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Cross-linguistic priming of syntactic hierarchical configuration information

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## **Abstract**

An important psycholinguistic discussion centers on the question of whether bilinguals use the same representations and mechanisms for the languages they speak (the interactive view) or whether the representations and mechanisms for each language are kept strictly separated (the modular view). Empirical investigations of this question have focused on the lexical level of language processing, either by looking at activation of word-level information or at activation of syntactic information that is closely tied to lexical entries. In three experiments we looked at the priming of syntactic information that is unrelated to lexical entries, namely relative clause attachments. For example, in a sentence like “Someone shot the servant of the actress who was on the balcony” the relative clause can be attached to two possible noun phrases, “the servant” or “the actress”. This type of attachment is syntactic because it cannot be represented by lexical subcategorization frames (relative clauses are modifiers) or by lexically related combinatorial nodes (both interpretations have the same NP + RC structure). We found that relative clause attachments can be primed from Dutch to English in Dutch-English bilinguals. This is the first demonstration of cross-linguistic priming of syntactic information that is not directly linked to lexical entries and favors the interactive view of bilingual syntactic processing.

## Introduction

An intriguing question in psycholinguistics is whether bilinguals make use of the same representations and mechanisms for processing the different languages that they know or whether they make use of separate representations and mechanisms for each of their languages. In the last decade this question has received a lot of attention from psycholinguists interested in the lexical level of language processing. This research has largely been driven by two opposing theoretical views on bilingual word processing. According to the first – the language-selective or modular view – both languages of a proficient bilingual are processed independently of each other (e.g. Kroll & Stewart, 1994). According to the other view – the non-selective-language or interactive view – the lexical representations of both languages strongly interact with each other during word processing (e.g. van Heuven, Dijkstra, & Grainger, 1998). The question of modular versus interactive processing of lexical representations in bilinguals has led to a large number of influential empirical and theoretical studies (e.g. Alvarez, Holcomb, & Grainger, 2003; Bloem & Lahey, 2003; Costa, Caramazza, & Sebastian-Galles, 2000; Costa, Miozzo, & Caramazza, 1999; Francis, Augustini, & Saenz, 2003; Gollan, Forster, & Frost, 1997; Grainger & Frenck-Mestre, 1998; Jiang & Forster, 2001; Jiang, 2000; Scheutz & Eberhard, 2004; Sebastian-Galles, Echeverria, & Bosch, 2005, among many others).

In contrast to the abundance of studies on language (non-)selectivity in lexical processing, researchers interested in the syntactic level of language processing have been less active in investigating bilinguals' organization of linguistic knowledge. The same theoretical question can be asked about syntactic processing. On the one hand, bilinguals may take advantage of the existence of similar syntactic structures in the languages they know (e.g. Chomsky, 1981; Greenberg, 1966; Hawkins, 1988) by representing these syntactic structures only once or by representing them in a highly integrated way. On the other hand, it could be argued that there are

so many syntactic differences between any two languages and that activating representations related to one language while processing another language is so resource demanding that it might be more parsimonious for bilinguals to keep the syntactic representations of their languages strictly separated. Following Hartsuiker, Pickering, and Veltkamp (2004) we shall refer to these two possibilities as respectively the shared-syntax account (which corresponds to the non-selective-language view in the bilingual lexical processing literature) and the separate-syntax account (which corresponds to the language-selective view in the bilingual lexical processing literature).

One plausible reason for why the question of language specificity in bilingual language processing has received less attention in syntactic processing than in lexical processing is that it has proven difficult to design methods that allow researchers to directly investigate the activation of syntactic structures and, consequently, even harder to find methods to study how the activation of a syntactic structure in one language might help or interfere with the activation of a syntactic structure in another language. Note that the situation for bilingual lexical processing is somewhat different because there were many early demonstrations that lexical characteristics can be primed (e.g. Meyer & Schvaneveldt, 1971) and it was relatively easy to adapt these priming paradigms to bilingual contexts. The situation for syntactic processing changed when it was shown – much later than in lexical processing – that syntactic structures can also be primed (Bock, 1986; Bock, 1989; Bock & Loebell, 1990). The syntactic priming effect is the observation that people are more likely to use a syntactic structure when the same syntactic structure was used in a preceding sentence compared to when a different syntactic structure was used in a preceding sentence. Bock (1986) observed this effect in a picture-description task, in which participants were asked to describe pictures after repeating prime sentences, which were conceptually unrelated and only shared the structural information with the target sentences. For instance, she found that participants were more likely to describe the picture in a passive voice (e.g. ‘The building

manager was mugged by a gang of teenagers”) when they had just repeated a prime containing a passive syntactic structure (e.g. “The referee was punched by one of the fans”) than when they had just repeated a prime containing an active syntactic structure (e.g. “One of the fans punched the referee”).

