2 targets from Experiment 1a). Additional filler items (unrelated French primes and English nonwords) were created as in Experiment 1a.

Procedure. The procedure was identical to the procedure used in Experiment 1a. The order of the experiments was counterbalanced across subjects.

Data Analysis. Averaged ERPs time-locked to target onset were formed off-line, excluding trials with ocular and muscular artifact (< 1.07%). Trials with lexical decision errors, RTs below 200 ms and above 1500 ms and post-translation errors were excluded (15.22% of all data).

Results

Behavioral. English targets preceded by their French translation (559 ms) were recognized faster than those preceded by an unrelated French word (583 ms). This 24 ms priming effect was significant, $F_1(1,19) = 23.67, p< .001$, and $F_2(1,155) = 4.77, p< .05$. The effect of Concreteness was not significant (both *Fs*< *1*). Mean response time was 572 ms for abstract French targets, and 570 ms for concrete French targets. The priming effect did not interact with Concreteness (both *Fs*< *1;* 28 ms priming for abstract pairs vs. 19 ms priming for concrete pairs).

The L2 to L1 priming effect on the percentage of errors to words (2%) was significant, $F_1(1,19) = 11.86, p< .01$, and $F_2(1,158) = 4.61, p< .05$. English targets preceded by their French translation yielded fewer errors (3%) than those preceded by English unrelated primes (5%). Concrete English targets (3%) also yielded fewer errors than their abstract equivalents (5%), $F_1(1,19) = 7.92, p< .05$, and $F_2(1,158) = 4.99, p< .05$, but the Prime type x Concreteness interaction was not significant (both *Fs*< 1).

ERPs. ERPs for Prime type and Concreteness conditions in this experiment are shown in the right panel of Figure 2 and 3 respectively. Figure 6 and 7 present the voltage maps (formed from all 29 scalp sites), per effect and across different time windows.

100- to 200-ms Target Epoch. Figures 2 and 6, between 100 and 200 ms, show no clear effect of the priming manipulation, F(1,19) = 2.32, p = .144, and no interaction between Prime type and Front-to-back distribution (*F*<1). As can be seen in Figures 3 and 7 (at 150 ms), there is no clear concreteness effect. ANOVAs indicated that the Concreteness effect was not significant (*F*<1).

200- to 300-ms Target Epoch. Inspecting Figures 2 and 6, between 200 and 300 ms, shows a strong and widely distributed L2 to L1 priming effect peaking at about 250 ms. This observation is supported by a significant effect of Priming, $F(1,19) = 26.51$, $p < .001$. In Figures 3 and 7, a concreteness effect starts to show at left anterior sites at about 250 ms, and appears to increase in size and distribution towards 300 ms. ANOVAs confirmed that there is a significant effect of Concreteness, $F(1,19) = 9.08$, $p = .007$, as well as a significant Concreteness x Front-to-back distribution interaction, $F(2,38) = 4.60$, $p = .027$, and a significant three-way interaction between Concreteness, Front-to-back distribution and Laterality, $F(4,76) = 5.33$, $p = .004$.

300- to 400-ms Target Epoch. By inspecting Figures 2 and 6, an effect of priming can be seen at 350 ms, although it is more apparent at right frontal electrode sites. ANOVAs confirmed that this L2 to L1 priming effect was significant, $F(1,19) = 13.38$, $p = .002$. Although the Prime type x Front-to-back distribution interaction did not reach significance ($F<1$), the three-way interaction with Laterality was significant, $F(4,76) = .004$. In Figures 3 and 7, a strong effect of concreteness can be seen around 350 ms, especially at left anterior sites. ANOVAs confirmed that the main Concreteness effect was significant, $F(1,19) = 17.47$, $p < .001$, as well as its interaction with Front-to-back distribution, $F(2,38) = 9.78$, $p < .001$, and the three-way interaction between Concreteness, Front-to-back distribution and Laterality, $F(4,76) = 5.31$, $p = .004$.

400- to 500-ms Target Epoch. Figures 2 and 6 show very strong effects of priming at about 450 ms over the more posterior electrode sites. ANOVAs confirmed that the L2 to L1 priming effect was significant, $F(1,19) = 20.19$, $p < .001$, as well as its interaction with Front-to-back distribution, $F(2,38) = 34.02$, $p < .001$. As can be seen in Figures 3 and 7, the left anterior concreteness effect starts to decrease around 450 ms. ANOVAs supported this observation: The concreteness effect was still somewhat significant, $F(1,19) = 4.74$, $p < .042$. Both the two-way interaction with Front-to-back distribution, and the three-way interaction with Front-to-back distribution and Laterality almost reached significance: F(2,38) = 2.94, p = .080, and *F*(4,76) = 2.37, p = .085, respectively.

500- to 600-ms Target Epoch. Figures 2 and 6 still show some of the L2 to L1 priming effect around 500 ms. ANOVAs confirmed that there was a significant priming effect, F(1,19) = 6.53, p = .019. Inspection of Figures 3 and 7, shows that the concreteness effect has faded out in this late epoch, although some of it is still visible at electrode sites more to the left. ANOVAs confirmed the absence of a significant Concreteness effect (*F*<1), while its interaction with Laterality still reached significance, *F*(2,38) = 4.58, p = .036.

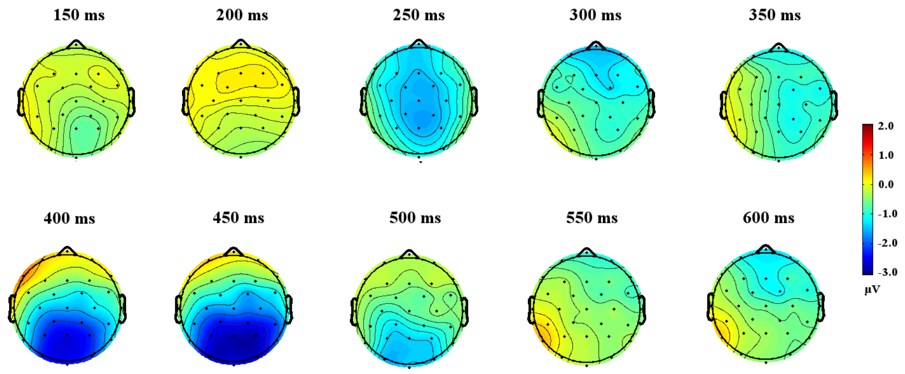

Figure 6. Voltage maps calculated from difference waves (*unrelated - translation*) in Experiment 1b (L2 to L1 priming), at each of nine time points encompassing the N250 and N400 epochs.

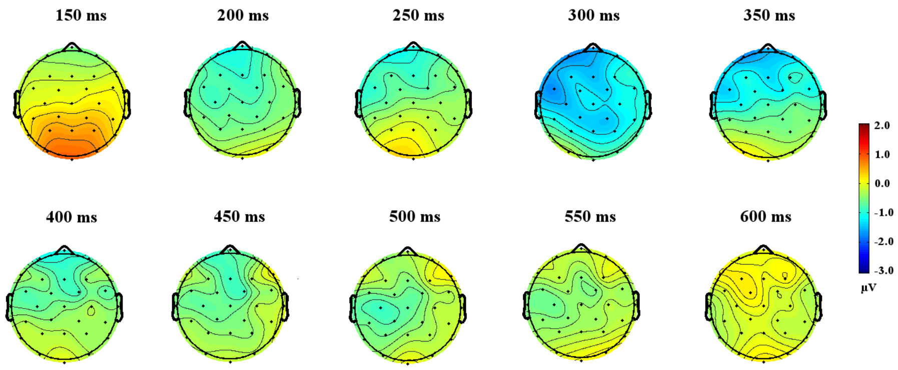

Figure 7. Voltage maps calculated from difference waves (*concrete* - *abstract*) in Experiment 1b (L2 primes and L1 targets), at each of nine time points encompassing the N400 epochs for primes and targets.

Combined analysis and discussion for Experiment 1a-b

The *behavioral analyses* showed a significant translation priming effect from L1 to L2 as well as from L2 to L1, although the latter effect was smaller (70 ms vs. 24 ms). An additional analysis across both experiments, adding Direction (*L1-L2* vs. *L2-L1*) as a within-subjects factor, confirmed this traditional translation priming asymmetry [$F_1(1,19) = 36.20, p < .001$, and $F_2(1,158) = 40.59, p < .001$.]. This analysis also indicated that targets were recognized faster and more accurately in L1 than in L2 [all *Ps* < .01]. Concrete words were more accurately recognized than abstract words, but this was true only for L1 targets. The combined analysis for both experiments vaguely confirmed this interaction [$F_1(1,19) = 3.35, p < .09$, and $F_2(1,158) = 2.78, p < .10$]. The concreteness effects did not interact with the priming manipulation. This pattern of results is a strong replication of the data of Schoonbaert, et al. (2008), where priming effects from L1 to L2, and vice versa ran to 90 ms and 21 ms respectively, irrespective of concreteness. However, more interesting at this point are the data from the ERPs analyses.

We will first summarize the *ERP effects due to priming*. The ERP analyses confirmed the existence of L1 to L2 priming effects, as well as L2 to L1 priming effects. The effects start at *about 250 ms*, which is the typical N250 window. We seem to observe a strong widely distributed N250 translation effect for the L2 to L1 priming condition (i.e., no interaction with distribution). There is also a smaller N250 effect in the L1 to L2 condition, but it is present only at anterior sites (it shows up only in the priming x Front-to-back distribution interaction). The combined analysis confirmed what ~~we~~ could be labelled as a 'N250-asymmetry' [Direction x Prime type interaction, $F(1,19) = 5.77$, $p = .027$; Prime type x Front-to-back distribution, $F(2,38) = 5.85$, $p = .009$; and a marginal three-way interaction between Direction, Prime type, and Front-to-back distribution interaction, $F(2,38) = 2.64$, $p = .087$]. At a later window, at *about 350 ms*, the L1 to L2 priming condition is producing the larger effect, that is widely distributed. Based on its distribution (in comparison with the N250-distribution for L2-L1 priming in the previous window, see Figures 4 and 6), the effect looks like an N250-effect, but it is 100 ms late. We will further discuss this in the General Discussion. The small L2-L1 priming effect is seen most strongly at right frontal electrode sites. The combined analysis for both experiments indeed indicated a three-way interaction between Prime type, Front-to-back distribution, and Laterality [$F(4,76) = 2.93$, $p = .049$], as well as a marginal Direction x Prime type x Front-to-back distribution interaction [$F(2,38) = 2.80$, $p = .088$]. At *about 450 ms*, large N400-translation priming effects are observed for both priming directions. These effects have a typical N400 posterior distribution. The combined analysis further confirmed this [Prime type x Front-to-back distribution, $F(2,38) = 49.33$, $p < .001$]. N400 translation priming effects are still visible early in the *500-600 ms* time window, but are larger and longer lasting for the L1 to L2 direction of priming. This was confirmed in the combined analysis [marginal Direction x Prime type interaction, $F(1,19) = 3.53$, $p = .076$, and a Direction x Prime type x Front-to-back distribution interaction, F(2,38) = 6.46, p = .009]. This is probably a latency shift in the N400 for L2 targets, due to slower processing of these items.

The first clear *ERP-concreteness effects* (typically more frontal) are seen as early as *150ms*, which is somewhat surprising. These effects are only visible in the L1-L2 condition. The combined analysis for both directions further confirmed this [Direction x Concreteness interaction, $F(1,19) = 7.43$, p = .013, and Direction x Concreteness x Front-to-back distribution interaction, $F(2,38) = 7.09$, p = .003]. These L2 targets were all preceded by L1 primes that had the same concreteness as the targets. Therefore, and considering the rather long prime duration of 100 ms and 20 ms ISI, these early concreteness effect are most likely elicited by the English primes. This effect is still somewhat visible early in the next time window. However, at this point (around *250ms*) a concreteness effect elicited by the L2-L1 condition starts to show (at left anterior sites). This was confirmed in the cross-experiment comparison [Direction x Concreteness x Front-to-back distribution x Laterality interaction, F(4,76) = 4.12, p = .020]. It is hard to say whether this is the beginning of the L1 target concreteness effect, or the slightly later prime concreteness effect for L2 primes, as seen in the previous epoch for L1 primes. Around *350 ms*, clear N400-concreteness effects are found in the L2-L1 condition (larger at left anterior sites). This probably reflects the largest N400 for the L1 concreteness effect. The L2 concreteness (L1-L2 condition) are weaker and appear posterior in this epoch. The cross-experiment comparison showed a significant Direction x Concreteness x Front-to-back distribution interaction [$F(2,38) = 9.28$, $p < .001$] as well as a four-way interaction with Laterality [F(4,76) = 3.11, p = .032]. At about *450ms*, the L1 concreteness is starting to wane, but the L2 effect is nearing its largest. The L2 effect does not interact with Front-to-back distribution, although the cross-experiment comparison indicated a significant four-way interaction between Direction, Concreteness, Front-to-back distribution and Laterality [$F(4,76) = 5.15$, p = .002]. At *500-600ms*, the concreteness effect to L2 targets is still visible and bigger than the L1 target concreteness effect, although the cross-experiment comparison did not indicate a significant Direction x Concreteness interaction [only a marginal Concreteness x Front-to-back distribution interaction, $F(1,19) = 3.27$, $p = .055$]. No interactions between the priming and the concreteness manipulations were observed.

As mentioned in the introduction, we also manipulated the priming procedure, in order to see if and how this affected the different priming effects. In the first set of experiments, we used a 120-ms SOA, according to recommendations offered in recent study by Altarriba & Basnight-Brown (2007) on how to perform cross-language priming. These authors stated that preferably SOAs below 200-300ms should be used. However, due to the very early ERP-effects observed in the concreteness manipulations, most likely due to unexpected N400-effects to our primes, we wanted to increase the SOA in an attempt to disentangle late concreteness effects to L2 primes and the early effects of concreteness to the L1 targets (see Experiment 1a). In these conditions, both effects may have overlapped, which causes difficulties to interprete the effects. A second reason to increase the SOA was to maximize comparability with our previous research where we used a 250-ms SOA. Therefore, the following set of experiments will examine masked translation priming from L1 to L2 (Experiment 2a) and from L2 to L1 (Experiment 2b), at a 200-ms SOA (keeping in mind the recommendations by Altarriba & Basnight-Brown, 2007).

EXPERIMENT 2A: TRANSLATION PRIMING FROM L1 TO L2, AT 200 MS SOA

Method

Participants. Twenty English-French bilinguals comparable to those in Experiment 1 (see Table 1) participated in this experiment (18 female; mean age = 22.00, *SD* = 2.73). Mean age of acquisition for French was 11.25 (*SD* = 2.75). The number of months of immersion in a French-speaking environment ranged from .25 to thirty-six (mean = 9.33; *SD* = 9.87). Mean performance on their post-translation task was 85.99% correct (*SD* = 9.32%, range 70.00 to 98.75 %).

Stimuli. All stimuli were identical to the stimuli of Experiment 1a.

Procedure. The procedure was identical to the procedure used in Experiments 1a-b, except for the duration of the backward mask. In this experimental set, we increased the SOA between prime and target onset from 120 ms to 200 ms by increasing the duration of the backward mask from 20 ms to 100 ms.

Data Analysis. Averaged ERPs time-locked to target onset were formed off-line, excluding trials with ocular and muscular artifact (< 1.07%). Trials with lexical decision errors, RTs below 200 ms and above 1500 ms and post-translation errors were also excluded (19.97% of all data).

Results

Behavioral. French targets preceded by their English translation (581 ms) were recognized faster than those preceded by an unrelated English word (650 ms). This 69-ms priming effect was significant, $F_1(1,19) = 46.71$, $p < .001$, and $F_2(1,155) = 126.46$, $p < .001$. The main effect of Concreteness was not significant (both $Fs < 1$). Mean response time was 617 ms for abstract French targets, and 614 ms for concrete French targets. The priming effect did not interact with Concreteness, $F_1(1,19) = 3.07$, $p < .10$, and $F_2(1,155) = 1.26$, $p < .30$; 60 ms priming for abstract pairs vs. 78 ms priming for concrete pairs).

There was a significant effect of Prime type on the *percentage of errors* to words, $F_1(1,19) = 27.73$, $p < .001$, and $F_2(1,158) = 24.33$, $p < .001$. French targets preceded by their English translation yielded less errors (4%) than those preceded by English unrelated primes (8%).

ERPs. ERPs for Prime type and Concreteness conditions in this experiment are plotted separately in the left panel of Figure 8 and 9 respectively, for the nine electrodes used in the analyses. Figure 10 and 11 present the voltage maps (formed from all 29 scalp sites), per effect and across different time windows.

100- to 200-ms Target Epoch. Figures 8 and 10 show no indication of a priming effect in this epoch. ANOVAs confirmed that there was no significant priming effect, ($F<1$). As can be seen in Figures 9 and 11 (at about 150 ms), a concreteness effect appears at more anterior electrode sites, and seems somewhat stronger in left anterior regions. ANOVA statistics were consistent with this observation: There was a significant Concreteness effect, $F(1,19) = 10.15$, p = .005, as well as a significant interaction with Front-to-back distribution, $F(2,38) = 12.42$, p <.001.

200- to 300-ms Target Epoch. Inspecting Figures 8 and 10 shows a small L1 to L2 priming effect at about 250 ms, only seen at posterior sites. This observation is supported by a significant Prime type x Front-to-back distribution interaction, $F(2,38) = 4.93$, $p = .017$. In Figures 9 and 11, there is no real indication of a concreteness effect. ANOVAs showed that the effect of Concreteness is not significant ($F<1$).

300- to 400-ms Target Epoch. By inspecting Figures 8 and 10, a clear effect of L1 to L2 priming can be seen around 350 ms, most strongly at center/middle electrode sites. ANOVAs confirmed that this L1 to L2 priming effect was significant, $F(1,19) = 20.09$, $p < .001$, as were the Prime type x Front-to-back distribution interaction, $F(2,38) = 4.87$, $p = .018$, and the Prime type x Laterality, $F(2,38) = 13.67$, $p < .001$. In Figures 9 and 11, there is no indication yet of a concreteness effect ($F<1$).

