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The representation of lexical and syntactic information in bilinguals: Evidence from syntactic priming

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Abstract

To what extent do bilinguals have a single, integrated representation of syntactic information? According to Hartsuiker et al. (2004) [Hartsuiker, R. J., Pickering, M. J., & Veltkamp, E. (2004). Is syntax separate or shared between languages? Cross-linguistic syntactic priming in Spanish–English bilinguals. *Psychological Science, 15*, 409–414.], 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.

Keywords: Sentence production; Speech production; Syntactic priming; Bilingualism; Verb

Introduction

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

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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, Pickering, & Veltkamp, 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 reuse 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 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, & Cleland, 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, Clifton, & Ehrlich, 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 et al., 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, 2006; Chang, Dell, Bock, & Griffin, 2000). 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 10 intervening sentences between prime and target (Bock & Griffin, 2000; Bock & Kroch, 1989; Hartsuiker & Kolk, 1998b). However, other authors did not find such a long-lasting syntactic priming effect (Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; 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, and 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 inte-

grated 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 Fig. 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.

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; Cleland & Pickering, 2003; Pickering & Branigan, 1998). 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, 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 such as 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 are 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

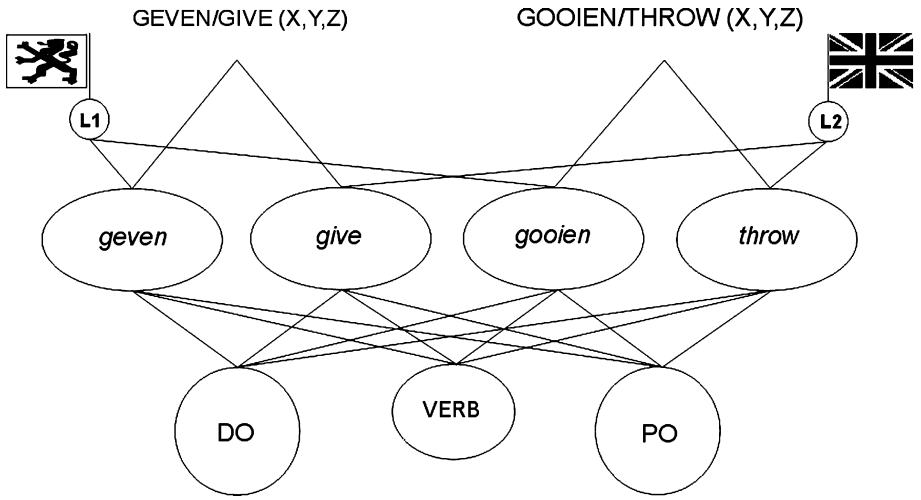

Fig. 1. An example of lexico-syntactic representations of the verbs 'geven', 'give', 'gooien', and 'throw' at the lemma stratum in bilingual memory. In this integrated (shared lexicon, shared syntax) network, each lemma node (*geven*, *give*, *gooien*, and *throw*) is linked to one conceptual node (GEVEN/GIVE (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 [DO] and prepositional object [PO]), and to one language node (represented by a Flemish or British flag).

for *geven* because of the shared concept GEVEN (X,Y,Z), and so additional activation will travel to the double object 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-equivalent 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 A 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.

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) × 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

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 and 3: L2 to L2 and L1 to L1		
1	PO	identical
	The cook shows a hat to the boxer	*show*
	De kok toont een hoed aan de bokser	*tonen*
2	PO	unrelated
	The cook shows a hat to the boxer	*throw*
	De kok toont een hoed aan de bokser	*gooien*
3	DO	identical
	The cook shows the boxer a hat	*show*
	De kok toont de bokser een hoed	*tonen*
4	DO	unrelated
	The cook shows the boxer a hat	*throw*
	De kok toont de bokser een hoed	*gooien*
Experiments 2 and 4:L1 to L2 and L2 to L1		
1	PO	translation equivalent
	De kok toont een hoed aan de bokser	*show*
	The cook shows a hat to the boxer	*tonen*
2	PO	unrelated
	De kok toont een hoed aan de bokser	*throw*
	The cook shows a hat to the boxer	*gooien*
3	DO	translation equivalent
	De kok toont de bokser een hoed	*show*
	The cook shows the boxer a hat	*tonen*
4	DO	unrelated
	De kok toont de bokser een hoed	*throw*
	The cook shows the boxer a hat	*gooien*

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.

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) × 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).