The syntactic priming phenomenon has not only been demonstrated with active versus passive sentences but has been found in a variety of grammatical structures. In fact, the most frequently used syntactic structure in syntactic priming studies involves two alternative dative constructions (e.g. Bock, 1986; Bock, 1989; Bock & Loebell, 1990; Branigan, Pickering, & Cleland, 1999; Branigan, Pickering & Cleland, 2000; Corley & Scheepers, 2002; Pickering & Branigan, 1998; Pickering, Branigan, & McLean, 2002; Potter & Lombardi, 1998; Schoonbaert, Hartsuiker, & Pickering, 2005). For instance, when the prime consists of a double-object construction, like the sentence “A rock star sold an undercover agent some cocaine”, participants are more likely to describe a picture using a sentence with a similar structure as the prime, like “The girl handed the man the paintbrush” than in trials where the prime had the structure of a prepositional-object construction, like the sentence “A rock star sold some cocaine to an undercover agent”.

Syntactic priming is a promising tool to study the question of whether syntax is shared or separate in bilinguals. If bilinguals represent the syntax of both languages separately, as is argued by the modular view, the activation of a syntactic structure in one language should have no influence on the activation of a similar syntactic structure in the other language. On the other hand, if bilinguals have a highly integrated representation of the syntax of both languages, it should be possible to find that the activation of a structure in one language primes the activation of a corresponding structure in the other language. There are only two published studies that have used syntactic priming in online processing in a bilingual context, namely Loebell and Bock (2003) and Hartsuiker et al. (2004).

Loebell and Bock (2003) had fluent German-English bilinguals repeat a sentence in either their first (German) or their second (English) language and describe a picture of an unrelated event in the other language. The prime constructions they used were dative (double-object and prepositional-object sentences) and transitive structures (passive and active sentences). After being primed with a prepositional-object construction, participants described the picture more frequently with a prepositional-object construction. The same results were found with the double-object construction and with active sentences. The passive primes showed no syntactic priming. However, according to Bock and Loebell (2003) this may have been due to the fact that the structures differed in prime and target sentence: Whereas the double-object, prepositional-object and active sentences have the same syntactic structure in both German and English, the passive structure differs between the two languages. In German the verb occurs at the end of the sentence in passives (e.g. “Die Böden werden täglich von dem Hausmeister gereinigt”; literally: “The floors are daily by the janitor cleaned”), whereas this is not the case in English (e.g. “The floors are cleaned daily by the janitor”).

Hartsuiker et al. (2004) found evidence for syntactic priming between English and Spanish. In their experiment, they had naive participants who were primed by a confederate. The experiment consisted of a picture description task in which the naive participant had to describe the pictures in English and the confederate described other pictures in Spanish. Hartsuiker et al. found that when the confederate used a passive sentence in Spanish, the participant was more likely to produce a passive sentence in English. The same results were found with active sentences. So, the results of both of these studies seem to favor the shared-syntax account over the separate-syntax account of bilingual syntactic processing.

Although the studies described above have demonstrated cross-linguistic syntactic priming, the syntactic information that is primed in these cases is very closely tied to specific lexical entries. The syntactic structures used are actives versus passives (Hartsuiker et al., 2004) and double-object datives versus prepositional-object datives (Loebell & Bock, 2003). In both cases priming could be explained – partly or entirely – by priming of the lexical entries of function words, namely the preposition “by” in passives and the preposition “to” in prepositional-object datives. One of the first reports of syntactic priming involves priming of a function word (“at”): When Levelt and Kelter (1982) asked storeowners “At what time do you close?”, compared to “What time do you close?”, they were more likely to answer “At five o’clock” than “Five o’clock”. So, it cannot be excluded that the use of the Spanish preposition “por” simply primed the use of the English preposition “by”, inducing a higher number of passives in the target sentences. This is not improbable, considering that in monolingual syntactic priming there is evidence for priming of “by”-phrases without there being an active versus passive interpretation. For instance, Bock and Loebell (1990) found that sentences containing a passive “by”-phrase (like “The man is being stung by a bee”) were primed by sentences containing a locative “by”-phrase (like “The 747 was landing by the airport’s tower”). Similar findings have been reported for the double-object versus prepositional-object dative cases, where activation of the preposition “to” could arguably be underlying the priming effect. For instance, sentences where the preposition introduces a locative prepositional phrase instead of an indirect object prepositional phrase (“The widow drove the Mercedes to the church”) nonetheless prime dative prepositional phrase structures (“The girl handed the paintbrush to the man”).

However, it is important to note that these latter monolingual findings (“by”-locatives prime “by”-passives and “to”-locatives prime “to”-datives) can also be explained through priming of simple context-free phrase structure rules instead of through priming of function words. For instance, both the sentence containing the locative “to the church” and the sentence containing the