400- to 500-ms Target Epoch. Figures 8 and 10 show very strong effects of priming at about 450 ms, over the more posterior electrode sites. ANOVAs confirmed that the L2 to L1 priming effect was significant, $F(1,19) = 18.19$, $p < .001$, as well as its interaction with Front-to-back distribution, $F(2,38) = 29.00$, $p < .001$. As can be seen in Figures 9 and 12, the concreteness manipulation is nearing its largest effect. The effect seems to be widely distributed, although somewhat stronger at frontal sites. ANOVAs supported this observation: There was a significant Concreteness effect, $F(1,19) = 27.59$, $p < .001$, and a significant interaction with Front-to-back distribution, $F(2,38) = 4.59$, $p = .027$.

500- to 600-ms Target Epoch. Figures 8 and 10 still show a residual L1 to L2 priming effect around 550 ms, although only visible at posterior electrode sites. ANOVAs confirmed that there was a significant interaction between Prime type x Front-to-back distribution, $F(2,38) = 7.45$, $p = .005$. Inspection of Figures 9 and 12, shows that there still is evidence for a concreteness effect in this late epoch, most strongly at middle electrode sites. ANOVAs confirmed the presence of this late Concreteness effect,

$F(1,19) = 20.06$, $p < .001$, and also showed a significant interaction with Front-to-back distribution, $F(2,38) = 6.00$, $p = .012$.

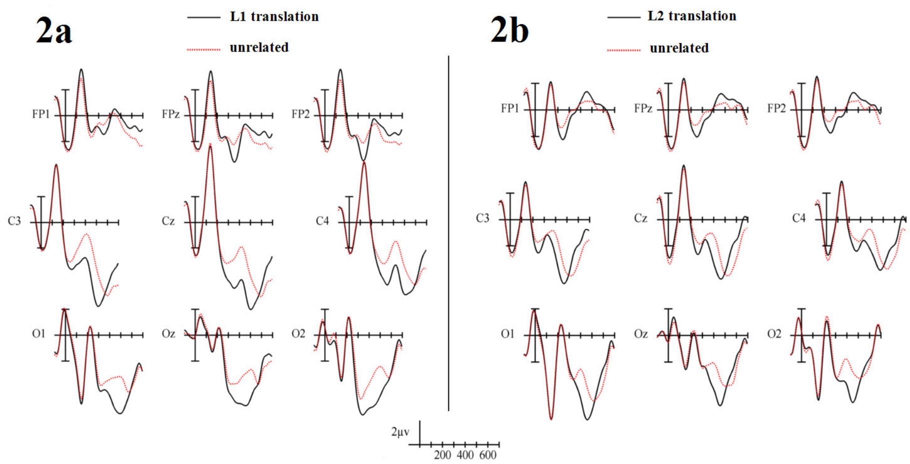

Figure 8. Event-related potentials time-locked to target onset in L1 to L2 translation priming conditions (2a) and L2 to L1 translation priming conditions (2b), plotted with the waveforms for their respective control conditions (Experiment 2).

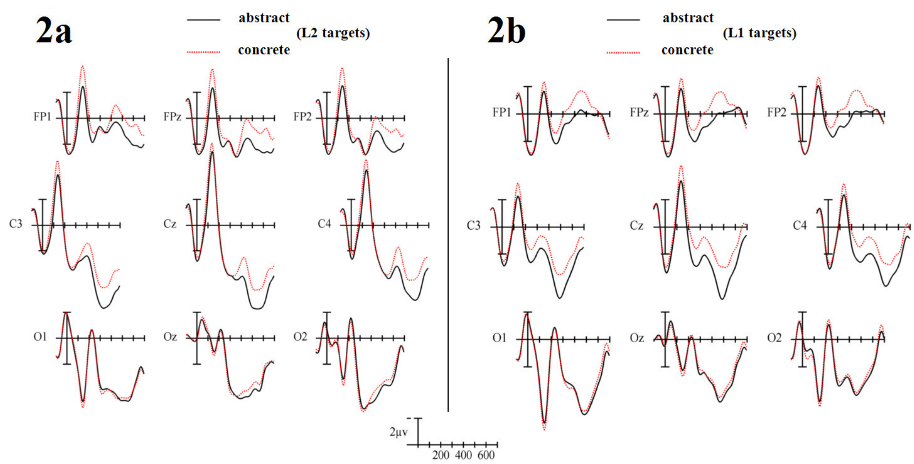

Figure 9. Event-related potentials time-locked to target onset for abstract and concrete L2 targets (2a) and L1 targets (2b) (Experiment 2).

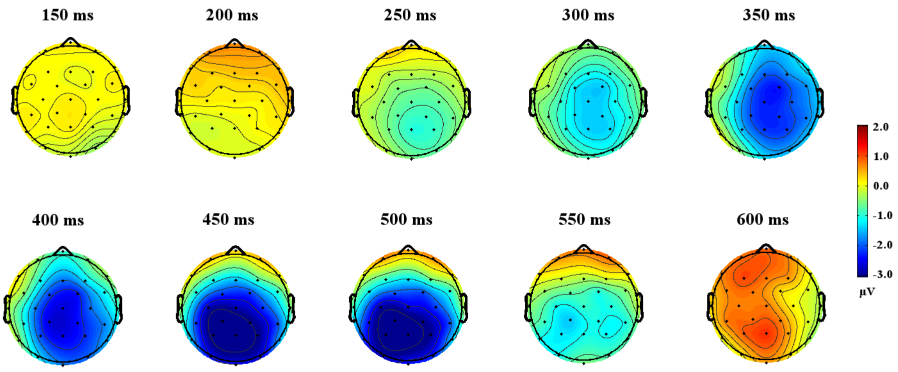

Figure 10. Voltage maps calculated from difference waves (*unrelated - translation*) in Experiment 2a (L1 to L2 priming), at each of nine time points encompassing the N250 and N400 epochs.

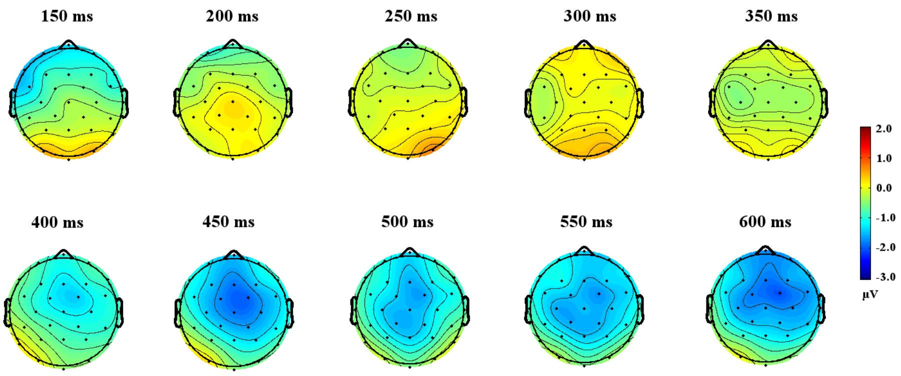

Figure 11. Voltage maps calculated from difference waves (*concrete - abstract*) in Experiment 2a (L1 primes and L2 targets), at each of nine time points encompassing the N400 epochs for primes and targets.

The data of the present experiment will be discussed in comparison with the data of the reverse priming direction, L2 to L1 (Experiment 2b). Experiment 2b tested this, while using the same stimuli and participants as in Experiment 1a, as well as the 200-ms SOA.

EXPERIMENT 2B: TRANSLATION PRIMING FROM L2 TO L1, AT 200 MS SOA

Method

Participants. The same twenty English-French bilinguals who participated in Experiment 2a also participated in Experiment 2b.

Stimuli. Stimuli were identical to the stimuli of Experiment 1b.

Procedure. The procedure was identical to the procedure used in Experiment 2a.

Data Analysis. Averaged ERPs time-locked to target onset were formed off-line, excluding trials with ocular and muscular artifact (< 1.29%). Trials with lexical decision errors, RTs below 200 ms and above 1500 ms and post-translation errors were also excluded (16.31% of all data).

Results

Behavioral. English targets preceded by their French translation (558 ms) were recognized faster than those preceded by an unrelated English word (587 ms). This 29-ms priming effect was significant, $F_1(1,19) = 25.69,$

p< .001, and $F_2(1,155) = 23.33$, *p< .001*. Concrete English targets (561 ms) were also faster recognized than their abstract equivalents (581 ms), $F_1(1,19) = 9.73$, *p< .01,* and $F_2(1,155) = 14.15$, *p< .001*, but the prime x concreteness interaction was not significant (both *Fs*< 1; 32 ms priming for abstract pairs vs. 26 ms priming for concrete pairs).

There was a significant effect of Prime type on the *percentage of errors* to words, $F_1(1,19) = 14.94$, *p< .001,* and $F_2(1,158) =10.26$, *p< .001*. French targets preceded by their English translation yielded less errors (1%) than those preceded by English unrelated primes (2%). There were no other significant effects.

ERP. ERPs for Prime type and Concreteness conditions in this experiment are shown in the right panel of Figure 8 and 9 respectively. Figure 12 and 13 present the voltage maps (formed from all 29 scalp sites), per effect and across different time windows.

100- to 200-ms Target Epoch. Figures 8 and 12 show no indication of an L2 to L1 priming effect in this epoch. ANOVAs confirmed that there was no significant priming effect (*F*<1). As can be seen in Figures 9 and 13 (at about 150 ms), a concreteness effect appears at more anterior electrode sites. ANOVAs confirmed that although the main Concreteness effect was not significant, *F*(1,19) = 1.67, p = .212, there was a significant interaction with Front-to-back distribution, *F*(2,38) = 17.61, p <.001.

200- to 300-ms Target Epoch. Figures 8 and 12 show a small L2 to L1 priming effect at about 250 ms, which is more widely distributed. This observation is supported by a significant effect of Priming, *F*(1,19) = 4.71, p = .043. In Figures 9 and 13, a clear concreteness effect can be observed at about 250 ms, which appears to be somewhat more frontal and stronger at central electrode sites. ANOVAs showed that the effect of Concreteness is significant, *F*(1,19) = 9.13, p = .007, as well as its two-way interaction with

Front-to-back distribution, $F(2,38) = 9.77$, $p = .006$, and their three-way interaction with Laterality, $F(4,76) = 3.25$, $p = .040$.

300- to 400-ms Target Epoch. Figures 8 and 12 indicate the presence of a small L2 to L1 priming effect, at about 350 ms, over the posterior electrode sites. ANOVAs confirmed that this L2 to L1 priming effect was significant, $F(1,19) = 4.65$, $p = .044$. In Figures 9 and 13, a clear effect of concreteness is present at more frontal electrode sites. ANOVAs confirmed that the main Concreteness effect was significant, $F(1,19) = 8.51$, $p = .009$, as well as its interaction with Front-to-back distribution, $F(2,38) = 11.97$, $p < .001$.

400- to 500-ms Target Epoch. Figures 8 and 12 show very strong effects of priming at about 450 ms, over the more posterior electrode sites. ANOVAs confirmed that the L2 to L1 priming effect was significant, $F(1,19) = 6.96$, $p = .016$, as well as its interaction with Front-to-back distribution, $F(2,38) = 19.27$, $p < .001$. As can be seen in Figures 9 and 13, the concreteness manipulation is nearing its largest effect. The effect seems to be widely distributed, although somewhat stronger at frontal sites. ANOVAs confirmed that there was a significant Concreteness effect, $F(1,19) = 11.23$, $p = .003$, and a significant interaction with Front-to-back distribution, $F(2,38) = 14.68$, $p < .001$.

500- to 600-ms Target Epoch. Figures 8 and 10 show a reversed L2 to L1 priming effect around 550 ms, although the ANOVAs indicated that this effect was only marginally significant, $F(1,19) = 4.19$, $p = .055$. Inspection of Figures 9 and 12, shows that there still is some evidence for a concreteness effect in this late epoch. ANOVAs confirmed the presence of this late Concreteness effect, $F(1,19) = 6.62$, $p = .019$, and also showed a significant interaction with Front-to-back distribution, $F(2,38) = 7.81$, $p = .003$.

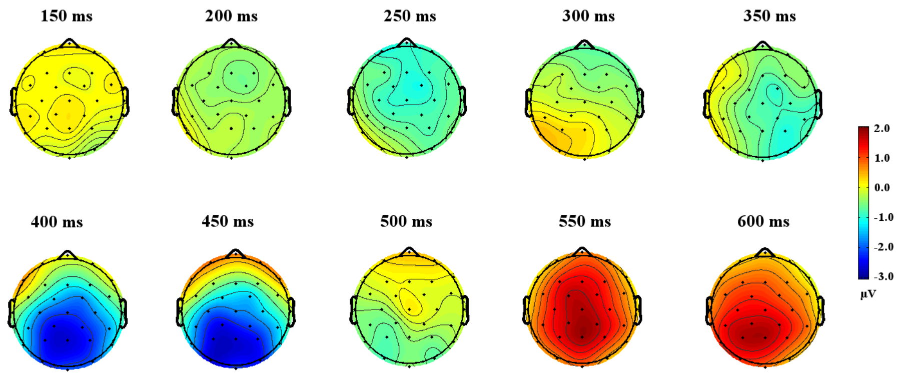

Figure 12. Voltage maps calculated from difference waves (*unrelated - translation*) in Experiment 2b (L2 to L1 priming), at each of nine time points encompassing the N250 and N400 epochs.

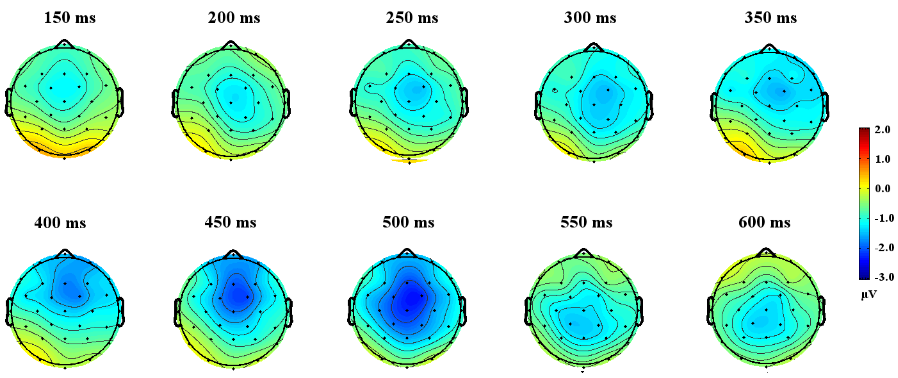

Figure 13. Voltage maps calculated from difference waves (*concrete - abstract*) in Experiment 2b (L2 primes and L1 targets), at each of nine time points encompassing the N400 epochs for primes and targets.

Cross-experimental comparison and discussion for Experiment 2a-b.

The *behavioral analyses* again showed translation priming from L1 to L2 as well as from L2 to L1, the latter being a weaker, though significant effect (69 ms vs. 29 ms). An additional analysis across both experiments, adding Direction (*L1-L2* vs. *L2-L1*) as a within-subjects factor, confirmed this asymmetry [$F_1(1,19) = 16.74, p < .01,$ and $F_2(1,158) = 29.40, p < .001$]. Concrete words were recognized faster than abstract words, but this was true only for L1 targets. The combined analysis for both experiments further confirmed this interaction [$F_1(1,19) = 3.18, p < .10,$ and $F_2(1,158) = 5.56, p < .05$]. The concreteness effects did not interact with the priming manipulation. Overall, targets were recognized faster and more accurately in L1 than in L2 [all *ps* < .01]. This pattern of results replicates the data of Schoonbaert et al. (2008), as well as the behavioral data from Experiments 1a-b, where a somewhat shorter SOA was used. Below, we will first discuss the ERP results of the present experiments, before going into a detailed discussion comparing the data of both SOAs (Experiment 1a-b versus Experiment 2a-b).

Earliest *ERP priming effects* (while priming at 200ms SOA) were observed at about *250 ms*, the typical N250 window, in both priming directions. Interestingly, the cross-experiment comparison suggests that the N250 effect has a different distribution for the two languages [Direction x Prime type x Front-to-back distribution, $F(2,38) = 7.78$, p = .002]. While the effect is more anterior/widely distributed in the L2-L1 direction (as in Experiment 1b), it is more posterior for the L1-L2 priming direction (unlike Experiment 1a). We will return to this point in the General Discussion. At a later time-window, around *350ms,* we observed the beginning of what looks like strong N400-like priming effects for the L1-L2 priming direction (although most strongly at center/middle electrode sites), and weaker effects for L2-L1 (more posterior). The cross-experimental comparison showed a nearly significant interaction [Direction x Prime type, $F(2,38) = 3.29$, p = .086]. This trend towards an asymmetry may be due to faster processing of the L1 than L2 primes as the L1 targets produce just as large N400-effects in the next epoch. Note that concreteness effects (see below) are not that apparent yet for the L1-L2 condition around this time. Around *450 ms*, similar to Experiment 1a-b, clear N400 priming effects (note the posterior distribution) were found for both translation directions in this classic N400 window, although the cross-experiment comparison suggested that the L2-L1 effect was somewhat weaker [marginal interaction between Direction and Prime type, $F(2,38) = 3.39$, $p = .081$]. At the late *500-600 ms* epoch, L2-L1 priming effects have now reversed polarity (although not significantly), while at posterior sites residual N400 priming effects can still be seen for the L1-L2 priming condition. This is further evidence for a delayed (or weaker?) N400 effect in L2. The cross-experiment comparison adds to this evidence [Direction x Prime type interaction, $F(1,19) = 5.83$, $p = .026$; Direction x Prime type x Front-to-back distribution interaction, $F(2,38) = 9.12$, $p = .001$]. The reversal in the L2 to L1 condition probably reflects the overlap of the N400 with the P3 component which is known to be delayed for unrelated items in the lexical decision task (see Figure 8, right panel: overlapping positive P3 peaks, nicely illustrated at Cz; see also Bentin, McCarthy & Wood, 1985). This delay might make the unrelated condition look like it is less negative.