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

Prime type (L2)	Verb type			
	Identical		Unrelated	
	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

Experiment	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 × verb	1,31	40.08***	1,47	42.01***	1,74	20.51***
	Prime (for related verbs)[a]	1,31	54.11***	1,47	129.81***	1,71	38.19***
	Prime (for unrelated verbs)[a]	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***
(LI to L2)	Verb	1,31	1.38	1,47	<1	1,77	<1
	Prime × verb	1,31	5.12*	1,47	4.95*	1,75	2.52
	Prime (for related verbs)[a]	1,31	18.22***	1,47	41.02***	1,72	12.71***
	Prime (for unrelated verbs)[a]	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***
(LI to LI)	Verb	1,31	2.53	1,47	1.31	1,77	<1
	Prime × verb	1,31	48.30***	1,47	40.09***	1,77	21.91***
	Prime (for related verbs)[a]	1,31	61.97***	1,47	112.20***	1,78	39.92***
	Prime (for unrelated verbs)[a]	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–LI)	Verb	1,31	2.49	1,47	3.09	1,71	1.38
	Prime × Verb	1,31	<1	1,47	<1	1,75	<1
	Prime (for related verbs)[a]	1,31	7.79**	1,47	3.73	1,81	2.52
	Prime (for unrelated verbs)[a]	1,31	11.13**	1,47	3.46	1,74	2.64
Cross Experiment	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 × verb	1,124	69.20***	1,47	36.40***	1,99	23.85***
	Mode × prime	1,124	28.50***	1,47	32.80***	1,125	12.97***
	Mode × verb	1,124	9.70**	1,47	4.70*	1,95	3.17
	Mode × prime × verb	1,124	37.70***	1,47	40.40***	1,141	19.50***
	Mode × target language	1,124	<1	1,47	7.10*	1,137	<1
	Mode × target language × prime	1,124	3.50	1,47	4.40*	1,15	1.95

[a] planned comparison.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

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.

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. /givz/). Furthermore, post-hoc tests revealed that there was no main effect of near-cognate status (*give/geven*,

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

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

Note. Percentages are derived from the participants analysis.

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, Pickering, Stewart, & Mclean, 2000, within English as L1). Experiment 3 therefore tested for syntactic 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 for the entire experiment. The female confederate differed from the confederates for Experiments 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) × 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

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

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

Note. Percentages are derived from the participants analysis.

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.

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) × 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.

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

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

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

Note. Percentages are derived from the participants analysis.

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. Fig. 2 summarizes the priming effects across the four experiments in the related and unrelated conditions.

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 among 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

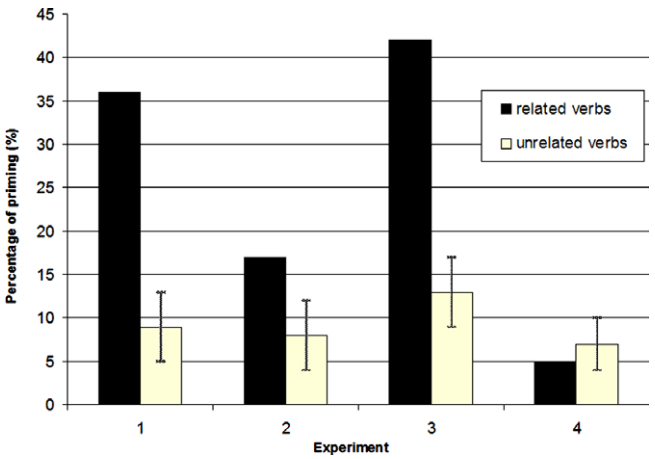

Fig. 2. Percentages of priming for both related and unrelated verb conditions, and 95% confidence intervals for the priming effect in all experiments. Related verb conditions refer to identical verbs or translation equivalent verbs depending on the experiment.

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 within 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, Von Eckardt, & Feldman, 1984), and hence suggest that

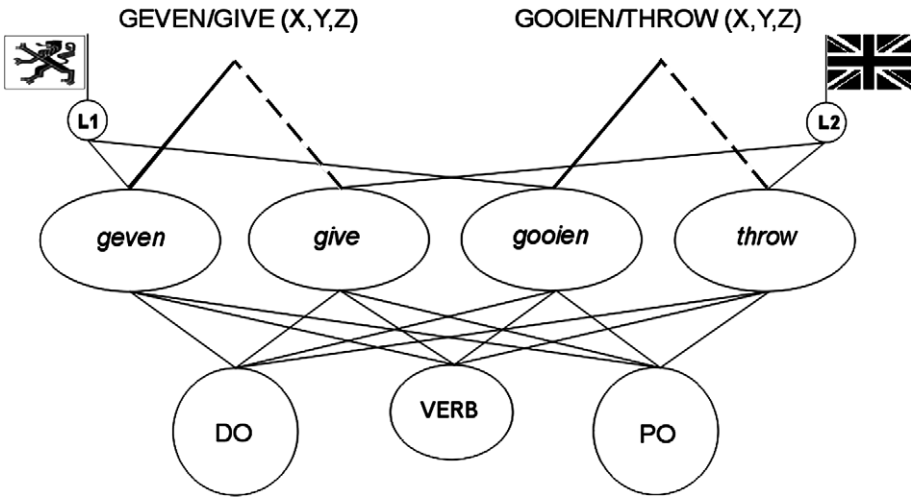

Fig. 3. Adaptation of the model of Hartsuiker et al. (2004), depicted in Fig. 1. Stronger connections between different nodes (resulting in more spreading activation) are indicated by full lines; weaker connections between different nodes (resulting in less activation spreading) are indicated by dotted lines.

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).

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 of Experiments 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–L2: 8%; L2–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 boost) 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 A

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-s-ailor-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.

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