dative “to the man” are generated by the rule  $VP \rightarrow V NP PP$  (assuming a very simple phrase-structure grammar). Activating this rule in prime production may have made it easier to activate it subsequently to produce the target, compared to when the rule  $VP \rightarrow V NP NP$  would have been activated in the production of an alternative double-object dative prime (“The girl handed the man the paintbrush”). Most psycholinguists investigating syntactic priming actually argue that phrase structure rule priming – and not lexical priming of function words – is the correct interpretation of these findings. The argument in favor of this interpretation is twofold. First, Bock (1989) showed that primes containing the lexical item “for” (“A cheerleader saved a seat for her friend”) were equally successful in priming target sentences containing the lexical item “to” (“The girl handed the paintbrush to the man”) as were primes containing the lexical item “to” (“A cheerleader offered a seat to her friend”). Second, Bock and Loebell (1990) showed that primes with a different structure but with the same lexical item “to” did not prime prepositional object datives containing “to”: Whereas primes like “Susan brought a book to Stella” primed sentences like “The girl handed the paintbrush to the man”, primes like “Susan brought a book to study” did not. Interestingly, this last study also suggest that syntactic priming is not due to superficial relationships in phonological or prosodic similarity (e.g. metrical structure in terms of number of syllables and lexical stress patterns), because both prime types (“Susan brought a book to study” and “Susan brought a book to Stella”) were constructed to be identical in that regard. Crucially, these two studies show that it is not necessary to have the same word to obtain a significant priming effect and that it is not sufficient to have the same word in order to obtain a significant priming effect. However, it is important to observe that (1) half of the argument is (necessarily) supported by a null effect (e.g. constructions containing the inflectional marker “to” as in “to study” don’t prime constructions containing the dative preposition “to” as in “to Stella”), (2) the contribution of lexical priming of function words has only been evaluated once (other papers claiming to have found syntactic priming never include control conditions for lexical priming of

function words), and (3) it has only been investigated for one syntactic construction, namely for the dative structures (e.g. no study has demonstrated that the passive/active priming effect is not due to lexical priming of the function word “by”).

Nonetheless, even if the priming results are unlikely to be due to lexical priming of function words such as “to” or “by”, the results of syntactic priming are still primarily interpreted in terms of priming of information that is contained in lexical entries (namely the lexical entries of the main verbs that are used, e.g. “give” in “The girl gave the paintbrush to the man”). Both the monolingual and bilingual syntactic priming effects have mainly been interpreted in terms of theories of sentence production that state that the lemma stratum – the level of lexical representations that encodes syntactic information – is driving the syntactic priming effects (e.g. Levelt, 1989; Roelofs, 1992, 1993). For instance, in Pickering & Branigan’s (1998) model of monolingual syntactic priming and Hartsuiker et al.’s (2004) adaptation of this model for bilingual syntactic priming, the lemma stratum contains combinatorial nodes, which represent which syntactic categories can be combined with the lexical entry of specific verbs. In these models the lexical entry for “give” is linked to the combinatorial nodes NP\_NP and NP\_PP (among others). So when a sentence like “The girl gave the paintbrush to the man” is produced, both the lemma “give” and the combinatorial node NP\_PP will be activated. Since combinatorial nodes are shared among lemmas, the residual activation of the NP\_PP node will make it somewhat easier to subsequently produce “Susan brought a book to Sue” than “Susan brought Sue a book”. The combinatorial nodes can be interpreted as encoding something close to subcategorization frames (information about the number and nature of arguments that specific verbs take) or phrase structure rules, but in both cases the specific verb that is used will completely determine which combinatorial nodes will be activated. The same explanation in terms of combinatorial nodes is adopted for passive versus active sentences (Hartsuiker et al., 2004; Pickering & Branigan, 1998). A strong indication that the syntactic information that is

primed is very closely tied to the specific lexical (verbal) entry is the so-called “lexical boost effect” (Pickering & Branigan, 1998): the priming effect is much stronger when the prime and target contain the same verb (e.g. “give” in the prime and target) than when they are different (e.g. “give” and “hand”). There is also very recent evidence that the same holds in bilingual syntactic priming. Schoonbaert et al. (submitted) showed that the cross-linguistic dative priming effect is significantly stronger when translation equivalents are used in the prime and target (e.g. “give” in the English prime and “geven [give]” in the Dutch target), than when different verbs are used (e.g. “give” in the English prime and “aanreiken [hand]” in the Dutch target). Schoonbaert et al. call this the “translation equivalent boost”.

### **The present study**

The syntactic information that is activated in the only two studies on cross-linguistic syntactic priming (Loebell & Bock, 2003; Hartsuiker et al. 2004) is still very closely related to lexical representations: the combinatorial information is argued to be represented in the lemma stratum and its activation is totally dependent on the lexical entries of specific verbs. Given that there is a large amount of evidence for the interaction of lexically related information across languages, it has not been surprising to find cross-linguistic priming with the specific structures that have been studied so far (passives/actives and datives). An interesting question concerning the syntactic representations of bilinguals remains whether syntactic information that is truly structural in nature (and cannot be represented lexically or tied to specific lexical entries) can also be primed between the languages of bilinguals.