Very early *concreteness effects* (*150ms*), likely to both French and English primes, are observed, although more lateralized for English primes (L1-L2 condition). The cross-experiment comparison indicates that the latter effect is the strongest [Direction x Concreteness x Front-to-back distribution, $F(2,38) = 3.60$, $p < .049$], but show no significant laterality difference. As in Experiment 1a-b, the concreteness effects in the *200-300 ms* epoch are likely to be mostly due to L1 targets, but could be partly due to L2 primes as well. The cross-experiment comparison confirms that there is only an effect in the L2-L1 condition [Direction x Concreteness, $F(1,19) = 8.94$, $p = .008$, Direction x Concreteness x Laterality, $F(2,38) = 4.26$, $p = .029$], and again the effect is anterior [Concreteness x Front-to-back distribution, $F(2,38) = 7.08$, $p = .004$]. Around *350ms*, clear anterior N400-

concreteness effect in the L2-L1 condition (to L1 targets), not seen yet for L2 targets, as confirmed by the cross-experiment comparison [Direction x Concreteness, $F(2,38) = 4.34$, $p = .051$; Concreteness x Distribution, $F(2,38) = 7.85$, $p = .002$] (see also voltage maps). This is again strong evidence that the L1 concreteness starts about 100 ms earlier than the L2 effect. At about *450 ms*, clear anterior target N400 concreteness effects were observed for both L1 and L2 targets (more widely distributed for L2 targets, as confirmed by the cross-experiment comparison [Concreteness x Laterality, $F(2,38) = 9.22$, $p < .001$; Concreteness x Front-to-back distribution, $F(2,38) = 25.27$, $p < .001$; Direction x Concreteness x Front-to-back distribution x Laterality, $F(4,76) = 2.88$, $p = .045$]). At *500-600ms*, we observed the tail-end of the concreteness effects for L1 targets, while the effect for L2 targets is still strong (especially at middle electrode sites). The cross-experiment comparison showed the Concreteness x Front-to-back distribution interaction [$F(2,38) =11.86$, $p < .001$].

GENERAL DISCUSSION

In this study, we tested masked translation priming for abstract and concrete non-cognates translation pairs with English (L1) –French (L2) bilinguals engaging in a lexical decision task. Both behavioral and ERP measures were collected, for the two priming directions (L1 to L2 and L2 to L1). Our key innovation was the inclusion of ERPs, and the search for the N400 as evidence for semantic activation across languages, and possibly the N250 as a measure of earlier lexical processing. More specifically, we were interested to know if L2 lexical representations can rapidly pre-activate their L1 translation equivalents through semantic mediation (or either through direct lexical activation), and exactly how rapidly this is possible compared to the L1 to L2 effect. Additionally, we sought to examine if abstract and concrete words act differently in this priming paradigm. We investigated all of the above using two different SOAs (120ms vs. 200ms). To our knowledge, this is the first study to report masked cross-language priming effects with ERPs using a lexical decision task.

Our first set of experiments used an SOA of 120ms. In this priming paradigm, we observed large posterior N400-priming effects (at about 450ms) in both priming directions. However, the L1 to L2 priming effect was longer lasting than the reverse effect. This probably reflects a N400-latency shift for L2 targets, due to slower processing in L2. Furthermore, we observed strong and widely distributed N250-priming effects from L2 to L1, while the N250-effect for the reverse priming direction seemed to be 100ms later (at 350ms). The presence of the earlier N250 might be evidence for an RHM type of explanation of strong lexical links being used between L2 primes and L1 targets.

With respect to the concreteness manipulation, we observed a clear anterior N400-modulation (at about 350ms) for L1 targets. A comparable N400-concreteness effect was observed for L2 targets, only it peaked about 100 ms later (450ms), and continued strongly into the 500-600ms window, while the L2-L1 effect was fading at that point. Surprisingly, we also observed a very early, but clear effect of the concreteness manipulation for L2 targets, about 150 ms after target onset. However, a more likely explanation for this early effect is that it is due to the L1 prime and reflects an N400-concreteness effect to these items (in this L1 to L2 priming condition). This would explain why a similar but later (250ms) concreteness effect is also observed in the L2 to L1 priming condition, although at this point the picture is more ambiguous as we might be dealing with the onset of the concreteness effect elicited by the L1 targets as well (which then continues strongly into the 300-400 time window, see earlier).

In the second set of experiments, we increased the SOA from 120ms to 200 ms. Although this set basically provided a strong replication of the above mentioned effects, for both behavioral and ERP measures, there are subtle differences with respect to the ERP effects that are most likely due to this longer SOA. First of all, we observed clear posterior N400 priming effects as soon as 350 ms, more strongly for the L1 to L2 priming condition. Note that this is 100 ms earlier then in Experiment 1a, possibly reflecting even faster processing of L1 primes in this longer SOA. At 450 ms, the L2 to L1 priming effect peaks, and is stronger than the reverse effect. In an even later time window (500-600 ms), as in Experiment 1a, we observed the tail-end of the L1 to L2 priming, again reflecting the delay for L2 targets. The data pattern of the N400-priming effect (in both experimental sets) is evidence for a translation priming asymmetry, which in behavioral studies is typically indicated by a overall stronger effect for L1 to L2 priming, though in ERPs it seems we need to interpreted this mostly in terms of time-course rather than in terms of strength (delayed but strong L2 to L1 effect).

Second, we observed N250 priming effects in both priming directions, but with a different distribution for the two languages. While it is more anterior/widely distributed in the L2-L1 direction (as in Experiment 1b, about 350ms), it is more posterior for the L1-L2 priming direction (unlike Experiment 1a). This suggests that different neural systems are mediating priming in this 250 ms epoch. At this point, we would like to speculate that the longer SOA might have given our participants enough time with the L1 prime, so that semantics were more strongly activated by the time the L2 target is being processed. Possibly, the meaning of *girl* in L1 is almost fully processed when the reader is starting to activate the semantic entry for its L2 translation equivalent (*FILLE*). When priming at a 200-ms SOA (as in Experiments 2a-b), this could happen around 200 ms after the L2 target had its onset, considering that this is also 400 ms after the L1 prime had its onset– which is exactly the time window of the N400, and the peak moment of L1 semantic activation. Importantly, the shared semantic representation for *BOY* and *FILLE* would be actived early in the processing of the L2 target, and this might serve to drive down the early part of the N400 time-locked to this L2 target (compared to unrelated prime-target trials), as is shown in Experiment 2 where early but weaker N400-effects were found for the L1 to L2 priming condition compared to the L2 to L1 priming condition. Evidence for this speculation is that the scalp distribution of the priming effect (at 250ms) is more posterior (like the classic priming N400). Note the difference with the pattern in Experiment 1. There, the L1 to L2 translation effect looked more like an N250-effect (although it occurred somewhat later, it was widely distributed, instead of posterior). So, why wouldn't we see a robust widely distributed N250-effect for L2 targets in Experiment 2? Maybe it is due to the longer SOA. Holcomb et al. (2007) found that the N250-effect (but not the N400-effect) dissipated between 180 and 300 ms SOA in a monolingual context. The SOA in Experiment 1 is well within the Holcomb et al. time range, but that of Experiment 2 might be near the edge. Then why do we observe N250 effects in Experiment 2 for the L2 to L1 priming condition? We would argue this is because the L2 primes are processed slower, which allows the N250-effect to continue even with this longer SOA.

Thanks to very time-sensitive ERP-measures, we collected further evidence in favor of the processing delay for L2 (e.g., the BIA model by Dijkstra & Van Heuven, 2002). Our SOA manipulation yielded very similar effects for the 120ms and 200ms SOA experiments, although at 200 ms SOA, we observed a (small) N400-concreteness effect to L2 primes, whereas this was not seen at the shorter SOA. There, only L1 primes were processed deep enough to elicit N400-concreteness effect. The clear N400-priming effects, as well as the N400-concreteness effects indicate that our bilinguals processed the stimuli to a deeper, semantic level. However, as stated in the introduction, the observed N250 modulations which were indeed larger for the L2 to L1 priming condition provide some evidence for the use of a lexical route as well. This is consistent with the revised hierarchical model of Kroll and Stewart (1994).

On the basis of the Distributed Representation model by Van Hell & de Groot (1998), and on the basis of the previous behavioral study by Schoonbaert et al. (2008), we hypothesized that concrete words have more conceptual overlap and thus more to prime (because more is shared) than abstract words. However, based on the context availability theory (Schwanenflugel, 1991), one could hypothesize that abstract words will benefit more from priming, because additional context is given to make them easier to process. Holcomb, Kounios, Anderson, & West (1999) reported that abstract words benefit more from supportive context (i.e. sentences), and thus context overrides the concreteness effect. However, a recent study by Swaab and colleagues (2002) found the concreteness effect to be independent of context in word priming. They concluded that supportive context can only override the effects of concreteness when the context is relatively strong, as in a sentence. This could explain why we have not observed any interactions between our two manipulations. In our study, the different distribution of the N400-priming effect (posterior) and N400-concreteness effect (anterior) is a strong indication that these effect represent different underlying processes. Note that again no robust effects of concreteness were found in the behavioral part of this study (only for L1 targets some benefit for concrete over abstract words was observed), although the priming manipulation did elicit effects in both directions. This is similar to the study of Schoonbaert et al. (2008).

To conclude, our study replicated recent translation priming studies by showing robust priming from L1 to L2, and vice versa, and extended this finding to English-French unbalanced bilinguals. We also contributed to the existing literature by including ERP measures, which mirrored the behavioral results by showing clear N400-priming effects, the latter being an indication of semantic involvement during priming in both directions. Additionally, we showed anterior N400-concreteness effects in L1 and in L2, irrespective of the priming manipulation. In both sets of experiments (short and long SOA), we found strong evidence for asymmetric N400 effects, mostly likely caused by a 100-ms processing delay for L2 representations.

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APPENDIX

English-French abstract and concrete translation pairs, used as critical stimuli in Experiments 1-4

Abstract						Concrete					
	English (L1)	French (L2)		English (L1)	French (L2)		English (L1)	French (L2)		English (L1)	French (L2)
1.	advice	conseil	41.	mood	humeur	1.	apple	pomme	41.	kitchen	cuisine
2.	anger	colère	42.	need	besoin	2.	beach	plage	42.	knee	genou
3.	another	autre	43.	new	nouveau	3.	belt	ceinture	43.	knife	couteau
4.	belief	croyance	44.	next	prochain	4.	bird	oiseau	44.	leaf	feuille
5.	better	mieux	45.	noise	bruit	5.	boat	bateau	45.	leather	cuir
6.	boredom	ennui	46.	nothing	rien	6.	book	livre	46.	leg	jambe
7.	broken	cassé	47.	old	vieux	7.	boy	garçon	47.	meat	viande
8.	care	soin	48.	peace	paix	8.	brain	cerveau	48.	milk	lait
9.	century	siècle	49.	poor	pauvre	9.	breast	sein	49.	monkey	singe
10.	disgust	dégoût	50.	pride	fierté	10.	brother	frère	50.	moon	lune
11.	dream	rêve	51.	reminder	rappel	11.	butter	beurre	51.	mouth	bouche
12.	early	tôt	52.	shame	honte	12.	cake	gâteau	52.	nail	ongle
13.	empty	vide	53.	sick	malade	13.	candle	bougie	53.	needle	aiguille
14.	english	anglais	54.	sight	vue	14.	castle	château	54.	queen	reine
15.	faith	foi	55.	sin	péché	15.	cheese	fromage	55.	rabbit	lapin
16.	fame	renom	56.	size	taille	16.	chicken	poulet	56.	rain	pluie
17.	fear	peur	57.	slippery	glissant	17.	child	enfant	57.	ring	anneau
18.	god	dieu	58.	soon	bientôt	18.	chin	menton	58.	river	fleuve
19.	goodness	bonté	59.	soul	âme	19.	church	église	59.	roof	toit
20.	guilty	coupable	60.	speed	vitesse	20.	cloud	nuage	60.	school	école
21.	happy	heureux	61.	state	état	21.	coal	charbon	61.	screen	écran
22.	hatred	haine	62.	taste	goût	22.	coat	manteau	62.	sheep	mouton
23.	health	santé	63.	thought	pensée	23.	curtain	rideau	63.	shirt	chemise
24.	heavy	lourd	64.	tomorrow	demain	24.	dish	assiette	64.	shoulder	épaule
25.	hell	enfer	65.	truce	trêve	25.	duck	canard	65.	silk	soie
26.	help	secours	66.	truth	vérité	26.	father	père	66.	sister	soeur
27.	hope	espoir	67.	ugliness	laideur	27.	fire	feu	67.	skin	peau
28.	hunger	faim	68.	unknown	inconnu	28.	fish	poisson	68.	skirt	jupe
29.	illness	maladie	69.	useless	inutile	29.	foot	pied	69.	sleeve	manche
30.	joke	blague	70.	wait	attente	30.	girl	fille	70.	snow	neige
31.	last	dernier	71.	weak	faible	31.	glove	gant	71.	soap	savon
32.	late	tard	72.	wealth	richesse	32.	goat	chèvre	72.	stone	pierre
33.	law	loi	73.	week	semaine	33.	heart	coeur	73.	tail	queue
34.	less	moins	74.	weight	poids	34.	heel	talon	74.	tear	larme
35.	level	niveau	75.	welcome	bienvenu	35.	hill	colline	75.	ticket	billet
36.	life	vie	76.	wisdom	sagesse	36.	hole	trou	76.	tree	arbre
37.	loss	perte	77.	wish	souhait	37.	house	maison	77.	truck	camion
38.	lost	perdu	78.	worse	pire	38.	hunter	chasseur	78.	wheel	roue
39.	love	amour	79.	worthy	digne	39.	husband	mari	79.	window	fenêtre
40.	month	mois	80.	young	jeune	40.	key	clé	80.	wing	aile

CHAPTER 4
THE REPRESENTATION OF LEXICAL AND SYNTACTIC INFORMATION IN BILINGUALS: EVIDENCE FROM SYNTACTIC PRIMING

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To what extent do bilinguals have a single, integrated representation of syntactic information? According to Hartsuiker, Pickering, and Veltkamp (2004), bilinguals represent syntactic information in terms of links between lexical representations and combinatorial nodes that specify syntactic structure, in a single cross-linguistic network. We describe predictions of this account and test them in two pairs of syntactic priming experiments with Dutch-English bilinguals. In Experiments 1 and 2, we tested priming in English (L2) production. Experiment 1 showed priming within English, and found that this priming was boosted by lexical repetition. Experiment 2 showed priming from Dutch to English, and found that this priming was boosted when prime and target used translation-equivalent verbs. However, this boost was weaker than the lexical boost in Experiment 1. In Experiments 3 and 4, we tested priming in Dutch (L1) production. Experiment 3 showed priming within Dutch, again boosted by lexical repetition. Experiment 4 showed priming from English to Dutch, but found no boost when prime and target were translation-equivalent verbs. We interpret these results in terms of an integrated model of lexical-syntactic representation.

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[1] This paper was co-authored by Robert Hartsuiker and Martin Pickering

Research on bilingualism focuses on the question of how the representations of the two languages are related in memory. Are they closely integrated, with information being shared as much as possible, or are they kept largely separate? The answer may of course depend on the level of representation in question. Most research has been concerned with conceptual and lexical representations (Dijkstra, Van Heuven, & Grainger, 1998; Kroll & Stewart, 1994; Van Hell & De Groot, 1998). Recently, phonological representations in bilinguals have also received more attention (Colomé, 2001; Dijkstra & Van Heuven, 2002). The findings from both comprehension tasks (e.g., lexical decision) and production tasks (e.g., naming and translation) indicate that there is at least some overlap in the representation of the languages, and that the languages interact to at least some extent during processing (see also Scheutz & Eberhard, 2004).

The great majority of this research has investigated the comprehension and production of single words only. In contrast, there has been very little work on syntactic representations in bilinguals. This is surprising because there is a great deal of research into syntactic processing in monolinguals, both in production (e.g., Bock & Levelt, 1994) and comprehension (e.g., Mitchell, 1994). The present study considers syntactic processing in bilinguals, and specifically asks how syntactic and lexical information interact during language production in bilinguals, to help answer the question of whether syntactic information is shared across languages. In this paper, we follow recent accounts in assuming that both lexical and syntactic representations are situated at the *lemma* level (Hartsuiker et al., 2004; Levelt, Roelofs, & Meyer, 1999; Pickering & Branigan, 1998). In these accounts, the lemma is treated as part of the lexical representation of a word which is connected to nodes specifying syntactic information (cf. Roelofs, 1992) and thus shared by different morphological variants. This syntactic information becomes highly relevant when the word is embedded in a sentence. Our specific interest is in the use of this information during speech production. We will turn to the theoretical accounts in more detail, after discussing some relevant findings of earlier research on syntactic representations in both monolingual and bilingual speech production. We then derive a number of predictions from these accounts and report four experiments that tested these predictions.

Syntactic Priming

A frequently used method to investigate the formulation of syntactic structures is *syntactic priming*. Syntactic priming (or syntactic persistence) occurs when speakers tend to repeat the syntactic structure they had recently encountered. In other words, it is the tendency to re-use previously activated syntactic information. Bock (1986) had participants repeat auditorily presented prime sentences and describe visually presented target pictures in English. In one manipulation, the syntactic structure of the prime sentences was either a passive or an active (e.g., *The building manager was mugged by a gang of teenagers* vs. *A gang of teenagers was mugged the building manager*). Participants were more likely to describe the target picture with a passive after a passive prime than after an active prime. In another manipulation, Bock found a similar effect for prepositional object versus double object constructions in the description of dative target pictures (e.g., *The governess made a pot of tea for the princess* vs. *The governess made the princess a pot of tea)*. Bock (1989) demonstrated that such effects occurred without any lexical repetition between prime and target, thus ruling out a lexical explanation of the effects (cf. Levelt & Kelter, 1982).

Since Bock's (1986) original study, many researchers have found syntactic priming with different tasks (Branigan, Pickering, Stewart, & Mclean, 2000; Pickering & Branigan, 1998; Potter & Lombardi, 1998), different types of constructions (Ferreira, 2003; Hartsuiker, Kolk, & Huiskamp, 1999; Hartsuiker & Westenberg, 2000; Scheepers, 2003), different languages (Hartsuiker & Kolk, 1998b) and different ages (Brooks & Tomasello, 1999; Huttenlocher, Vasilyeva, & Shimpi, 2004). Syntactic priming has also been found in studies with aphasics (Hartsuiker & Kolk, 1998a; Saffran & Martin, 1997). There is also some evidence for priming in language comprehension (e.g., Branigan, Pickering, & McLean, 2005; Noppeney & Price, 2004; cf. Frazier, Taft, Roeper, Ehrlich, & Clifton, 1984; Kaschak & Glenberg, 2004), and for extensive syntactic repetition in naturalistic corpora (e.g., Gries, 2005; Schenkein, 1980; Weiner & Labov, 1983). Additionally, syntactic priming occurs between production and comprehension in dialogue (Branigan, Pickering, & Cleland, 2000), so that interlocutors appear to align their syntactic representations (Pickering & Garrod, 2004).

Although syntactic priming is not dependent on lexical repetition between prime and target, it can be greatly enhanced by such repetition. In Branigan et al. (2000), verb repetition roughly doubled the magnitude of the syntactic priming effect (*the lexical boost*); comparable effects occurred using other paradigms (Cleland & Pickering, 2006; Corley & Scheepers, 2002; Pickering & Branigan, 1998). In addition, Cleland and Pickering (2003) found similar effects for noun phrases in dialogue. Participants were more likely to use a complex noun phrase like *the sheep that's red* after hearing *the door that's red* than after *the red door*. This tendency was enhanced when the prime was *the sheep that's red* rather than *the door that's red*. Interestingly, it was also enhanced, though to a smaller extent, by *the goat that's red*, where *goat* and *sheep* are semantically related (*the semantic boost*). Hence, repetition of content-word heads (verbs or nouns) enhances syntactic priming. In contrast, repetition of function words does not appear to enhance priming (Bock, 1989; see also Fox Tree & Meijer, 1999).

As already noted, there have been very few experimental investigations of syntactic processing in bilinguals. However, four studies have investigated syntactic priming between languages in bilinguals. In a picture-description task, Loebell and Bock (2003) found syntactic priming between English and German dative sentences. Specifically, a similar dative alternation appears to occur in both languages, with both languages admitting comparable prepositional-object constructions (e.g., *The girl bought a newspaper for the blind woman vs. Das Madchen kaufte eine Zeitung für die blinde Frau)* and double-object constructions *(e.g., The girl bought the blind woman a newspaper vs. Das Mädchen kaufte der blinde Frau eine Zeitung),* even though the use of the former construction in German is restricted to only few dative verbs. In contrast, they did not find cross-linguistic priming effects with English and German transitives (actives and passives). This might have been due to word order differences between German and English (with the main verb occurring at the end of the sentence in German). They found larger but non-significant within-language effects (in German) for transitives. Meijer and Fox Tree (2003) also found some evidence for dative priming from Spanish to English when bilinguals performed a sentence recall task. However, they did not rotate items across conditions, so it is possible that effects were due to item idiosyncrasies. Additionally, the memory component of this task was highly demanding and therefore they had to exclude a large number of participants (i.e., 30-60%).

Hartsuiker et al. (2004) investigated Spanish-English syntactic priming in dialogue, using a variant of the paradigm introduced by Branigan et al. (2000), in which a naïve participant and a confederate alternately described pictures to each other and decided whether a given description matched their own picture. In the critical conditions, the confederate produced a Spanish active or passive sentence, and the naïve participant responded with an English utterance. The participant was more likely to produce an English passive following a Spanish passive than following a Spanish active. This suggested that some syntactic representations can be shared between languages.

Finally, Desmet and Declercq (2006) showed syntactic cross-linguistic priming of the attachment of relative clauses to noun phrases (e.g., *Someone shot the servant of the actress who was on the balcony*; see Scheepers, 2003, for comparable within-language effects). In their target sentences the relative clause (*who was on the balcony*) could either be attached to the first noun phrase (*the servant*; high attachment), or to the second noun phrase (*the actress*; low attachment). The critical experiment showed that, in ambiguous English target sentences such as *The tutor advised the students of the school mistress that …*, participants were more likely to attach the relative clause to the first noun phrase (*the students*) after completing a Dutch prime sentence in which they also attached the relative clause to the first noun phrase (*Alle mensen staarden naar het herenhuis van de miljonair dat …* [*Everyone stared at the mansion of the millionaire that …*]) than after completing a Dutch prime sentence in which they attached the relative clause to the second noun phrase (*Alle mensen staarden naar het herenhuis van de miljonair die …* [*Everyone stared at the mansion of the millionaire who …*]). The Dutch primes were disambiguated by gender agreement. These data provide further evidence for shared syntactic representations or procedures across languages.

The use of syntactic information in monolinguals and bilinguals

The results of syntactic priming experiments provide considerable information about the way in which monolinguals and bilinguals represent and use syntactic information during language production. One way to look at this is in terms of implicit learning of syntactic procedures (Bock & Griffin, 2000; Chang, Dell, Bock, & Griffin, 2000; Chang, Dell & Bock, 2006). An implicit learning account implies that processing a certain syntactic structure makes it more accessible for future use. The knowledge of this structure is unconsciously, but permanently, strengthened and can therefore be easily primed. Specific evidence for an implicit learning account is the existence of a long-lasting priming effect where priming survives across up to ten intervening sentences between prime and target (Bock, Dell, Chang, & Onishi, in press; Bock & Griffin, 2000; Bock & Kroch, 1989; Hartsuiker & Kolk, 1998b). However, other authors did not find such a long-lasting syntactic priming effect (Branigan et al., 1999; Levelt & Kelter, 1982; Wheeldon & Smith, 2003).

Another way to interpret syntactic priming data is in terms of the representation and use of lexical information. Pickering and Branigan (1998) incorporated syntactic information into the model of lexical production developed by Roelofs (1992, 1993) and Levelt et al. (1999). The account was then extended by Hartsuiker et al. (2004) to provide an account of syntax in bilinguals. We now outline this account and draw a range of predictions about syntactic priming in bilinguals. Levelt et al. (1999) proposed that a lexical entry consisted of three separate strata: a conceptual stratum, containing semantic information; a lemma stratum, containing syntactic information; and a word-form stratum, containing morpho-phonological information. The lemma stratum, which is common to production and comprehension, represents both lexical information (the lemma itself) and syntactic information (that is linked to the lemma), and is located between the other strata. Its existence is supported by evidence that grammatical gender can be accessed before phonological information (Van Turennout, Hagoort, & Brown, 1998), and even in its absence (Vigliocco, Antonini, & Garrett, 1997). However, Levelt et al.'s account did not provide detailed information about syntactic representation or how the lexical representation could affect syntactic processing.

Pickering and Branigan (1998) proposed that lemma nodes (representing the base form of each known word) are connected to other nodes specifying the word's syntactic properties. They assumed categorical nodes specifying grammatical category (e.g., noun, verb, preposition), and featural nodes (e.g., gender, number). Additionally, they assumed the existence of *combinatorial nodes*, corresponding to a lemma's combinatorial properties. These nodes specify the kinds of grammatical construction in which a word can be used. As such, there are different combinatorial nodes for the passive construction and the active construction, and for the prepositional-object construction and the double-object construction. Lemma nodes are linked to appropriate combinatorial nodes, so that, for example, *give* and *send* are both linked to both the prepositional-object combinatorial node and the double-object combinatorial node, whereas *donate* is linked to the prepositional-object combinatorial node but not the double-object combinatorial node (as *donated the charity the clothes* is ungrammatical). Note that the prepositional-object and double-object combinatorial nodes correspond to Pickering and Branigan's (1998) NP,PP and NP,NP nodes, respectively. Lemma nodes are also linked to nodes at the conceptual and the word-form strata.

This basic architecture is to be interpreted in the context of a spreading-activation-based network. Processing *The cook gives the swimmer a hat* (a double object dative) activates the lemma *give* at the lemma stratum. Activation spreads to the associated nodes: the corresponding syntactic category node (verb), the corresponding feature nodes (e.g., third person, singular), and the relevant combinatorial node (the double object node). Pickering and Branigan (1998) claimed that syntactic priming is due to residual activation of the combinatorial node when producing the next sentence. Thus, people will be more likely to produce another sentence with a double object structure. When a sentence contains the same verb as a previous one (e.g., *give*), syntactic priming results from residual activation of the pre-activated lemma node (e.g., *give*), of the strengthened link between this lemma node and the double object combinatorial node, and of the combinatorial node itself. When subsequent sentences contain a different verb, the priming effect should be smaller, because it results only from residual activation of the combinatorial node. Hence, Pickering and Branigan could explain syntactic priming in monolinguals, and predicted a repeated verb boost. Similarly, their account predicts a repeated head noun boost in the production of complex noun phrases (Cleland & Pickering, 2003). That is, if *the sheep that's red* was presented as a prime, this leads to activation of the lemma *sheep*, the combinatorial node which specifies a noun phrase containing a relative clause structure (N,RC), and the link between them. Producing a subsequent noun phrase with the noun *sheep* will re-activate the lemma *sheep*. Because of the strengthened link between this lemma and the N,RC combinatorial node, participants are even more likely to use a structure with a relative clause when describing *the sheep that's red*, than when describing *the door that's red*.

Importantly, Pickering and Branigan's (1998) account could also explain Cleland and Pickering's (2003) observation of enhanced priming when prime and target employed semantically related head nouns (e.g., *goat-sheep*). On a *prime-based account*, processing the prime sentence *the goat that's red* will strongly activate both the lemma *goat* and its concept GOAT, but activation will also spread to related concepts. The concept SHEEP receives activation (although to a lesser extent than the concept GOAT), which in turn leads to some activation of the target lemma *sheep*. Additionally, the combinatorial node N,RC is activated. The co-activation of *sheep* and the N,RC node leads to the activation of the link between them, and therefore predicts enhanced priming (i.e., a semantic boost) when the target noun phrase includes *sheep* versus when the target noun phrase includes a semantically unrelated noun like *door*. However, because the lemma *goat* received more activation than *sheep*, priming will even be more enhanced when the target noun phrase repeats the head noun of the prime, here *goat* (i.e., a lexical boost).

However, Cleland and Pickering's (2003) data can also be interpreted in terms of *a target-based account*, using an identical network. In this case, the semantic boost is explained as the result of the target lemma re-activating the prime lemma during target processing (due to overlapping semantic representations). In their example, processing the prime *the goat that's red* would lead to activation of the *goat* lemma and hence activation of the link between the *goat* lemma and the N,RC combinatorial node. Although the *sheep* lemma will also become somewhat activated, it will not be selected, and therefore the link between the sheep lemma and the N, RC combinatorial node will not be strengthened. Production of *the sheep that's red* activates the *sheep* lemma and its concept SHEEP, but also spreads activation to related concepts and their lemmas, for example, the GOAT concept and the *goat* lemma. Because the link between the *goat* lemma and the N,RC node retains activation from the prime, the activation of the N,RC node is strengthened.

In sum, we can conclude that repetition of content-word heads (either verbs or nouns) enhances syntactic priming. Moreover, the model of Pickering and Branigan (1998), and the extension by Cleland and Pickering (2003), can explain the observed syntactic priming patterns. However, these data cannot yet distinguish between a prime-based account or a target-based account to explain interactions between strata in syntactic priming.

As mentioned above, syntactic priming between languages in bilinguals has been taken as evidence for shared syntactic representations across languages. Hence these findings rule out an account in which bilinguals simply have separate lemma strata for each language. Instead, Hartsuiker et al. (2004) modeled their results in a minimal extension of Pickering and Branigan's (1998) account, where bilinguals have a single integrated lemma stratum, and where individual lemma nodes are linked to language nodes (i.e., they are *tagged* for language; Dijkstra & Van Heuven, 2002). Additionally, they assumed that lemmas for translation equivalents are connected to the same concept node (Kroll & Stewart, 1994; cf. Costa, Miozzo, & Caramazza, 1999). According to this model (see Figure 1), bilinguals can be primed to use a verb in a particular grammatical structure (as specified in combinatorial nodes) by processing this grammatical structure first in another known language. For example, when the Dutch verb *slaan* (to hit) is used as part of a passive, it activates the (cross-linguistic) passive node, and so there is a greater tendency to produce a passive, whether in Dutch (L1) or English (L2). This accords with the findings of Hartsuiker et al., who found cross-linguistic syntactic priming with transitives from L1 to L2.

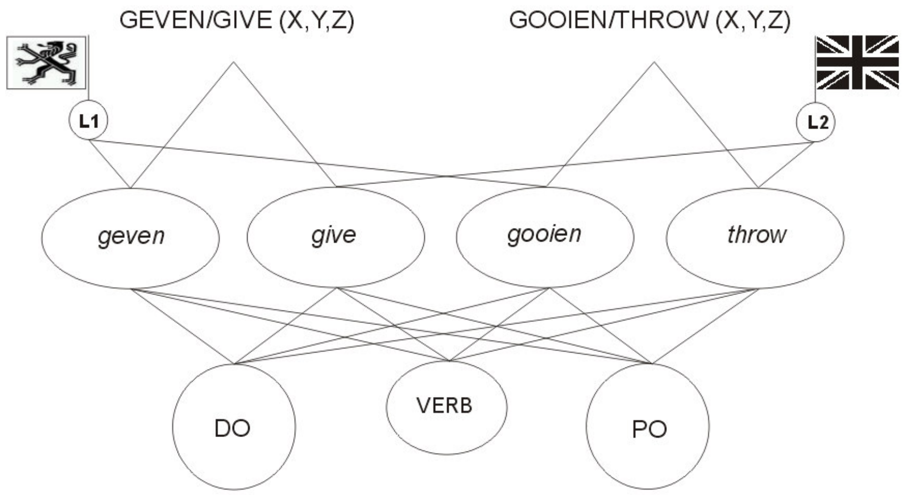

Figure 1. An example of lexico-syntactic representations of the verbs 'geven' and 'gooien' at the lemma stratum in bilingual memory. In this integrated (shared lexicon, shared syntax) network, each lemma node (geven, give, gooien, and throw) is linked to one conceptual node (GEVEN/GIVE (X,Y,Z) or GOOIEN/THROW (X,Y,Z)) at the above conceptual stratum, to one category node (Verb), to combinatorial nodes (such as double object and prepositional object), and to one language node (represented by a Flemish or British flag).

However, Hartsuiker et al.'s (2004) model makes a number of additional predictions about syntactic priming in bilinguals. First, it predicts priming within L2, just as it predicts priming within L1, as the lemma stratum makes no distinction between combinatorial nodes of the native language and a later-acquired language. Second, it predicts that priming within L2 will be enhanced by verb repetition (i.e., there will be a lexical boost to syntactic priming within L2), just as within L1 (Branigan et al., 2000; Pickering & Branigan, 1998; Cleland & Pickering, 2003). Third, priming will occur from L1 to L2 with datives (similar to Hartsuiker et al.'s, 2004, findings with transitives), as well as from L2 to L1.

The further cross-linguistic predictions are more striking. Because translation equivalents are assumed to share concepts (e.g., GEVEN/GIVE(X, Y, Z) in the model of Hartsuiker et al. (2004, see Fig. 1) we predict that translation equivalent verbs will, indirectly, activate each other's lemmas. This is analogous to the semantically related condition in the study of Cleland and Pickering (2003), in which semantically related words like sheep and goat will activate each other's lemmas, as a result of strong conceptual overlap. Thus, syntactic priming should be enhanced when prime and target sentences use translation-equivalent verbs (*geven/give)* as compared to different verbs. It is important to note that there two possible mechanisms of such a translation-equivalence boost (just as there are two possible mechanisms for the semantic boost in the case of Cleland & Pickering, 2003): a prime-based mechanism and a target-based mechanism. On a target-based mechanism, listening to a Dutch prime sentence using *geven* as part of the prepositional object construction (e.g., *De kok geeft een hoed aan de zwemmer [The chef gives a hat to the swimmer]*) leads to the activation of the corresponding lemma *geven* and the prepositional object node. If subsequently a target picture has to be described with an English dative, a prepositional object response will be more likely than a double object response because of residual activation of the prepositional object node. More importantly, a prepositional response will be even more likely if the English target description requires the translation equivalent of the Dutch prime verb *geven*, namely the verb *give*. This is because *give* will re-activate the lemma for *geven* (because of the shared concept GEVEN(X, Y, Z), and so additional activation will travel to the DO-combinatorial node via the link that had been strengthened during prime processing. The same prediction follows from a prime-based account.

Finally, the model predicts that priming between sentences containing translation equivalent verbs will be weaker than priming between sentences containing the same verb, in a manner analogous to Cleland and Pickering's (2003) finding of weaker syntactic priming with semantically related head nouns as compared to syntactic priming with repeated head nouns. In the model, additional priming for translation-equivalence verbs (as compared to unrelated verbs) depends on a lemma indirectly activating its translation, while the additional priming for identical verbs (as compared to unrelated verbs) depends on directly activating the same lemma in prime and target. Therefore a translation-equivalence boost to syntactic priming across languages is predicted to be smaller than a lexical boost to syntactic priming within languages.

In the following, we report four syntactic priming experiments with datives that tested the above mentioned predictions during a dialogue game in which a naïve participant and a confederate took turns to describe pictures to each other and to match those descriptions to pictures. Unbeknownst to the naïve participant, the confederate's descriptions were scripted and we were interested in the extent to which the naïve participant employed the same construction (prepositional object or double object) that the confederate had just used. We used a computerized variant of the technique introduced by Branigan et al. (2000) and extended to bilingualism by Hartsuiker et al. (2004). All participants spoke Dutch as L1 and English as L2. Experiment 1 had participants produce English target descriptions after hearing English primes and tested the predictions that syntactic priming occurs from L2 to L2 and that it displays the lexical boost. Experiment 2 had participants produce English target descriptions after hearing Dutch primes and tested the predictions that syntactic priming occurs from L1 to L2 and displays a boost with translation-equivalent verbs. Experiment 3 had participants produce Dutch target descriptions after hearing Dutch primes and tested the predictions that syntactic priming occurs from L1 to L1 and again that it displays the lexical boost. Experiment 4 had participants produce Dutch target descriptions after hearing English primes and tested the predictions that syntactic priming occurs from L2 to L1 and displays a boost with translation-equivalent verbs. A cross-experiment comparison tested the final prediction, namely that the boost due to translation equivalents is smaller than the boost due to within-language verb repetition (Experiments 1 and 3 vs. Experiments 2 and 4).

EXPERIMENT 1: L2 TO L2 PRIMING

Method

Participants. Thirty-two students of Ghent University took part as naïve participants in exchange for a small payment or course credit. All were unbalanced bilinguals, namely native Dutch speakers living in Flanders, The Dutch speaking region of Belgium. They had formal instruction in English for at least 5 years. Mean age was 22 (range 18 - 26). A female native Dutch speaker, of comparable age, served as the confederate for the entire experiment.