In a recent paper, Scheepers (2003) demonstrated that the relative clause attachment ambiguity is susceptible to priming. In this type of syntactic ambiguity (e.g. “Someone shot the servant of the actress who was on the balcony”) the relative clause (“who was on the balcony”) can be attached

high in the syntactic tree representation, to the first possible noun phrase (“the servant”) or low in the syntactic tree representation to the second possible noun phrase (“the actress”). Scheepers used sentence completion in German with prime sentences such as “Die Assistentin verlas den Punktestand<sub>masc</sub> der Kandidatin<sub>fem</sub>, der<sub>masc</sub> / die<sub>fem</sub> ... [The assistant announced the score of the candidate that...].” In these prime sentences the relative clause attachment was forced towards high or low attachment by using relative pronouns that were marked for gender. In the example sentence, the relative pronoun “der” can only refer to “Punktestand [score]” whereas the relative pronoun “die” can only refer to “Kandidatin [candidate]”. Scheepers showed that target sentences with ambiguous relative pronouns immediately following such prime sentences were subject to syntactic priming: Participants produced more high-attachment relative clauses following high-attachment primes than following low-attachment primes.

This is an interesting demonstration of syntactic priming because the syntactic representation of the two alternative attachments is not lexical and cannot be tied to specific lexical entries. First, both the construction where the relative clause is attached high and the construction where the relative clause is attached low use the same relative pronouns, so lexical priming of function words cannot underlie the relative clause attachment priming effect. Second, relative clauses are modifiers and, according to standard linguistic theories, are not represented in the argument structure of the lexical entities they modify. For instance, whereas the lexical entry of a ditransitive verb like “give” contains the information that this verb should be followed by two complements in order to form a grammatical sentence (either by two noun phrases as in the double-object construction “Mary gave John the book” or by a noun phrase and a prepositional phrase as in the prepositional-object construction “Mary gave the book to John”), the lexical entry of a noun does not contain the information that it should be followed by a relative clause in order to obtain a grammatical sentence (both “Someone shot the servant of the actress” and “Someone shot the servant of the actress who was on the balcony” are grammatical sentences). Even more

intriguing, the priming effect that was demonstrated in relative clause attachments cannot be explained in terms of activation of context-free phrase structure rules, because both the high attachment and the low attachment construction can be generated by the same set of phrase-structure rules (e.g. the rules “NP → det N”, “NP → NP PP”, “NP → NP RC”, and “PP → prep NP” would suffice to render both constructions). Scheepers (2003) argues that the syntactic priming effect of relative clause attachments can only be explained by taking into account syntactic tree configurations that are broader and more encompassing than simple context-free phrase structure rules, which he calls the “hierarchical tree configuration”: The only difference between the relative clause attachment alternatives is that in the high attachment the context-free phrase structure rule “NP → NP RC” is used to modify a noun phrase that is higher in the tree configuration, whereas in the low attachment the same rule is used to modify a noun phrase that is lower in the tree configuration. In this sense, the mental representation that is primed in Scheepers’ study is a high-level syntactic type of information, which is quite remote from the specific lexical items that are used (see the General Discussion section for a more thorough consideration of the nature of this syntactic information).

The present study is aimed to contribute to the research question of language (non)selective bilingual syntactic processing by investigating whether this syntactic information related to the hierarchical tree configuration is shared or separate between the languages of bilinguals. The present study consists of three experiments. In the first experiment we show that the gender agreement marked on Dutch relative pronouns is strong enough to elicit a similar relative clause attachment priming effect as in German. Subsequently, we use these Dutch primes in Experiment 2 to show that relative clause attachments can be primed from Dutch to English in native Dutch speakers with a very good knowledge of English. In the third experiment we tested and excluded an alternative explanation of this priming effect in terms of discourse-level priming.

## Experiment 1

This first experiment is a replication in Dutch of the syntactic priming effect demonstrated by Scheepers (2003) in German. We translated Scheepers' items (his Experiment 2) from German to Dutch and used exactly the same methodology and design. The main goal of this experiment was to find out whether the gender agreement on relative pronouns in Dutch is strong enough to force high and low attachments in the prime sentences. In contrast to the elaborate gender marking in German, the gender marking on Dutch relative pronouns is quite simple. The relative pronoun "dat" is required when referring to a word that takes the definite article "het" (i.e. neuter words such as in "het meisje dat [the girl that]" or "het huis dat [the house that]"), whereas the relative pronoun "die" is required when referring to a word that takes the definite article "de" (i.e. non-neuter words such as in "de vrouw die [the woman that]" or "de auto die [the car that]"). Plural noun phrases always take the definite article "de" and thus require the relative pronoun "die" (e.g. "de meisjes die [the girls that]", "de huizen die [the houses that]", "de vrouwen die [the women that]", "de auto's die [the cars that]"). Just like Scheepers (2003) we used gender agreement to force relative clause attachment in the primes. If this gender agreement manipulation in Dutch leads to a replication of the priming effect in German (i.e. more high-attaching target relative clauses after forced high-attachment primes and more low-attaching target relative clauses after forced low-attachment primes) than these Dutch primes can be used in our more crucial cross-linguistic priming experiment (Experiment 2).

## Method

**Participants.** Thirty volunteers from the Ghent University community participated in the experiment and were paid 10 EUR for their participation. They were all native Dutch speakers and unaware of the purpose of the study.

**Materials and design.** The experimental items consisted of 24 target sentence beginnings and 24 triplets of prime sentence beginnings. The experimental items were very close translations of the items that were used in Experiment 2 of Scheepers (2003) and all had the same structure: subject noun phrase – main verb – noun phrase – van [of] – noun phrase – relative pronoun. The only structural difference with the German items was that we did not use a comma before the relative pronoun (in German a comma is mandatory). Previous studies on relative clause attachment in languages where the comma is not mandatory (e.g. Dutch, English, Spanish, French) it has consistently been left out because the presence of the comma might induce a non-restrictive reading. The Dutch relative pronouns “die” and “dat” were used. Because the Dutch relative pronouns “die” and “dat” are marked for gender, their use allowed us to force high or low attachment in the prime. The relative pronoun “dat” can only refer to neuter nouns (nouns that take the determiner “het”), whereas the relative pronoun “die” can only refer to non-neuter or plural nouns (nouns that take the determiner “de”). In the 24 target sentences the relative pronoun was ambiguous: we only used the relative pronoun “die” and both noun phrases preceding the relative pronoun were “de”-words. For instance, in example (1), the relative pronoun “die” can refer equally well to the first noun phrase (“**de** bazin [the boss]”) as to the second noun phrase (“**de** bediendes [the employees]”).

- (1) John ontmoette de bazin van de bediendes die ...  
[John met the boss of the employees who ...]

We only used “de”-words in the targets, because we wanted to use a plural noun phrase – which is always a “de”-word - and a singular noun phrase in each target. Half of the targets had a plural first noun phrase and a singular second noun phrase, whereas the other half of the targets had a singular first noun phrase and a plural second noun phrase. This was done so that number agreement between the head noun and the verb in the relative clause that was provided by the participants could help to identify the intended attachment site in the target sentence. When the participant used a plural verb, the relative clause was attached to the plural noun phrase and if the verb was singular, it was clear that the participant attached the pronoun to the singular noun phrase. Taking advantage of the number agreement feature, we made sure almost no continuations would remain ambiguous in the coding phase.

Each of the 24 target sentence beginnings was immediately preceded by one of three prime sentence beginnings: a high-attachment inducing prime, a low-attachment inducing prime or a baseline prime. The prime sentences were semantically and conceptually unrelated to the target they preceded. In the high-attachment primes the relative pronoun agreed in gender only with the first noun phrase and thus could not refer to the second noun phrase. For instance, in (2a) the relative pronoun “die” can only refer to the first noun phrase (“**de** veroorzaakster”) and not to the second noun phrase (“**het** ongeval”). In the low-attachment primes the relative pronoun agreed in gender only with the second noun phrase and thus could not refer to the first noun phrase. For instance, in (2b) the relative pronoun “dat” can only refer to the second noun phrase (“**het** ongeval”) and not to the first noun phrase (“**de** veroorzaakster”).

- (2) a. De politie ondervroeg de veroorzaakster van het ongeval die ...  
[The police interrogated the causer of the accident that ...]
- b. De politie ondervroeg de veroorzaakster van het ongeval dat ...  
[The police interrogated the causer of the accident that ...]

- c. De politie ondervroeg de veroorzaakster van het ongeval nadat ...

[The police interrogated the causer of the accident after ...]

In the baseline prime, the relative pronoun was replaced by an adverb that did not refer to either noun phrase, such as “nadat [after]” (see 2c), “toen [when]”, “terwijl [while]”, etc. Given that the syntactic structure of the continuation that participants are providing in this case is not a relative clause, this condition should not influence subsequent relative clause continuations. Therefore this condition informs us of the baseline relative clause attachment preference with the target sentences we constructed and should be followed by targets showing a relative clause attachment preference that is in between those of targets following the high-attachment and low-attachment primes.

In addition to the 24 prime and target pairs (i.e. 48 sentence beginnings), the participants also received 51 filler sentence beginnings. These fillers contained a variety of different syntactic structures, none of which were related to the relative clause attachment ambiguity. The full set of experimental items that were used can be found in Appendix A.

**Procedure.** The three possible pairs of prime and target sentences of each item (each of the three prime conditions paired with a target sentence) were allotted to three master versions so that every sentence appeared exactly once in every version, in one of the three conditions. Every version contained 8 items of every condition and within every condition the amount of targets that had a singular first noun phrase and a plural second noun phrase was the same as the amount of targets that had a plural first noun phrase and a singular second noun phrase. Six different lists were made out of each master version, in which the fillers and experimental items always stood in a different randomized order. Each list always started with 5 fillers and the different experimental prime-target pairs were separated from each other by 2 fillers.

Each sentence was printed on a single line and was followed by a printed line underneath it where the participant could generate a hand-written sentence completion. The participants were free to write any continuation, however they were instructed that the sentences had to be grammatical and realistic. The participants were told to rely on their first impression rather than trying to be creative in their sentence completions. They were asked to fill in the sentences in the given order and work through the list at a reasonable pace, without going back to previous items. On average participants took about 40 minutes to complete all sentence beginnings.