Materials. The naïve participants were presented with two sets of 192 pictures, each illustrating an action. An English verb in the infinitive, describing the action, was printed underneath each picture. The *description set* contained 48 experimental target pictures, illustrating a ditransitive action involving an agent, a theme, and a beneficiary. There were eight pictures for each of six ditransitive verbs (*give*, *throw*, *show*, *hand*, *offer*, and *sell*). The remaining 144 pictures were filler items, containing a verb which could not be used with a prepositional object or double object construction. The *matching set*, consisting of 192 pictures, were used as filler items in a secondary task of matching pictures with the confederate's descriptions (see Procedure and Design).

A set of 192 English sentences served as a description set for the confederate. In addition to 144 filler sentences, this set contained 48 dative prime sentences. There were eight prime sentences per ditransitive verb used in the confederate's description set. Each dative structure (prepositional object, double object) appeared four times with each of the six verbs. Eight different master lists were constructed by pairing the confederate's set of prime sentences to the naïve participant's set of experimental target pictures. In each list, there were 24 prime-target combinations where the verbs were identical (e.g., *give-give*), and 24 prime-target combinations where the verbs were unrelated (e.g., *throw-give*). The pairing was done so that all four experimental conditions (i.e., prepositional object prime, identical verbs; prepositional object prime, unrelated verbs; double object prime, identical verbs; double object prime, unrelated verbs) were represented 12 times in each list, twice for each verb. In one instance the verb appeared with a target picture having the agent on the left side of the theme, in the other instance the verb appeared with a target picture having the agent on the right side of the theme. Hence, we controlled for the variable position, creating two extra (non-critical) conditions (Hartsuiker & Kolk, 1998a). Each target picture occurred once in each condition across the eight lists. The nouns (animate agent, beneficiary, and inanimate patient) of the prime sentence and the nouns in the subsequent target picture were never identical or related in form or meaning.

An experimental trial consisted of an English dative prime sentence, to be produced by the confederate, followed by a target picture, shown to the naïve participant. Examples of the four different kinds of experimental trials are presented in Table 1, and the Appendix lists the prime sentences. All experimental trials were preceded by three filler trials. For both confederate and naïve participant, we derived separate sublists from the eight master lists. These were implemented and designed to run simultaneously on two different PCs.

Table 1. Examples of the four different kinds of experimental trials, as used in the experiments.

Condition	Prime Sentence	Verb type on Target Picture
EXPERIMENTS 1 & 3: L2 to L2 and L1 to L1		
1	**PO** *The cook shows a hat to the boxer* *De kok toont een hoed aan de bokser*	**identical** *show* *tonen*
2	**PO** *The cook shows a hat to the boxer* *De kok toont een hoed aan de bokser*	**unrelated** *throw* *gooien*
3	**DO** *The cook shows the boxer a hat* *De kok toont de bokser een hoed*	**identical** *show* *tonen*
4	**DO** *The cook shows the boxer a hat* *De kok toont de bokser een hoed*	**unrelated** *throw* *gooien*
EXPERIMENTS 2 & 4: L1 to L2 and L2 to L1		
1	**PO** *De kok toont een hoed aan de bokser* *The cook shows a hat to the boxer*	**translation equivalent** *show* *tonen*
2	**PO** *De kok toont een hoed aan de bokser* *The cook shows a hat to the boxer*	**unrelated** *throw* *gooien*
3	**DO** *De kok toont de bokser een hoed* *The cook shows the boxer a hat*	**translation equivalent** *show* *tonen*
4	**DO** *De kok toont de bokser een hoed* *The cook shows the boxer a hat*	**unrelated** *throw* *gooien*

Procedure and Design. All objects (e.g., the nun, the hat) appearing on the pictures in the experiment were excised from the pictures, and were introduced to the participants one-by-one on the computer screen at the beginning of each session. Their Dutch and English names were spoken by the investigator to ensure that both names were known. After this introduction, the confederate and naïve participant sat opposite each other, separated by two computer screens. Participants were instructed to take turns to describe pictures to each other in English, so that we could examine conversation between bilinguals using their second language. The confederate pretended to give English picture descriptions, while in fact reading aloud English prime sentences from the screen. After hearing the other's description, the participant decided whether the picture displayed on the screen matched this description. There was a match on 50% of the trials, but all experimental trials provided a mismatch. Pressing a *Yes* button (for a match) or a *No* button (for a mismatch) resulted in the presentation of the next picture for both participants. During the entire session, the confederate acted and was treated as a naïve participant. Sessions lasted approximately 50 minutes, and were recorded on minidisc, using clip-on microphones.

Thus, the experiment involved a 2 (Prime type: prepositional object vs. double object) x 2 (Verb type: identical vs. unrelated) design. ANOVAs treated participants (F_1) and items (F_2) as random effects, and both factors were within-participants and within-items.

Scoring. Experimental target descriptions were scored on the basis of their syntactic form as *prepositional objects*, *double objects*, or *Others*. A description was scored as a prepositional object if the theme of the action immediately followed the verb, and was followed by the preposition *to* and the beneficiary (e.g., *The swimmer gives a jug to the nun*). A description was scored as a double object if the beneficiary immediately followed the verb, and was followed by the theme (e.g., *The swimmer gives the nun a jug*). The verb could be in the simple present (e.g., *gives*) or the present progressive (e.g., *is giving*), and responses involving errors in subject-verb agreement or using the preposition *at* instead of *to* were permitted. Such minor mistakes were common, and previous studies have suggested that priming is unaffected by changes in preposition (Bock, 1989) or the form of the verb (Pickering & Branigan, 1998). All other responses were scored as Others.

Results

Out of 1536 target descriptions, there were 1040 prepositional objects (68%), 353 double objects (23%), and 143 Others (9%). The Other descriptions were almost equally often present in the four conditions (prepositional object prime, identical verbs: 8%; prepositional object prime, unrelated verbs: 10%; double object prime, identical verbs: 9%; double object prime, unrelated verbs: 10%). Mean percentages of prepositional object responses out of all valid target descriptions (i.e., descriptions scored as prepositional objects or double objects) are shown in Table 2. ANOVA test statistics (including Min *F'* values) for all experiments are shown in Table 3. All significant effects were reliable at less than p< .05. Confidence intervals (95%) for the differences between the means (following Masson & Loftus, 2003) are reported for all significant effects, and are based on the participants analyses, as are all reported means.

Table 2. Proportion of prepositional datives (out of double object and propositional datives) and standard deviation for each experimental condition tested in Experiment 1

	Verb Type			
	Identical		Unrelated	
Prime Type (L2)	Percentage	Standard deviation	Percentage	Standard deviation
DO	55%	33%	72%	28%
PO	91%	18%	81%	23%

Note - Percentages are derived from the participants analysis

Table 3. Analysis of variance summary for all experiments.

Exp	Effect	By participants		By items		Min F`	
		df	F_1	*df*	F_2	*df*	*Min F`*
1	Prime	1,31	47.72***	1,47	85.16***	1,63	30.58***
(L2 to L2)	Verb	1,31	3.48	1,47	2.08	1,78	1.30
	Prime x Verb	1,31	40.08***	1,47	42.01***	1,74	20.51***
	Prime (for related verbs)°	1,31	54.11***	1,47	129.81***	1,71	38.19***
	Prime (for unrelated verbs)°	1,31	13.32**	1,47	11.14**	1,88	6.07*
2	Prime	1,31	20.78***	1,47	38.53***	1,62	13.50***
(L1 to L2)	Verb	1,31	1.38	1,47	<1	1,77	<1
	Prime x Verb	1,31	5.12*	1,47	4.95*	1,75	2.52
	Prime (for related verbs)°	1,31	18.22***	1,47	41.02***	1,72	12.71***
	Prime (for unrelated verbs)°	1,31	11.83**	1,47	11.65**	1,88	5.87*
3	Prime	1,31	51.30***	1,47	81.01***	1,65	31.41***
(L1 to L1)	Verb	1,31	2.53	1,47	1.31	1,77	<1
	Prime x Verb	1,31	48.30***	1,47	40.09***	1,77	21.91***
	Prime (for related verbs)°	1,31	61.97***	1,47	112.20***	1,78	39.92***
	Prime (for unrelated verbs)°	1,31	17.99***	1,47	12.62***	1,87	7.42**
4	Prime	1,31	29.82*	1,47	6.04*	1,64	5.02*
(L2 to L1)	Verb	1,31	2.49	1,47	3.09	1,71	1.38
	Prime x Verb	1,31	<1	1,47	<1	1,75	<1
	Prime (for related verbs)°	1,31	7.79**	1,47	3.73	1,81	2.52
	Prime (for unrelated verbs)°	1,31	11.13**	1,47	3.46	1,74	2.64
Cross-exp	Prime	1,124	137.80***	1,47	149.10***	1,141	71.61***
	Mode	1,124	6.20*	1,47	93.80***	1,139	5.82*
	Prime x Verb	1,124	69.20***	1,47	36.40***	1,99	23.85***
	Mode x Prime	1,124	28.50***	1,47	32.80***	1,125	12.97***
	Mode x Verb	1,124	9.70**	1,47	4.70*	1,95	3.17
	Mode x Prime x Verb	1,124	37.70***	1,47	40.40***	1,141	19.50***
	Mode x Target language	1,124	<1	1,47	7.10*	1,137	<1
	Mode x Target language x Prime	1,124	3.50	1,47	4.40*	1,15	1.95

° planned comparison
* p< .05
** p< .01
*** p< .001

Prepositional object descriptions occurred more frequently in the prepositional object prime condition (86%) than in the double object prime condition (64%). This 22% priming effect was significant (CI = ±10%). Both verb conditions produced significant priming, but the priming effect was larger (27%, CI = ±4%) for identical verbs (36%) than for unrelated verbs (9%).

Discussion

Experiment 1 showed syntactic priming within L2 and further showed that this effect was enhanced by verb repetition. This supports a model in which the same representation is used in L2 as in L1 and is compatible with the extension of Pickering and Branigan's (1998) model to L2, as proposed by Hartsuiker et al. (2004). But in order to get a fuller picture of the nature of the bilingual lemma stratum, we now need to ask whether priming occurs from L1 to L2, and, more interestingly, whether it is enhanced when prime and target use translation-equivalent verbs. This was addressed in Experiment 2.

EXPERIMENT 2: L1 TO L2 PRIMING

Method

Participants. Thirty-two further participants took part in exchange for course credit. Mean age was 21 (range 18 - 46). A female native Dutch speaker acted as a confederate for the entire experiment. The female confederate differed from the confederate in Experiment 1, but was again of comparable age with the participants.

Materials, Procedure, and Design. The materials and procedure of Experiment 2 were identical to those in Experiment 1, except for the language of the prime sentences (see Table 1). Specifically, the English (L2) prime sentences of Experiment 1 were translated in Dutch (L1), as were the verbs printed underneath the matching pictures. Consequently, the design in the following experiment was a 2 (Prime type: prepositional object vs. prepositional object) x 2 (Verb type: translation equivalent vs. unrelated) design, creating four conditions (prepositional object prime, translation-equivalent verbs; prepositional object prime, unrelated verbs; double object prime, translation-equivalent verbs; double object prime, unrelated verbs).

Scoring. The scoring was identical to that of Experiment 1.

Results

Out of 1536 target descriptions, there were 1167 prepositional-objects (76%), 268 double-objects (18%), and 101 Other descriptions (6%). Other descriptions were almost equally often present in the four critical conditions (prepositional object prime, translation-equivalent verbs: 6%; prepositional object prime, unrelated verbs: 7%; double object prime, translation-equivalent verbs: 7%; double object prime, unrelated verbs: 7%). Table 4 lists the mean percentages of prepositional object responses out of all valid responses (i.e., descriptions scored as prepositional object or double object) in each critical condition and ANOVA test statistics are shown in Table 3. The data are analyzed and reported as in Experiment 1.

Table 4. Proportion of prepositional datives (out of double object and propositional datives) and standard deviation for each experimental condition tested in Experiment 2

	Verb Type			
	Translation		Unrelated	
Prime Type (L2)	Percentage	Standard deviation	Percentage	Standard deviation
DO	74%	32%	77%	25%
PO	91%	15%	85%	21%

Note - Percentages are derived from the participants analysis

Prepositional object descriptions occurred more frequently in the prepositional object prime condition (88%) than in the double object prime condition (76%). This 12% priming effect was significant (CI = ±8%). Both verb conditions produced significant priming, but the priming effect was larger (9%, CI = ±4%) for translation-equivalent verbs (17%) than for unrelated verbs (8%).

Because the set of depictable dative verbs is limited, we could not control whether the translation-equivalent verb pairs (e.g., *geven* - *give*) were near-cognates. It is important to point out, however, that even for this orthographically similar pair, the third-person present-tense forms (*geeft* - *gives*) do not have even a single phoneme in common. (Note that the Dutch letter <G> maps onto a different phoneme than the English <G>: /xeft/ vs. /gɪvz/). Furthermore, post-hoc tests revealed that there was no main effect of near-cognate status (*give/geven*, *hand/overhandigen* vs. *throw/gooien*, *sell/verkopen*, *show/tonen*, *offer/presenteren*) and, crucially, no second- or third-order interaction with prime type or verb repetition (all ps > .15).

Discussion

Experiment 2 showed syntactic priming from L1 to L2 and that this priming was stronger for translation-equivalent verbs than unrelated verbs. To our knowledge, this experiment was the first to demonstrate a translation-equivalence boost to priming. However, it remains to be seen whether a similar syntactic priming effect occurs in the opposite direction, from L2 to L1. Before doing so, we need to establish priming within L1, in order to be sure that Dutch target sentences can be primed syntactically, and to be able to compare syntactic priming effects within and across languages. We also wanted to replicate the lexical boost to syntactic priming (as observed by Branigan et al., 2000, within English as L1). Experiment 3 therefore tested forsyntactic priming and a lexical boost within L1 (Dutch).

EXPERIMENT 3: L1 TO L1 PRIMING

Method

Participants. Thirty-two further participants took part in exchange for course credit. Mean age was 21 (range 19 - 25). A female native Dutch speaker acted as a confederate in the entire experiment. The female confederate differed from the confederates in Experiment 1 and 2, but was again of comparable age with the participants.

Materials, Procedure, and Design. The materials and procedure of Experiment 3 were identical to those in Experiment 1, except for the language of the materials (L1 instead of L2). The Dutch prime sentences (see Table 1) were taken from Experiment 2, and the verbs printed underneath all pictures were translated to Dutch. Consequently, the design in the following experiment was a 2 (Prime type: prepositional object vs. prepositional object) x 2 (Verb type: identical vs. unrelated) design, creating four conditions (prepositional object prime, identical verbs; prepositional object prime, unrelated verbs; double object prime, identical verbs; double object prime, unrelated verbs).

Scoring. The scoring was identical to that of Experiment 1.

Results

Out of 1536 target descriptions, there were 1057 prepositional objects (69%), 397 double objects (26%), and 82 Other descriptions (5%). Other descriptions were almost equally often present in the four critical conditions (prepositional object prime, identical verbs: 5%; prepositional object prime, unrelated verbs: 5%; double object prime, identical verbs: 6%; double object prime, unrelated verbs: 6%). Table 5 lists the mean percentages of prepositional object responses out of all valid responses (i.e., descriptions scored as prepositional object or double object) in each critical condition and ANOVA test statistics are shown in Table 3. The data are analyzed and reported as in Experiment 1.

Table 5. Proportion of prepositional datives (out of double object and propositional datives) and standard deviation for each experimental condition tested in Experiment 3

	Verb Type			
	Identical		Unrelated	
Prime Type (L1)	Percentage	Standard deviation	Percentage	Standard deviation
DO	50%	34%	68%	31%
PO	92%	13%	81%	23%

Note - Percentages are derived from the participants analysis

Prepositional object descriptions occurred more frequently in the prepositional object prime condition (87%) than in the double object prime condition (59%). This 28% priming effect was significant (CI = ±11%). Both verb conditions produced significant priming, but the priming effect was larger (29%, CI = ±4%) for identical verbs (42%) than for unrelated verbs (13%).

Discussion

Experiment 3 showed strong syntactic priming within L1, as well as the predicted lexical boost due to repeating the verb between prime and target. This pattern of priming replicates the pattern found in Branigan et al. (2000) in a new language, namely Dutch. Given that syntactic priming and a lexical boost of priming occur in Dutch production, we can now complete the picture and test whether priming also occurs from English (L2) to Dutch (L1), and whether it is enhanced when prime and target use translation-equivalent verbs. This was done in Experiment 4.

EXPERIMENT 4: L2 TO L1 PRIMING

Method

Participants. Thirty-two further participants took part in exchange for course credit. Mean age was 21 (range 18 - 26). The confederate was the female native Dutch speaking confederate of Experiment 3.

Materials, Procedure, and Design. The materials and procedure of Experiment 4 were similar to those in the previous experiments. The English prime sentences (see Table 1) and matching set of pictures were taken from Experiment 1. The set of pictures to be described in Dutch (with Dutch verbs printed underneath) was taken from Experiment 3. Consequently, the design in the following experiment was a 2 (Prime type: prepositional object vs. double object) x 2 (Verb type: identical vs. unrelated) design, creating four conditions (prepositional object prime, identical verbs; prepositional object prime, unrelated verbs; double object prime, identical verbs; double object prime, unrelated verbs).

Scoring. The scoring was identical to that of Experiment 1.

Results

Out of 1536 target descriptions, there were 1233 prepositional-objects (80%), 223 double-objects (15%), and 80 Other descriptions (5%). Other descriptions were almost equally often present in the four critical conditions (prepositional object prime, identical verbs: 3%; prepositional object prime, unrelated verbs: 5%; double object prime, identical verbs: 7%; double object prime, unrelated verbs: 6%). Table 6 lists the mean percentages of prepositional object responses out of all valid responses (i.e., descriptions scored as prepositional object or double object) in each critical condition and ANOVA test statistics are shown in Table 3. The data are analyzed and reported as in Experiment 1.

Table 6. Proportion of prepositional datives (out of double object and propositional datives) and standard deviation for each experimental condition tested in Experiment 4

	Verb Type			
	Translation		Unrelated	
Prime Type (L2)	Percentage	Standard deviation	Percentage	Standard deviation
DO	83%	21%	80%	20%
PO	89%	16%	87%	18%

Note - Percentages are derived from the participants analysis

Prepositional object descriptions occurred more frequently in the prepositional object prime condition (88%) than in the double object prime condition (82%). This 6% priming effect was significant (CI = ±3%). The priming effect did not significantly differ for translation-equivalent verbs (5%) and for unrelated verbs (7%; CI = ±3%).