## **Results**

We started the analyses of the experimental trials by looking at the completion of the prime sentences. Primes were denoted as correct if the sentence was completed according to the intention of the gender agreement manipulation, i.e. when a relative clause was provided that referred to the antecedent which agreed in gender with the relative pronoun that we had provided. Most of the time, incorrectly completed prime sentences concerned the wrong use of the relative pronouns “die” and “dat”. This affected only 9% of the priming sentences. In order not to simply discard these data we coded the prime sentences as they were actually completed by the participants and not as we intended them to be completed, as is usual in syntactic priming studies using sentence fragment completion (e.g. Branigan et al., 1999; Pickering & Branigan, 1998). However, to ensure that we were not changing the pattern of results because of this decision we also analyzed the data without these trials. This way of analyzing the data led to an identical pattern of results.

Next, the completions of the targets were examined. In most sentence completions, the attachment to either the low or high attachment host noun phrase could be read off the number

agreement between the host noun phrase and the verb that was used in the relative clause. For instance, in the sentence “Klara bezocht de studenten van de pianole leraars die aan het oefenen waren [Klara visited the students of the piano teacher that were rehearsing]” the verb in the relative clause “waren [were]” can only be attached to a plural noun, in this case the first noun phrase. For the other sentences – for instance, when the relative clause was object extracted and the intended attachment site could not be read off the number of the relative clause verb - the intended host for the attachment was derived from the context. For instance, in the sentence “De ouders hielden niet van de zanger van de liedjes die het meisje had gekocht [The parents disliked the singer of the songs that the girl had bought]”, we coded low attachment because someone can buy songs but not a singer. Sentences that could not be classified univocally as high attachment or low attachment were not further analyzed. Because this amounted to less than 1% for each of the three priming conditions, we simply excluded those continuations and calculated the percentages of high attachments and low attachments relative to the sum of high-attachment and low-attachment continuations. So for every prime condition the percentage high attachments in the target added with the percentage low attachments in the target was 100%.

All data were analyzed on the percentage of high attachments in the target sentences. The data for low attachments can be found by subtracting the percentage of high-attachment completions from 100. The mean percentage of high-attachment completions in the target sentences, as a function of prime type are presented in Table 1. The results of the analyses of variance are in Table 2. These tables show that – just as in German – there is a syntactic priming effect in the Dutch relative clause attachment ambiguity. The amount of high-attachment completions was 11% higher after a high-attachment prime (46%) than following a low-attachment prime (35%). Even though this effect is slightly smaller than the effects reported in German (between 15% and 19%), Table 2 shows that this difference between the high-attachment and low-attachment condition was statistically significant (95%CI = 7.52%). As expected, the baseline condition led to an

intermediate amount of high-attachment completions (43%). Table 2 shows that the 3% difference between high-attachment and baseline condition was not significant (95% CI = 9.57%) and that the 7.86% difference between the low-attachment and baseline condition just missed the 5% significance level (95% CI = 7.92%).

## **Discussion**

On the basis of the results of Experiment 1 it can be concluded that the syntactic priming effect that was demonstrated by Scheepers (2003) is not specific to German but can also be found in Dutch. When a prime fragment was provided that induced high attachment through gender agreement on the relative pronoun, participants were more likely to attach the relative clause of the ambiguous target fragment to the first noun phrase than when a low-attachment inducing prime fragment was given. The results of Experiment 1 ensure that the gender agreement feature on Dutch relative pronouns is strong enough to show syntactic priming of relative clause attachments in Dutch and should be suitable to test syntactic priming from Dutch to English.

It might be worth noting that the overall preference was to attach the relative clause low, which goes against the “traditional” high attachment preference in Dutch (e.g. Brysbaert & Mitchell, 1996; Desmet, De Baecke, & Brysbaert, 2002). However, studies have shown that the overall preference depends on the content of the complex noun phrase head. For instance, Gilboy, Sopena, Clifton, & Frazier (1995) have shown that the relations expressed within this head influence the attachment preference. Moreover, Desmet, Brysbaert, & De Baecke (2002) showed that changing the animacy of the noun phrases can completely shift the attachment preference (both in production experiments as in corpus counts) and Desmet, De Baecke, Drieghe, Brysbaert, & Vonk (2005) showed that animacy and concreteness of the first noun phrase influence the online attachment preference. Desmet et al. (2002) argued that the Dutch high

attachment preference is only present when the first noun phrase is animate and that in the majority of the sentences in different types of corpora low attachments are actually much more frequent than high attachments. Given that the sentences used in Scheepers (2003), on which our items were based, used animate and inanimate noun phrases the overall preference might not be that surprising (note that the overall high attachment preference in his study was also below 50%).

## **Experiment 2**

The main aim of this study was to investigate whether syntactic information related to the hierarchical tree configuration is shared between the two languages of a bilingual or whether this information is represented separately for each language. Given that the gender agreement manipulation on Dutch relative pronouns proved successful in Experiment 1, we were able to use the same Dutch prime fragments in Experiment 2, to see whether they have the same syntactic priming effect on English targets.