Discussion

Experiment 4 showed syntactic priming from L2 to L1. However, this priming was not enhanced by the use of translation-equivalent verbs in prime and target production. In other words, unlike the translation-equivalence boost from L1 to L2 (Experiment 2), there was no sign of any translation-equivalence boost from L2 to L1. We will return to this finding in the General Discussion, after presenting a combined analysis of the experiments in the present study.

Combined Analysis of Experiments 1-4

This cross-experiment comparison will allow us to test our final prediction, namely that the boost due to translation equivalents is smaller than the boost due to within-language verb repetition (Experiments 1 and 3 vs. Experiments 2 and 4). The four experiments yielded similar syntactic priming effects in the unrelated verb conditions (9%, 8%, 13%, and 7%), but the manipulation of repeating the verb in the monolingual experiments (Experiments 1 and 3) resulted in considerably larger priming effects (36% and 42%) than the manipulation of presenting translation-equivalent verbs between prime and target in the cross-linguistic experiments (Experiments 2 and 4; 17% and 5%).

To test whether these differences were significant, we conducted four-way ANOVAs with Mode (within-language, Experiments 1 and 3 vs. between-language, Experiment 2 and 4) and Target Language (L2, Experiments 1 and 2 vs. L1, Experiments 3 and 4) as additional between-participants and within-items factors. ANOVA test statistics for significant effects are shown in Table 3. Figure 2 summarizes the priming effects across the four experiments in the related and unrelated conditions.

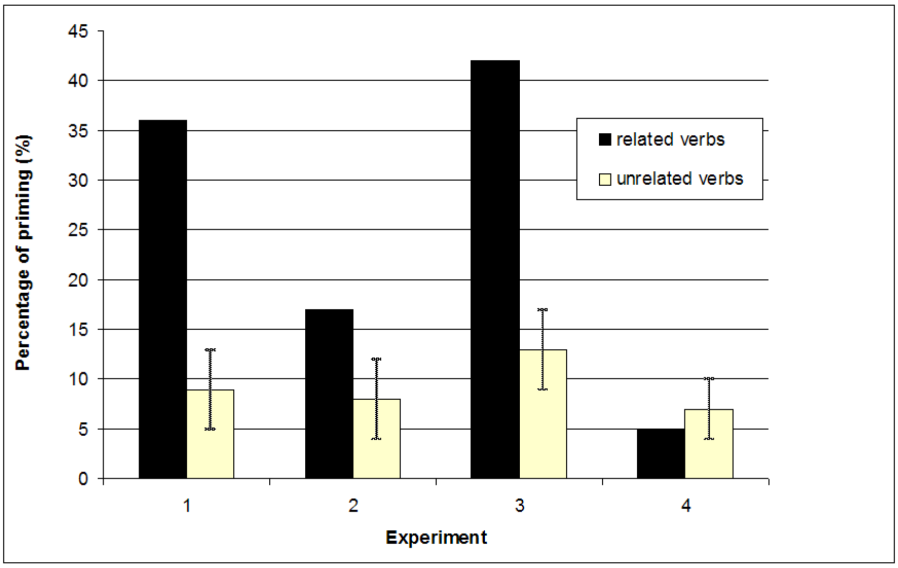

Figure 2. Percentages of priming for both related and unrelated verb conditions, and 95% confidence intervals for the priming effect in all experiments. Related verb conditions refer to identical verbs or translation equivalent verbs depending on the experiment.

Effects of the factor Prime Type. The analysis revealed an effect of Prime Type (CI = ±4%; confirming an overall priming effect of 17%). The interaction between Prime Type and Verb Type was significant, confirming that priming was stronger for related (i.e., translation-equivalent or identical) verbs (25%) than for unrelated verbs (9%; CI = ±2%).

Effects of the factor Mode (within vs. between language). There was a significant main effect of the factor Mode, an interaction of Mode with Target Language (by items only), and with both Prime Type and Verb Type. More importantly, the three-way interaction between Mode, Prime Type and Verb Type was significant. This suggests that the overall priming effect was stronger within languages than across languages, the difference largely being due to the related verb conditions where identical and translation-equivalent verbs caused 39% and 11% priming respectively (28% difference), whereas the unrelated verbs in both within-language and between-language experiments caused 11% and 8% priming respectively (4% difference; CI = ±2%). In other words, priming was enhanced for lexical repetition in comparison with translation equivalence, when differential effects of within- versus between-language priming were controlled for. This three-way interaction demonstrates that the overall lexical boost (28%) is considerably stronger than the overall translation-equivalence boost (9%). Note that the L2 to L1 translation-equivalence boost is actually negative (see also Fig. 2), though non-significantly so (see Results of Experiment 4). Furthermore, the interaction between Mode, Target Language, and Prime Type (by items only; CI = ±3%) also suggests that within-language priming is stronger than cross-linguistic priming, but only in L1 production (Experiments 3 vs. 4: 12% difference), and not in L2 production (Experiments 1 vs. 2: 5% difference).

GENERAL DISCUSSION

Our experiments clearly demonstrated syntactic priming within L1, within L2, from L1 to L2, and from L2 to L1. Additionally, Experiment 1 and 3 showed that the within-language syntactic priming effect was enhanced when prime and target sentences used the same verb. Experiment 2 showed that the cross-linguistic effect was enhanced when Dutch primes and English targets used translation-equivalent verbs, but Experiment 4 failed to show any boost to priming using translation-equivalent verbs with English primes and Dutch targets. A cross-experiment comparison also showed that the boost from translation-equivalent verbs was significantly smaller than the boost from repeated verbs.

These data accord fairly well with the predictions derived from the model of Hartsuiker et al. (2004). According to this model, syntactic priming within languages develops in the following way: Considering priming in L1, processing the verb *geven* in a prepositional object construction activates its lemma (*geven*) together with the prepositional object combinatorial node (see Fig. 1). As a result, the link between them is strengthened. The recent activation of the prepositional object node increases the likelihood that the speaker now selects the prepositional object construction. Because of the strengthened link, the prepositional object construction is even more likely to be selected when the prime verb *geven* is repeated and therefore re-seleced during target production. This account predicts priming and the lexical boost within L1 (see Experiment 3; Branigan, et al., 2000; Pickering & Branigan, 1998) and within L2 (see Experiment 1).

Moreover, the model can explain syntactic priming across languages. Considering priming from L1 to L2 (Experiment 2), hearing the verb *geven* in a Dutch prepositional object construction activates its lemma (*geven*), the prepositional object node, and the link between them. Because the same prepositional object node is used by both languages, the recent activation of the prepositional object node increases the likelihood that the speaker now selects the prepositional object construction, even though the prime utterance and the speaker's response were in different languages. These same predictions hold for priming from L2 to L1 (as observed in Experiment 4).

However, it seems that the model of Hartsuiker et al. (2004) cannot explain the asymmetric translation-equivalence boost to syntactic priming. The model incorrectly predicts an equally strong translation-equivalence boost when priming from L1 to L2 and vice versa. In contrast, we found a translation-equivalence boost from L1 to L2, but no translation-equivalence boost from L2 to L1. To incorporate this finding into the model, it is necessary to consider lexical processing in bilingualism. In our experiments, production of a target involves activating the appropriate verb lemma by the participant reading the verb printed underneath the target pictures and selecting it. Its concept is activated by the participant looking at the depicted action, but also via spreading activation from the verb lemma as soon as it is activated. In L2-L1 priming, activation from the shared concept GEVEN/GIVE (X,Y,Z) may not re-activate the English non-target lemma *give* to the same extent that it re-activates the Dutch non-target lemma *geven* in L1-L2 priming. This follows from the claim that the link between a L2 lexical representation and its concept is less strong than the link between an L1 lexical representation and its concept (see Fig. 3). A similar assumption of weak lexical-conceptual links for L2 can be found in a model of bilingual word production, namely the Revised Hierarchical Model by Kroll and Stewart (1994). These claims are also compatible with evidence showing that picture naming is harder (i.e., slower and more error-prone) in L2 than in L1 (Potter, So, Van Eckhardt, & Feldman, 1984), and hence suggest that lexicalizing a concept in L2 is harder than in L1. Converging evidence comes from the finding that it is easier to translate from L2 to L1 than vice versa (Kroll & Curley, 1988; Kroll & Sholl, 1992).

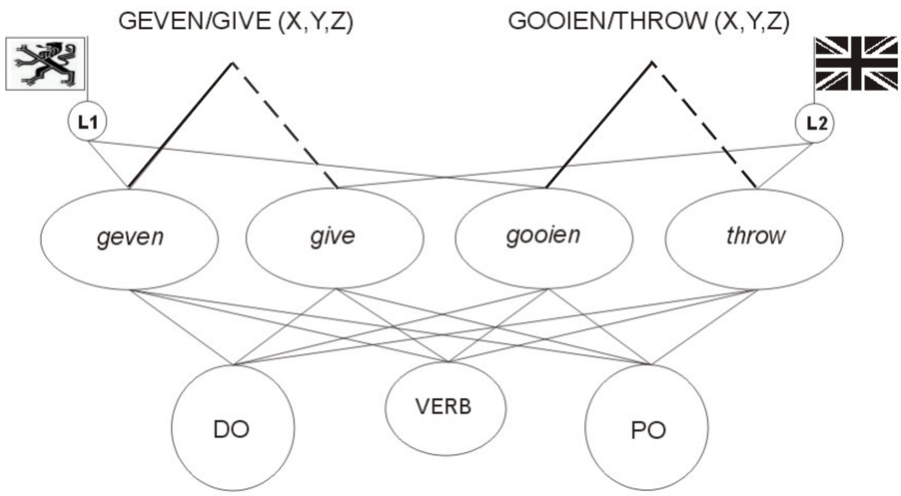

Figure 3. Adaptation of the model of Hartsuiker et al. (2004), depicted in Figure 1. Weaker connections between different nodes (resulting in less activation spreading) are indicated by dotted lines.

This account can explain the obtained asymmetric translation-equivalence boost on the basis of a target-based view of syntactic priming. Specifically, in priming from L1 to L2, the L2 target lemma (*give)* re-activates the L1 prime lemma (*geven*), with some activation spreading via the link between the lemma geven and the combinatorial node that has just been used with this lemma. But when priming from L2 to L1, the L1 target lemma (*geven*) does not strongly re-activate the L2 prime lemma (*give*), so that the priming effect is of a comparable magnitude as it is in the unrelated condition (with a prime like *show*).

Note that a prime-based account would incorrectly predict a stronger translation-equivalence boost from L2 to L1 than vice versa. This is because the link is strengthened between the target lemma and the combinatorial node (e.g., *give* and PO) and between other activated lemmas and that combinatorial node (e.g., *geven* and PO), during processing of the prime. On the assumption that L2 words activate L1 words more than vice versa, it incorrectly predicts a stronger translation-equivalence boost in the L2-L1 direction than in the L1-L2 direction.

In fact, the literature contains accounts that also explain priming effects in terms of target-based processing mechanisms. For example, Sevald and Dell's (1994) competitive cuing model explains phonological inhibition effects (*pin - pick*) in production as the result of the initial phoneme of the target word reactivating the prime word's phonemes. As a result, the (mismatching) later phonemes of the prime word become active, and compete for selection with the target word's phonology. Furthermore, on a target-based account but not on a prime-based account, the present results, and particularly the translation-equivalence boost, are also compatible with the critical claim of the Revised Hierarchical Model that L1 to L2 lexical-lexical links are relatively weak, whereas L2 to L1 lexical-lexical links are quite strong (Kroll & Stewart, 1994). The effect of such asymmetric lexical-lexical links is that in L1 to L2 priming, this model predicts that processing the L2 target verb strongly re-activates its L1 translation, which will increase priming via the mechanism of the within-language boost due to verb repetition (Experiment 2). However, in L2 to L1 priming, the L1 target verb will only weakly activate its L2 translation, insufficiently to result in an increase of priming via the within-language lexical boost mechanism (Experiment 4). Note that the model of Hartsuiker et al. (2004) does not provide explicit assumptions about lexical-lexical links between L1 and L2, but as explained above, the same predictions follow if that model incorporated weaker links between the conceptual level and L2 words than L1 words.

In sum, we conclude that the model of Hartsuiker et al. (2004) can account for a significant translation-equivalence boost from L1 to L2 (Experiment 2) and a weak or absent translation-equivalence boost from L2 to L1 (Experiment 4). It correctly predicts that this boost should be smaller than the within-language verb repetition boost (see Combined Analysis for Experiment 1-4).

Let us briefly consider some alternative explanations of our data. First, we might consider implicit learning mechanisms (Bock & Griffin, 2000; Chang et al., 2000, 2006) as an alternative to a spreading-activation account. Under the assumption that implicit learning involves a permanent change in the access to syntactic features, implicit learning accounts can correctly predict equal priming within languages in terms of more fluent access (instead of stronger activation) to a recently encountered syntactic structure. The predictions regarding cross-linguistic priming are less straightforward. According to Loebell and Bock (2003), an implicit learning account might predict stronger priming from L1 to L2, because the use of a well-mastered language might produce more effective priming than a less-mastered language. Thus priming should have more effect on L2 than L1. However, in the study by Loebell and Bock a trend towards greater priming from L1 to L2 than vice versa was not significant. Also, the present finding that priming across languages is about equally strong in both directions (L1 to L2: 8%; L2 to L1: 7%) is contrary to that prediction. It should be noted that the present results are consistent with the implicit learning account in the sense that this account considers the lexical boost (and presumably also the translation-equivalence boosts) to be target-based (Chang et al., 2006). In this account, the target verb acts as a retrieval cue, whereupon speakers can retrieve the prime sentence from explicit memory.

Another procedural view on syntactic priming involves the strengthening of the connection weights that link message-level representations (e.g., event semantics) with syntactic procedures (Griffin & Weinstein-Tull, 2003). The within-language lexical boost might then be due to the conceptual overlap between subsequent sentences that use the same head verb (or phrases that use the same head noun). This would correctly predict that the lexical boost is stronger than the semantic-relatedness boost (Cleland & Pickering, 2003) simply because a word is semantically more similar to itself (e.g., *sheep-sheep*) than it is to a semantically related noun (e.g., *sheep-goat*). But so long as the conceptual representations of semantically equivalent verbs do not differ, it incorrectly predicts that the translation-equivalence boost should be as strong as the within-language lexical boost.

In the absence of verb repetition or translation equivalence, the magnitudes of between- and within-language priming were very similar (8% vs. 11%). Although it would be unwise to draw a strong conclusion from this, it should be noted that Hartsuiker et al.'s (2004) model does not predict a difference between within- and between-language priming in the absence of within-language lexical repetition. As a consequence of the shared lemma stratum, between-language priming is in general predicted to be as robust as within-language priming (everything else being equal and regardless of the priming direction).

There are two obvious avenues for further research. First, we have only demonstrated cross-linguistic priming for fairly proficient but unbalanced bilinguals, who were not living in a community that spoke their second language.

Priming might differ for more or less proficient bilinguals. Second, we have found priming when the two languages use similar grammatical forms to each other under very similar conditions, and indeed where the languages are highly related. It remains to be seen whether priming would occur when the languages were less closely related, or perhaps more interestingly, when the two languages used slightly different constructions (cf. Loebell & Bock, 2003).

In conclusion, our study showed syntactic priming both within speakers' first and second languages and between their languages. More importantly, it demonstrated that priming can be enhanced when prime and target used translation-equivalent verbs, but that this enhancement only occurred when priming from L1 to L2, and that it was less than the lexical boost due to verb repetition. The findings support the view that bilinguals employ a single lexical-syntactic system, in which syntactic representations are shared between languages, in which syntactic choices are partly lexically mediated, and in which L2 words activate L1 words more than vice versa.

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APPENDIX

Experimental items. The (a) and (b) lines indicate the prime conditions: (a) was used in the related verb conditions; (b) was used in the unrelated verb condition. The noun phrase before the slash was used in the prepositional-object-inducing conditions; the noun phrase after the slash was used in the double-object-inducing conditions. The Dutch translations of the English prime sentences (in parentheses) were used in Experiments 2 and 3. The constituents of the target pictures are indicated in (c) in the order agent-beneficiary-theme-verb.

1a. The monk throws a hat/the sailor. [De monnik gooit een hoed/de matroos]

1b. The waitress offers a jug/the swimmer. [De serveerster presenteert een kan/de zwemmer]

1c. Policeman-clown-gun-throw.

2a. The chef gives a hat/the swimmer. [De kok geeft een hoed/de zwemmer]

2b. The burglar hands a ball/the pirate. [De inbreker overhandigt een bal/de piraat]

2c. Monk-doctor-book-give.

3a. The monk hands a book/the soldier. [De monnik overhandigt een boek/de soldaat]

3b. The chef throws a hat/the boxer. [De kok gooit een hoed/de bokser]

3c. Burglar-pirate-ball-hand.

4a. The nun shows a hat/the prisoner. [De non toont een hoed/de gevangene]

4b. The prisoner gives a pie/the boxer. [De gevangene geeft een taart/de bokser]

4c. Dancer-waitress-jug-show.

5a. The sailor throws a jug/the waitress. [De matroos gooit een kan/de serveerster]

5b. The monk sells a hat/the dancer. [De monnik verkoopt een hoed/de danseres]

5c. Pirate-soldier-gun-throw.

6a. The pirate hands a pie/the boxer. [De piraat overhandigt een taart/de bokser]

6b. The cowboy shows an apple/the pirate. [De cowboy toont een appel/de zeerover]

6c. Dancer-soldier-jug-hand.

7a. The pirate shows an apple/the burglar. [De piraat toont een appel/de inbreker]

7b. The policeman throws an apple/the waitress. [De agent gooit een appel/de serveerster]

7c. Prisoner-swimmer-gun-show.

8a. The teacher offers an apple/the soldier. [De leraar presenteert een appel/de soldaat]

8b. The policeman throws a jug/the swimmer. [De agent gooit een kan/de zwemmer]

8c. Cowboy-boxer-pie-offer.

9a. The cowboy offers a hat/the burglar. [De cowboy presenteert een hoed/de inbreker]

9b. The dancer gives a banana/the nun. [De danseres geeft een banaan/de non]

9c. Teacher-prisoner-jug-offer.

10a. The cowboy throws a ball/the dancer. [De cowboy gooit een bal/de danseres]

10b. The policeman shows a jug/the cowboy. [De agent toont een kan/de cowboy]

10c. Nun-swimmer-cup-throw.

11a. The cowboy throws a book/the clown. [De cowboy gooit een boek/de clown]

11b. The waitress offers a jug/the swimmer. [De serveerster presenteert een kan/de zwemmer]

11c. Policeman-monk-hat-throw.

12a. The policeman throws a hat/the sailor. [De agent gooit een hoed/de matroos]

12b. The chef sells a gun/the nun. [De kok verkoopt een geweer/de non]

12c. Cowboy-dancer-banana-throw.

13a. The burglar sells a ball/the doctor. [De inbreker verkoopt een bal/de dokter]

13b. The chef hands a jug/the soldier. [De kok overhandigt een kan/de soldaat]

13c. Prisoner-pirate-apple-sell.

14a. The teacher sells a jug/the cowboy. [De leraar verkoopt een kan/de cowboy]

14b. The chef hands a jug/the soldier. [De kok overhandigt een kan/de soldaat]

14c. Painter-doctor-gun-sell.

15a. The dancer hands an apple/the doctor. [De danseres overhandigt een appel/de dokter]

15b. The teacher gives an apple/the dancer. [De leraar geeft een appel/de danseres]

15c. Pirate-sailor-pie-hand.

16a. The chef gives a gun/the prisoner. [De kok geeft een geweer/de gevangene]

16b. The burglar hands a ball/the pirate. [De inbreker overhandigt een bal/de piraat]

16c. Teacher-swimmer-banana-give.

17a. The burglar shows a hat/the soldier. [De inbreker toont een hoed/de soldaat]

17b. The painter hands a hat/the waitress. [De schilder overhandigt een hoed/de serveerster]

17c. Pirate-clown-gun-show.

18a. The waitress gives a pie/the boxer. [De serveerster geeft een taart/de bokser]

18b. The cowboy offers a pie/the monk. [De cowboy presenteert een taart/de monnik]

18c. Burglar-nun-hat-give.

19a. The cowboy throws a book/the clown. [De cowboy gooit een boek/de clown]

19b. The policeman shows a cup/the cowboy. [De agent toont een kopje/de cowboy]

19c. Nun-dancer-apple-throw.

20a. The teacher sells a jug/the cowboy. [De leraar verkoopt een kan/de cowboy]

20b. The sailor throws a banana/the teacher. [De matroos gooit een banaan/de leraar]

20c. Painter-swimmer-hat-sell.

21a. The nun shows a hat/the prisoner. [De non toont een hoed/de gevangene]

21b. The policeman throws an apple/the waitress. [De agent gooit een appel/de serveerster]

21c. Burglar-soldier-cup-show.

22a. The cowboy throws a ball/the dancer. [De cowboy gooit een bal/de danseres]

22b. The chef sells a gun/the nun. [De kok verkoopt een geweer/de non]

22c. Pirate-sailor-book-throw.

23a. The chef gives a hat/the swimmer. [De kok geeft een hoed/de zwemmer]

23b. The cowboy offers a pie/the monk. [De cowboy presenteert een taart/de monnik]

23c. Dancer-sailor-cup-give.

24a. The dancer hands an apple/the doctor. [De danseres overhandigt een appel/de dokter]

24b. The teacher gives an apple/the dancer. [De leraar geeft een appel/de danseres]

24c. Chef-sailor-hat-hand.

25a. The soldier throws a jug/the waitress. [De soldaat gooit een kan/de serveerster]

25b. The monk sells a hat/the dancer. [De monnik verkoopt een hoed/de danseres]

25c. Cowboy-swimmer-pie-throw.

26a. The pirate shows an apple/the burglar. [De piraat toont een appel/de inbreker]

26b. The painter hands a hat/the waitress. [De schilder overhandigt een hoed/de serveerster]

26c. Nun-monk-banana-show.

27a. The cowboy offers a hat/the burglar. [De cowboy presenteert een hoed/de inbreker]

27b. The monk hands a cup/the dancer. [De monnik overhandigt een tas/de danseres]

27c. Waitress-sailor-gun-offer.

28a. The pirate hands a pie/the boxer. [De piraat overhandigt een taart/de bokser]

28b. The cowboy shows an apple/the pirate. [De cowboy toont een appel/de zeerover]

28c. Painter-waitress-gun-hand.

29a. The teacher sells a banana/the burglar. [De leraar verkoopt een banaan/de inbreker]

29b. The teacher offers a cup/the prisoner. [De leraar presenteert een tas/de gevangene]

29c. Dancer-nun-book-sell.

30a. The monk hands a book/the soldier. [De monnik overhandigt een boek/de soldaat]

30b. The chef throws a hat/the boxer. [De kok gooit een hoed/de bokser]

30c. Prisoner-doctor-banana-hand.

31a. The burglar shows a hat/the soldier. [De inbreker toont een hoed/de soldaat]

31b. The monk gives a cup/the doctor. [De monnik geeft een tas/de dokter]

31c. Pirate-boxer-jug-show.

32a. The prisoner sells an apple/the nun. [De gevangene verkoopt een appel/de non]

32b. The doctor shows a cup/the soldier. [De dokter toont een kopje/de soldaat]

32c. Chef-clown-pie-sell.

33a. The swimmer shows a gun/the soldier. [De zwemmer toont een geweer/de soldaat]

33b. The prisoner gives a pie/the boxer. [De gevangene geeft een taart/de bokser]

33c. Chef-nun-hat-show.

34a. The waitress offers a cup/the doctor. [De serveerster presenteert een tas/de dokter]

34b. The dancer gives a banana/the nun. [De danseres geeft een banaan/de non]

34c. Teacher-chef-hat-offer.

35a. The prisoner sells a ball/the doctor. [De gevangene verkoopt een bal/de dokter]

35b. The teacher offers a cup/the prisoner. [De leraar presenteert een tas/de gevangene]

35c. Burglar-sailor-book-sell.

36a. The cowboy offers a banana/the swimmer. [De cowboy presenteert een banaan/de zwemmer]

36b. The monk hands a cup/the dancer. [De monnik overhandigt een tas/de danseres]

36c. Policeman-painter-book-offer.

37a. The clown gives a jug/the sailor. [De clown geeft een kan/de matroos]

37b. The dancer sells a pie/the policeman. [De danseres verkoopt een taart/de agent]

37c. Prisoner-pirate-hat-give.

38a. The prisoner sells an apple/the nun. [De gevangene verkoopt een appel/de non]

38b. The doctor shows a cup/the soldier. [De dokter toont een kopje/de soldaat]

38c. Teacher-sailor-banana-sell.

39a. The clown gives a jug/the sailor. [De clown geeft een kan/de matroos]

39b. The clown shows a banana/the sailor. [De clown toont een banaan/de matroos]

39c. Chef-boxer-gun-give.

40a. The painter hands a pie/the doctor. [De schilder overhandigt een taart/de dokter]

40b. The teacher offers a banana/the chef. [De leraar presenteert een banaan/de kok]

41c. Monk-boxer-apple-hand.

41a. The chef gives a gun/the prisoner. [De kok geeft een geweer/de gevangene]

41b. The dancer sells a pie/the policeman. [De danseres verkoopt een taart/de agent]

41c. Nun-book-soldier-give.

42a. The swimmer shows a gun/the soldier. [De zwemmer toont een geweer/de soldaat]

42b. The monk gives a cup/the doctor. [De monnik geeft een tas/de dokter]

42c. Painter-cowboy-ball-show.

43a. The teacher sells a banana/the burglar. [De leraar verkoopt een banaan/de inbreker]

43b. The sailor throws a banana/the teacher. [De matroos gooit een banaan/de leraar]

43c. Monk-nun-jug-sell.

44a. The teacher offers an apple/the soldier.[De leraar presenteert een appel/de soldaat]

44b. The painter sells a gun/the sailor. [De schilder verkoopt een geweer/de matroos]

44c. Policeman-doctor-jug-offer.

45a. The painter hands a pie/the doctor. [De schilder overhandigt een taart/de dokter]

45b. The teacher offers a banana/the chef. [De leraar presenteert een banaan/de kok]

45c. Dancer-cowboy-apple-hand.

46a. The waitress gives a pie/the boxer. [De serveerster geeft een taart/de bokser]

46b. The clown shows a banana/the sailor. [De clown toont een banaan/de matroos]

46c. Painter-swimmer-jug-give.

47a. The cowboy offers a banana/the swimmer. [De cowboy presenteert een banaan/de zwemmer]

47b. The painter sells a gun/the sailor. [De schilder verkoopt een geweer/de matroos]

47c. Waitress-clown-cup-offer.

48a. The waitress offers a cup/the doctor. [De serveerster presenteert een tas/de dokter]

48b. The policeman throws a jug/the swimmer. [De agent gooit een kan/de zwemmer]

48c. Cowboy-soldier-apple-offer.

CHAPTER 5
GENERAL DISCUSSION

The aim of the present doctoral dissertation was to further investigate the mental organization of bilingual memory. Our research questions focussed on the representation of semantic and syntactic knowledge in both languages and their respective interactions with lexical representations. First, the main empirical findings from the previous chapters will be summarized, and then we discuss some theoretical implications for bilingual models and possible avenues for further research on the architecture of bilingual memory.

RESEARCH OVERVIEW AND THEORETICAL IMPLICATIONS

Our major interest was to find out if and to what extent linguistic representations can be shared across languages. Importantly, our work focussed on different kinds of linguistic representations in bilingual memory. The first two empirical chapters (*Chapter 2 and 3*) mainly investigated semantic representations across languages, while the third empirical chapter (*Chapter 4*) had its main focus on how syntactic structures are represented across languages. In all chapters, we also explored the interaction with lexical representations of both languages.

The presented work is limited to studies testing unbalanced bilinguals, i.e. bilinguals who typically learned a second language at a later age, and are less proficient in this second language than in their native language. The specific bilingual populations under study are Dutch [Flemish]-English bilinguals living in Flanders (*Chapter 2 and 4*), as well as English-French bilinguals living in the USA (*Chapter 3*).

The study reported in *Chapter 2* investigated to what extent semantic representations are shared across languages, and how strongly L2 lexical representations are connected to these shared concepts. Previous research using masked translation priming as a tool to unravel lexico-semantic representations has provided mixed evidence regarding the possibility of obtaining priming effects from the second language to the first, with most studies showing no effect at all (see Table 1, *Chapter 2*). These findings were traditionally taken as evidence for weak lexico-semantic connections for L2, as opposed to the strong connections in L1 (resulting in very robust L1 to L2 priming effects across many studies). In *Chapter 2*, we wanted to further investigate this asymmetry, as we reasoned that finding L2 to L1 priming might also depend on word variables, such as concreteness. We tested translation priming as well as cross-language semantic priming from L1 to L2 and vice versa in unbalanced Dutch-English bilinguals under masked conditions (using a 250 ms SOA, as was used in the study of Jiang & Forster, 2001). A lexical decision task was used with noncognate prime-target pairs (cf. the task and stimuli used in previous studies reporting the asymmetry), while we also manipulated the concreteness of our prime-target pairs (unlike previous experiments).

Experiment 1 replicated the translation priming effect from L1 to L2 with Dutch-English bilinguals (e.g., *meisje* [girl] – *GIRL*), while Experiment 2 showed a smaller but still reliable translation priming effect from L2 to L1 (e.g., *girl – MEISJE* [GIRL]). Although we replicated the traditional translation priming asymmetry, we also showed that L2 primes were able to pre-activate L1 targets. This is clearly in contrast with the previous lexical decision studies that failed to find such effects. Experiment 3 and Experiment 4 further showed that masked cross-language semantic priming can be observed both from L1 to L2 (e.g., *jongen [boy] – GIRL*; Experiment 3), and from L2 to L1 (e.g., *boy –MEISJE [GIRL];* Experiment 4). Note however that we did not observe a significant asymmetry in these experiments, possibly because our the cross-language priming effects were to weak for the effect to stand out.

None of these cross-language priming effects interacted significantly with concreteness, although numerically there was an indication for weaker priming across abstract prime-targets pairs as opposed to concrete pairs, especially when priming from L2 to L1 (where we observed a 16-ms priming difference). Before discussing the theoretical interpretations of this study, the results of a follow-up study will be summarized below.

The experiments reported in *Chapter 3* were set out to further examine the findings of *Chapter 2* concerning semantic representations and lexico-semantic mappings in bilingual memory. For this purpose, we used the ERP-methodology. One of the ERP-components we were interested in was the N400. This component is thought to reflect semantic activation across languages in our priming manipulations. The N250-component, on the other hand, is taken as an indication for earlier lexical processing. Thanks to the excellent temporal resolution of the ERP-measures, we could also investigate whether L2 lexical representations can rapidly pre-activate their L1 translation equivalents through semantic mediation (or either through direct lexical activation), and exactly how rapidly this is possible compared to the L1 to L2 effect.

We only tested masked translation priming (not cross-language semantic priming) for abstract and concrete non-cognates translation pairs, now with English (L1) –French (L2) bilinguals engaging in a lexical decision task. Both priming directions were tested as well as two different SOAs (120ms and 200 ms). The behavioral part of this study showed a nice replication of the findings of *Chapter 2*, at both SOAs. Moreover, both experiments showed that the N400-component was modulated due to the priming manipulations in both directions; this was a typical posterior effect that did not interact with concreteness. We also observed a latency shift in the N400 for L2 targets due to slower processing in L2.

Although, similar to our previous study, there was a lack of main concreteness effects (at both SOAs) in the behavioral data, ERPs clearly showed main concreteness effects to targets, indicated by a more atypical N400-effect at frontal sites. Interestingly, these N400-concreteness effects occured 100ms later in L2 (as opposed to in L1), and this was true not only for target concreteness effects, but very early (150ms) concreteness effects, possibly elicited by the primes. Finally, we also found an earlier ERP-component to be sensitive to our priming manipulations, i.e., the N250. Although still speculative, this component might indicate sublexical or lexical processing. Given that the N250-effect was larger from L2 to L1, this could indicate that L2 to L1 lexical links were activated during priming, conform predictions based on the architecture of the RHM. Although the long SOA in Experiment 2 did allow more time to process our stimuli, we observed a quite similar data pattern as with the shorter SOA (Experiment 1).

Throughout these first two chapters, the predictions of several bilingual models were tested. First of all, based on a strict interpretation of the Revised Hierachical model (RHM; Kroll & Stewart, 1994), a translation priming asymmetry was expected, but we did not expect significant priming from L2 to L1, because the locus of these priming effects is assumed to be semantic (see Grainger & Frenck-Mestre, 1998) and the RHM posits that only weak lexico-semantic links exist between L2 lexical representations and the conceptual system.

However, our data from the ERPs tentatively suggested that a lexical route might have been part of the effect as well (see below, for some alternative explanations regarding this interpretation). Although the strict interpretation of this model clearly is incompatible with our findings of L2 to L1 semantic priming, thanks to its developmental hypothesis this model can also be regarded more as a model of quantitative differences (as opposed to the strict model assuming qualitative differences between L2 and L1 representations and their respective lexico-semantic links). By demonstrating robust L2-L1 priming effects, in behavioral data as well as in ERPdata, we have shown that it is certainly not impossible for L2 learners to develop strong lexico-semantic links for L2 lexical representations.

Overall, the pattern of results that emerges from *Chapter 2* and *3* is one of quantitative differences: the priming effect is larger/earlier from L1 on L2 than vice versa, larger for translation priming than for semantic priming, and slightly larger (but not significantly) for concrete words than for abstract words, as predicted by the DRM (Van Hell & de Groot, 1998). So, although we did not find convincing evidence for more overlap between abstract L1-L2 versus concrete L1-L2 representations, we are tempted to agree with the underlying idea of the DRM that activation in bilingual memory has to do with more or less overlapping representations, and thus is defined in term of quantitative differences, rather than a quality difference. In such an account, is it also easily possible to account for effects of proficiency (with increased proficiency, there is an increased activation of semantic features in L2), and possible effects of SOA (with increasing SOA, more features can become active).

A third bilingual model that is supported by the data in *Chapter 2* and *3* is the Bilingual Interactive Activation + (BIA+) model, which is largely based on the influencial Interactive Activation model for monolingual word recognition (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). While in the DRM asymmetric priming effects would be the result of the proportion of shared semantic features (between L1 and L2 representations) that become active in each condition, the BIA+ model can account for this asymmetry through its temporal delay hypothesis. The idea is that L2 representations become active more slowly than L1 representations, and therefore might not receive enough activation in time to strongly pre-activate L1 targets and thus produce priming effects. The fine-grained temporal resolution of ERPs (used in *Chapter 3*) further confirmed this assumption by demonstrating a latency shift in N400-effects to L1 stimuli.

In *Chapter 4* of the presented dissertation, we considered another level of linguistic representations, namely syntactic representations, which are arguably more representative for natural language use. Instead of using a masked priming paradigm, we now used syntactic priming as a pre-eminent tool to investigate if syntactic representations can also be shared across languages. Given that both the double object (DO) dative structure and the prepositional dative (PO) structure occur in Dutch as well as in English, we hypothesized that the repesentation of these particular syntactic structure might be shared. For unbalanced Dutch-English bilinguals, we indeed demonstrated robust syntactic priming effects within L1 and L2, as well as across both languages (from L1 to L2, and from L2 to L1), using PO and DO dative structures. Additionally, we tested the lexical basis of these syntactic priming effects by manipulating verb repetition across prime and target sentences in all experiments. We showed that syntactic priming could not only be enhanced by verb repetition within L1 but also within L2, an effect known from monolingual studies as the *lexical boost*. Additionally, we were the first to demonstrate what we labelled as a *translation equivalence boost.* This boost was observed when translation equivalent verbs (e.g. *geven* and *give*) were used in prime and target sentences during syntactic priming from L1 to L2 (*geven* [give] – *GIVE*), but not from L2 to L1 (*give* – *GEVEN* [give]). A cross-experiment comparison further demonstrated the cross-lingual translation equivalence boost was significantly smaller than the monolingual lexical boost.