### **Method**

***Participants.*** Twenty-four volunteers from the Ghent University community participated in the experiment. They received 10 EUR for their participation. All participants had Dutch as their native language and had a very high proficiency in English. They had been taught English for at least five years in high school and they were all undergraduates who had university courses which require studying English textbooks on academic topics. They were all naive to the research questions. None had participated in Experiment 1.

**Materials and design.** The same 24 triplets of Dutch prime sentence beginnings that were used in the previous experiment were used in this experiment. The Dutch target sentence beginnings from Experiment 1 were translated to English. We changed some of the targets slightly to make sure that both noun phrases in the syntactic ambiguity were either human or nonhuman. This was done in order to have completely ambiguous target sentences whose attachment preference would not be influenced by the potential stronger tendency to attach the relative pronoun “that” to a nonhuman noun phrase than to a human noun phrase. By excluding combinations of a human and nonhuman noun phrase in the target sentence this tendency could play no role in the continuations of the participants. All target sentences that were used in Experiment 2 can be found in Appendix B (the prime fragments were those of Experiment 1 and can be found in Appendix A). Twenty-six of the 51 fillers that were used in the previous experiment were translated to English, the other 25 remained the same and were presented in Dutch. This means that about half of the sentence beginnings in the questionnaire were in Dutch (the 24 primes and 25 fillers), whereas the other half were in English (the 24 targets and 26 fillers). On average participants took about 40 minutes to complete the questionnaire.

**Procedure.** The procedure was identical to that of Experiment 1.

## **Results**

We started by coding the prime fragment continuations. As in the previous experiment and previous studies on syntactic priming using sentence completion (e.g. Branigan et al., 1999; Pickering & Branigan, 1998), the prime sentences were scored as they were completed by the participants and not as they were intended to be completed on the basis of the gender of the relative pronoun. Again, this affected a very small amount of the data (less than 5% of prime

fragments) and the pattern of results was identical when these items were discarded from the analyses.

Next we coded the attachment of the continuations that were provided for the target fragments. The amount of target sentences that could not be classified univocally was 16% for the high-attachment condition, 18% for the low-attachment condition and 16% for the baseline condition. These percentages are much higher than those of the first experiment (where they were less than 1% in each of the conditions). The reason for this is that in English number agreement is not marked as overtly as it is in Dutch. For example in the sentence “The maid gazed at the children of the countess that had new clothes”, the place of attachment is not clear because the verb “had” can be used for both plural and singular nouns. Because the number of undefined targets was higher than in Experiment 1 we executed t-tests to find out whether the amount of undefined targets differed significantly between each prime condition. The results showed no significant effects of the number of unclassifiable relative clauses between any of the three conditions (all t values < 1; all p values > .51). Because the percentage of undefined target completions did not differ between the prime types, the percentages of high attachments and low attachments were calculated relative to the sum of high-attachment and low-attachment continuations as was done in Experiment 1.

The percentage of high-attachment completions in the target sentence, as a function of prime type are presented in Table 1. Again, the percentage of low-attachment completions can be obtained by subtracting the percentage of high-attachment completions from 100. The results of the analyses of variance can be found in Table 2. The data of Experiment 2 show a significant syntactic priming effect that is numerically identical to that of the first experiment: the number of high-attachment completions was 11% higher after a high-attachment prime (42%) than following a low-attachment prime (32%). Table 2 shows that this difference between the high-

attachment and low-attachment condition was statistically significant (95%CI = 9.48%). As in Experiment 1, the baseline condition led to an intermediate amount of high-attachment completions (36%). The 6% difference between the high-attachment and baseline condition gave a significant result for the analysis over participants, but not over items (95%CI = 5.85%). The 5% difference between the low-attachment and the baseline condition was not significant (95%CI = 7.83%).

## **Discussion**

The results of this experiment showed that syntactic information related to the hierarchical tree configuration can be primed between the languages of bilinguals. When Dutch-English participants had just completed a Dutch prime fragment that induced high attachment, they were more likely to attach the relative clause in the ambiguous English target fragment to the first noun phrase than when they had just completed a Dutch prime fragment that induced low attachment. Moreover, the priming effect was as strong as in Experiment 1, where prime and target were in the same language (a priming effect of 11% in both cases). This might indicate that cross-linguistic syntactic priming is equally strong as syntactic priming within one language. We will discuss this issue further in the General Discussion.

One of the reviewers of an earlier version of this paper raised the concern that participants might have translated the English sentence beginnings into Dutch first, then came up with a continuation, and then translated that continuation back to English. We think this explanation for the cross-linguistic priming effect is rather implausible. First, it seems unlikely that participants will do more work than necessary and take three steps to do a task when it can be done in one. This is especially true given that the instructions were to continue the sentences with the first thing that came to mind (we emphasized to work relatively quickly) and given that the

participants were highly proficient speakers of English (who did not really need to perform these additional steps to feel comfortable with the task). Moreover, the average time to complete the questionnaire was identical in Experiment 1 and Experiment 2. If the participants had done two additional steps (translate a sentence beginning from their second language to their first language and then translate the continuation they came up with from the first language to their second language) for half of the items (i.e. 24 English targets and 26 English filler items), they probably would have taken considerably longer in the second experiment compared to the first experiment.