The data of *Chapter 4* provided further evidence for the model of Hartsuiker, Pickering and Veltkamp (2004). However, an adjustment seems necessary to account for the lack of a translation-equivalence boost in L2 to L1 syntactic priming. In its original version, the model of Hartsuiker et al. (2004) predicts an equally large boost to priming from L1 to L2 than vice versa. In the discussion of *Chapter 4*, we opted for an adjusted version supported by the RHM, namely the assumption of weak lexical-conceptual links for L2. More precisely, we incorporated the claim that the link between a L2 lexical representation and its concept is less strong than the link between an L1 lexical representation and its concept. Note that the original model of Hartsuiker et al. (like the RHM) already assumed that concepts are shared across languages. We hypothesized that in L2-L1 priming, activation from the shared concept GEVEN/GIVE (X,Y,Z) may not re-activate the English (L2) non-target lemma *give* to the same extent that it re-activates the Dutch non-target lemma *geven* in L1-L2 priming. The re-activation of this lemma in the latter case, causes stronger priming effects due to stronger connections from the shared concept to L1 as compared to the connections to L2. In short, the model can now correctly predict our data, while showing that bilinguals employ a single lexical-syntactic system, in which syntactic representations are shared between languages, in which syntactic choices are partly lexically mediated, and in which L2 words activate L1 words more than vice versa.

Note that in order to explain our effects in terms of the adjusted model, we needed to assume a target based account of priming in this production study (see *Chapter 4*, Discussion). Further research is ongoing in our lab to investigate a prime-based versus target-based account of lexical modulation in the syntactic priming. Also recently, a re-analysis of our syntactic priming data by Bernolet, Hartsuiker, Bressers, & Pickering (2008) pointed out proficiency effects in our data. In this recent study investigating syntactic cross-language priming with genitives (e.g., *the apple of the boy is blue* vs. *the boy's apple is blue*), Bernolet et al. also observed stronger between-language priming for repeated head nouns that were Dutch-English cognates (*appel – apple*) as opposed to head nouns that were non-cognates (*emmer – bucket*), when testing more proficient bilinguals. For less proficient bilinguals, no between-language priming was obtained whatsoever. This suggests that initially L2 structures receive separate representations, that become shared as L2 proficiency and the use of that particular structure across languages increases, meaning that the lexico-syntactic model for bilingual sentence production (Hartsuiker et al., 2004) represents a more advanced state of the L2 learning trajectory. This again marks the importance of proficiency as a necessary variable to include in bilingual modelling.

FURTHER DISCUSSION AND INDICATIONS FOR FUTURE RESEARCH

This research did not only lead to some new theoretical considerations, it has also put forward interesting questions about priming methodology (SOA), concreteness, and inhibition effects in bilinguals. These will be discusses in the next paragraph, together with some ideas for future research.

Indeed, a result that came as a surprise to us, was the absence of robust concretenesseffects in all reaction time experiments reported in this dissertation (see *Chapter 2* and *3*), while in previous studies a clear advantage for concrete over abstract words is observed, even in a lexical decision task as used in the our experiments (de Groot, 1992; Schwanenflugel, 1991). Clearly, the use of a lexical decision task could not be the cause of observing null-effects for concreteness. As mentioned in the discussion of *Chapter 3*, context availability theory (Schwanenflugel, 1991) suggests that concreteness effects are only observed if there is no context available. In this case, priming might be providing a single word context. However, Swaab and colleagues (2002) suggested that supportive context can only override the effects of concreteness when the context is relatively strong, as in a sentence[1].

One could also argue that the lack of concreteness effects has something to do with the stimuli used. For instance, it is possible that the concreteness effects do not fully develop when using one-to-one translations[2]. Recently, a study by Tokowicz and Kroll (2007) indicated that concreteness interacts with another variable, namely *number of translations*. They only observed concreteness effects when abstract words have more meanings than concrete words, a situation that was avoided in our study. Using one-to-one

[1] we are indebted to Janet van Hell to offer this suggestion
[2] we thank Judith Kroll for raising this possibility as way to account for the absence of clear main concreteness effects in *Chapter 2*

translations was neccesary in our study in order to ensure that L2 translation primes pre-activate the given L1 target, and vice versa.

However, the fact that we observed the same (null-)effects with two different stimulus sets (Dutch-English and English-French), and the fact that robust concreteness effects were observed in the ERP-measures of *Chapter 3* (even for primes), does not make this a very likely effect of stimulus set. Another suggestion that can be made is that our participants might be able to experience 'concreteness priming'. If the prime is concrete, participants know that if the targets is a word it will be a concrete one. Then because they already have a cue about the concreteness of the target, this may result in weaker behavioral concreteness effects, although it is not intirely clear why we then still observe equally robust N400-concreteness effects[3].

An argument that might be made as why we did not observe interactions between priming and concreteness is that our studies dealt with a lack of power. However, this is again not very likely given that the other reported effects (e.g., priming) were very robust, and thus clearly not borderline. Moreover, a meta-analyses of priming studies also shows that our data have somewhat more power than the other studies (see Table 1, *Chapter 2*). So, although we can think of some reasons why concreteness effects are not as robust as traditionally observed, it does not make sense that at the same time robust main concreteness effects were observed in the ERP data.

A possible alternative explanation for the N250-modulations due to the priming in *Chapter 3* might be found in the inhibition literature. Our N250-effects, which are observe more clearly in the L2 to L1 priming condition, might actually indicate that our subjects had to inhibite L2 to perform lexical decision on the L1 targets. Indeed, negative going peaks in the brain-

[3] We thank Walter van Heuven for this suggestion

waves have been associated with inhibition effects (Jackson et al, 2001). Given the fact that primes were shown for about 100ms, it is possible that they were consciously perceived. Literature on inhibition effects and switch costs shows that typically in reaction time studies there is a larger switch cost, reflected by longer RTs (e.g., Meuter & Allport, 1999), when switching from the second language to the first (L2 to L1 priming), while in ERP-studies switch cost is found to be larger when switching from L1 to L2, reflected by a modulation of the N200 at more frontal sites (e.g., Jackson et al., 2001). This is not consistent with our data, since the ERP-priming effects around 250 ms are stronger when priming from L2 to L1. However, it should be noted that the above mentioned effects were reported in production studies, and our studies tested recognition only. An interesting question for future research with respect to these inhibition effects is the following: 'Is the switch cost (from L2 to L1), as indicated by an negative going wave around 200 ms, supposed to be reduced when switching between translation equivalents (from fille [French for girl] to GIRL), relative to the switch cost when switching between unrelated L2 and L1 items?'

Although it might well be that our priming effects were boosted by this longer SOA, we believe that the 120ms-SOA in our studies was short enough to exclude strategic effects (see Altarriba & Basnight-Brown, 2007). However, we have to note that the fact that we observed concreteness effects to L1 primes when using an SOA as short as 120ms, might be an indication that participants were seeing the primes. Although our 120 ms-SOA was justified according to the guidelines of Altarriba & Basnight-Brown (2007) on how to perform masked priming studies across languages, further research is needed. Their advice was largely based on the finding that strategic effects occurred at 300-ms SOA, but dissapeared at a 167-ms SOA (Hutchison, Neely, & Jhonson, 2001). Given the fact that we observed very similar effects across our three different SOA manipulations, (*Chapter 2* and *3;* 250ms, 120ms and 200ms respectively), and given the assumption that a 120-ms SOA does not elicit strategic effects, we doubt the presence of strategic effects in our experiments. However, in order to conclusively deal with arguments regarding SOA, a replication of the data obtained in *Chapter 2* using a gradually shorter SOA seems helpful. In this respect, a very recent paper by Perea, Duñabeita & Carreiras (2008) is interesting. These researchers investigating masked cross-language priming with highly proficient Basque-Spanish bilinguals performing a lexical decision task. At an SOA of only 47ms, they obtained significant non-cognate translation priming and significant semantic priming from the first language to the second (16 ms and 11 ms respectively), but also from the second language to the first (12 ms and 15 ms respectively), using only concrete words. This replicates the observed priming effects in *Chapter 2* (and *3*) of this dissertation, although Perea et al. (2008) did not observe asymmetric priming effects (unlike our translation priming data). On the one hand, the fact that our studies tested unbalanced, moderately proficient bilinguals, is most likely responsible for the observed asymmetry in the translation priming studies. Although our L2 learners did access semantics in their L2, this lexico-semantic link is probably not as strong/fast yet as in L1. On the other hand, the fact that the L2 to L1 priming effect did reach significance in our study with only moderately proficient bilinguals could be explained by the use of somewhat longer SOAs (ranging from 120 ms to 250ms) than traditionally tested (50 ms to 100 ms).

An aspect of L2 representations that was not directly under study in this dissertation was the representation of lexical information. We did show that L2 lexical representations have early connections with the conceptual system but, as indicated in *Chapter 3*, the N250 priming effect from L2 to L1 might indicate the use of a lexical route to go from L2 to L1 as well. The question then is: which of these routes is fastest? Does L2 to L1 translation occurs fastest through semantic mediation, or is the lexical route between L2 and L1 representations faster ? A study that would possibly allow to answer this question is a study assessing the Lateralized Readiness Potential (LRP). The LRP is an ERP component, indicating (hand) response preparation (Van Turennout, Hagoort, & Brown, 1997). The underlying thought is that to prepare a response, information relevant to perform the task must be available. In a first experiment, bilinguals would be asked to name an L2 word, after performing a semantic and/or lexical decision. The semantic decision (*Is this animate or not?*) determines whether participants need to make a second – lexical – decision (*Is the first letter of the L1 translation letter 'm'?: press Left, if not: press Right*). If the stimulus is non-animate, the second lexical task does not need to be performed (no-go condition). If an LRP is then observed in this no-go condition, it can be taken as evidence for strong lexical links between L2 words and their L1 translation. It indicates that lexical information (needed to perform the unnecessary task) was already activate, before the semantic decision was made, and based on that a response was prepared (LRP). A second experiment can then apply this method to test what the fastest route for L1 to L2 translation is, by presenting an L1 target instead of an L2 target. The RHM clearly predicts (fastest) translation from L2 to L1 via direct lexical links, but (fastest) translation from L1 to L2 via conceptual mediation. As a further test, a variant of this paradigm would be executed, in which the lexical task determines the go/no-go response and the semantic task the hand response. If L2 to L1 translation indeed occurs through strong lexical links, then an LRP should not be observed when the no-go condition is depending on the lexical task. The lexical representation of the L1 translation would have been activated before semantic information became active.

Of course, the finding of which route is fastest to translate from L2 to L1 might depend on L2 proficiency. According to the RHM, low proficient bilinguals would then only use the lexical route, while more proficient bilinguals would be able to rely more on the semantic route. Therefore, it will be interesting to manipulate proficiency of the bilinguals in these LRP experiments.

Given that the re-analysis of our syntactic priming data revealed proficiency effects as well, it indeed seems important to further take into account the individual proficiency of tested bilinguals. To this respect, we must note that self-proficiency ratings on various aspects of L2 skills (although proven to correlate well with actual performance) might not be the most objective measures of L2 proficiency. It is challenge for future research to develop a standardized test to objectively assess the proficiency of the bilinguals at test.

TO CONCLUDE

Bilinguals are more efficient in language storage than is traditionally assumed. Using different paradigms and combining behavioral data with electrophysiological research techniques, such as ERPs, this doctoral dissertation clearly showed that several linguistic representations in bilingual memory can be shared across languages. Importantly, it is shown that the second language can influence native language processing at different processing levels, as indicated by the obtained translation priming, semantic priming, and syntactic priming effects from the second language to the first.

Goodbye,

Tot ziens,

Adiós,

Ďakujem,

Goeie dag,

Au revoir,

La revedere,

Köszönöm,

Arrivederci,

Dziękuję,

Прощай,

さようなら,

ייה,

안녕히 계세요

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NEDERLANDSE SAMENVATTING

Dit doctoraat had als doel de organisatie van het tweetalig geheugen te onderzoeken. Er werd nagegaan of en in welke mate verschillende linguïstische representaties voor beide talen kunnen gedeeld worden. In de eerste twee hoofdstukken werd de vraag omtrent gescheiden of gedeelde semantische representaties gesteld, waarbij ook aandacht was voor de lexico-semantische organisatie van beide talen. Het Revised Hierarchical model (RHM) van Kroll en Stewart (1994) veronderstelt namelijk dat L2 lexicale representaties (i.e. woorden in de tweede taal) niet of niet sterk verbonden zijn met het semantisch systeem, waar de betekenis zit opgeslagen. Het RHM stelt hierbij ook dat L2-woorden hun L1-vertaling (in de moedertaal) activeren via sterke woord-woord associaties en niet via conceptuele mediatie. Een tweede model, het Distributed Representation model (DRM) van Van Hell en de Groot (1998) stelt dat L2-woorden wél direct semantiek kunnen activeren (zonder eerst te vertalen naar L1). De mate waarin dit mogelijk is, is – volgens het DRM – echter afhankelijk van semantische woordvariabelen, zoals Concreetheid. Concrete vertalings-equivalenten, zoals bijvoorbeeld *meisje* en *girl* voor een Nederlands-Engels tweetalige, zouden meer overlappen qua betekenis dan abstracte vertalingsequivalenten (bvb. *wraak* en *revenge*). De predicties van beide modellen werden getest in Hoofdstukken 2 en 3. Het derde hoofdstuk richtte zich op de vraag of ook syntactische representaties tussen talen kunnen gedeeld worden (gegeven dat beide talen gelijkaardige structuren bevatten). Ook hier wordt de interactie tussen lexicale en syntactische representaties onderzocht. Predicties werden opgemaakt volgens een lexico-syntactisch model van tweetalige zinsproductie (Hartsuiker, Pickering, & Veltkamp, 2004).

Resultaten

Hoofdstuk 2 onderzocht de activatie van een gedeelde conceptuele representatie voor beide talen in een gemaskeerd priming paradigma. Zowel vertalingspriming als semantische priming over talen heen werd onderzocht bij ongebalanceerde Nederlands-Engels tweetaligen. Hierbij manipuleerden we tevens de semantische woordvariabele Concreetheid. Er werd significante vertalingspriming (bvb. boy-JONGEN) gevonden in de reactietijden (snellere reactietijd wanneer een target voorafgegaan werd door zijn vertaling in vergelijking met wanneer een ongerelateerd woord de target voorafging), alsook significante semantische priming tussen talen (bvb. boy-MEISJE). Beide effecten werden gevonden van L1 naar L2, alsook van L2 naar L1. Hoewel het L2-L1 priming effect minder sterk is in vergelijking met het L1-L2 effect, is het toch duidelijk een significant effect. Dit is in tegenstrijd met de predicties van het RHM. Er werden geen interacties gevonden tussen priming en concreetheid van de gebruikte woordparen. Nochtans voorspelt het DRM hier grotere primingseffecten voor concrete vertalingsparen in vergelijking met abstracte primingsparen, omdat de semantische representaties van concrete woorden meer zouden overlappen over talen heen. Zodoende kunnen dus meer semantische kenmerken van de target reeds door de prime worden geactiveerd. Conform deze ‘kwalitatieve’ hypothese, observeerden we wel meer priming van L1 naar L2 (dan omgekeerd), en grotere vertalingspriming dan semantische priming over talen heen.

Hoofdstuk 3 ging verder in op de onderzoeksvraag uit Hoofdstuk 2. Met een nieuwe proefgroep, ongebalanceeerde Engels-Frans tweetaligen, werden de effecten uit Hoofdstuk 2 grotendeels gerepliceerd. Echter, naast gedragsmaten werd hier ook gekeken naar electrofysiologische metingen, de zogenaamde Event-Related-Potentials (ERPs). Via deze sensitievere metingen van semantische activatie, werd duidelijke evidentie voor semantische mediatie (en dus gedeelde semantische representaties tussen talen, alsook sterke lexico-semantische links) gevonden, wat zich o.a. uitte in een N400-effect. De N400 is een ERP-component die als indicatie voor semantische activatie wordt naar voren geschoven (Kutas & Hillyard, 1984). Dit effect werd geobserveerd tijdens priming in beide richtingen, maar kwam iets later tot stand voor L2-targets. Dit laatste bleek ook evidentie voor de temporal delay assumptie, waarbij wordt gesteld dat L2-verwerking niet noodzakelijk minder diep maar vooral trager verloopt dan taalverwerking in de moedertaal (zie Dijkstra & Van Heuven, 2002). Interacties tussen priming en concreetheid bleven ook hier echter uit.

Deze resultaten duidden erop dat de lexico-semantische organisatie voor L2 niet kwalitatief maar eerder kwantatief verschilt van de lexico-semantische organisatie in L1. Met andere woorden: het bestaan van verbindingen (en dus invloeden) van de L2 lexicale representatie naar het conceptueel systeem valt zeker niet uit te sluiten.

Tenslotte werd in Hoofdstuk 4 de vraag naar gescheiden of gedeelde syntactische representaties onderzocht aan de hand van het syntactische priming, en op basis van de voorspellingen van het model van Hartsuiker et al. (2004). Hier werd gevonden dat Nederlands-Engels tweetaligen meer geneigd waren om een bepaalde datieve structuur in het Engels te produceren (bvb. *The boy gave the girl a hat*), indien ze net de Nederlandstalige variant van deze structuur hadden gehoord (bvb. *De kok gaf de zwemmer een appel*). Dit priming effect van syntactische structuur werd tevens versterkt wanneer in beide zinnen tussen talen hetzelfde werkwoord werd gehanteerd, en het effect werd ook gevonden in syntactische priming van de tweede taal naar de eerste taal (waar het sterkere effect voor herhaalde werkwoorden ontbrak).

Conclusie

Op basis van de verkregen data uit de drie empirische hoofdstukken werd geconcludeerd dat ongebalanceerde tweetaligen in staat zijn om linguistische representaties van beide talen op verschillende niveaus te delen. Hoofdstukken 2 en 3 toonden aan de vraag naar gedeelde versus gescheiden semantische representaties, eerder moet vervangen worden door de vraag naar de mate van overlap tussen deze semantische representaties en de snelheid waarmee semantiek geactiveerd wordt in L1 versus L2 (zie Dijkstra & van Heuven, 2002). Ook voor syntactische representaties werd gevonden dat deze kunnen gedeeld worden tussen talen, maar dit zou tevens afhankelijk zijn van de specifieke structuur en de mate van L2-berheersing bij de tweetalige. Door gebruik te maken van verschillende priming paradigmata en via de combinatie met electrophysiologische technieken (ERPs) werd wel duidelijk aangetoond dat een tweede, mindere gekende taal in staat is om taalverwerking in de moedertaal te beïnvloeden op semantisch en syntactisch niveau, en dit bij ongebalanceerde tweetaligen.

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