However, there is another more viable alternative explanation for the significant priming effects that were shown in Experiments 1 and 2. Scheepers (2003) noted that it could not be excluded that the relative clause attachment priming effect that was found in his study was driven entirely or partly by reactivation of discourse representations instead of syntactic representations. The two syntactic alternative interpretations of the ambiguity under scrutiny are not only different in the syntactic attachment site of the relative clause, but also in terms of anaphoric binding and focus structure. In terms of anaphoric binding, the relative pronoun could be considered as any other pronoun, referring to its antecedent at the discourse level (e.g. Hemforth, Konieczny, & Scheepers, 2000). In this regard, high attachment differs from low attachment in that in the former the relative pronoun is co-indexed with the first-mentioned entity, whereas in the latter the relative pronoun is co-indexed with the second-mentioned entity. In terms of focus structure, it is possible that elaborating on one of the noun phrases in the main clause by means of a relative clause focuses this noun phrase more than the noun phrase that is not elaborated on. Scheepers (2003) excluded a discourse-based explanation of the priming effects by running an experiment in which the primes no longer had the same syntactic structure as the target sentences, but in which the anaphoric binding relations and focus structure between the prime and target were preserved. This was done by replacing the relative pronoun in the prime fragments with a temporal or causal connective (e.g. example 3), but using the same relative clause attachment targets.

- (3a) Die Assistentin verlas den Punktestand<sub>mas/sing</sub> der Kandidatin<sub>fem/sing</sub>, als dieser<sub>mas/sing</sub>  
 [The assistant announced the score<sub>i</sub> of the candidate when it<sub>i</sub>...]
- (3b) Die Assistentin verlas den Punktestand<sub>mas/sing</sub> der Kandidatin<sub>fem/sing</sub>, als diese<sub>fem/sing</sub>  
 [The assistant announced the score of the candidate<sub>i</sub> when she<sub>i</sub>...]

In this type of primes the anaphoric binding is almost identical to the one in the original relative clause primes. As in the prime fragments that ended with a relative pronoun these fragments end with a pronoun that refers to the first-mentioned entity (see 3a) or to the second-mentioned entity (see 3b). Also the focus structure should be almost identical to the original primes, because these prime fragments also induce the production of a subordinate clause that elaborates on the first or second noun phrase, possibly putting focus on one over the other. Scheepers (2003) argued that if the original priming effect was due to these kinds of discourse-based representations, these prime fragments should have a similar priming effect. However, if the original priming effect was mainly due to syntactic representations, these prime fragments should not have any priming effects, because the syntactic structure in the primes (where an adverbial phrase is attached to the verb phrase of the main clause) is completely different from that in the targets (where a relative clause is attached to a noun phrase). As Scheepers (2003) found no priming effect with these kinds of primes, he concluded that the priming effects he found earlier were syntactic in nature.

Scheepers' (2003) results are convincing evidence for accepting that the priming effect that is found in relative clause attachment is syntactic priming. However, it might be premature to just assume that this finding (i.e. a null effect when discourse representations are similar between syntactically different primes and targets) generalizes to a bilingual context. We cannot exclude the possibility that in bilingual situations participants rely more on discourse representations than in monolingual situations. We do not know of any studies looking at how strongly discourse

representations guide sentence processing in bilinguals compared to monolinguals, but it has been suggested that processing a second language might be more conceptually driven than syntactically (Ulijn, 1980). Anyway, it is crucial for a shared-syntax account that the cross-linguistic priming effect is not due to shared discourse representations. Therefore, to be sure that the cross-linguistic priming that was found in our Experiment 2 is due to syntactic priming, we ran a similar control experiment as the one that was run by Scheepers (2003). In addition, it is useful to replicate the null effect that was obtained by Scheepers because of the importance of this null effect in the original study in assessing the syntactic nature of the priming effect.

### **Experiment 3**

The goal of this control experiment was to exclude an explanation of the cross-linguistic priming effect in Experiment 2 in terms of discourse representations. As in Scheepers (2003) we simply replaced the relative pronouns in the prime fragments by temporal and causal connectives. As explained in the discussion of Experiment 2 these changes preserve the anaphoric binding relations and the focus structure, but they alter the syntactic structure. Therefore, if the relative clause attachment priming effect in Experiment 2 (and Experiment 1) was a syntactic effect – as we predict on the basis of Scheepers' findings - we should not find priming in the present experiment. However, if the effects that were found in the previous experiments were due to the activation of discourse-based representations the priming effect should still be observed in this experiment.

***Participants.*** Thirty participants took part in the experiment. All participants were volunteers who received 10 EUR in exchange for their participation. All had Dutch as their native language and had the same proficiency in English as the participants in Experiment 2. They were unaware of the purposes of the research and had not participated in the previous two experiments.

**Materials and design.** The design was identical to the one used in the previous experiments. The same items as in Experiment 2 were used for this experiment, but the prime fragments were changed by replacing the relative pronoun in the high-attachment and low-attachment condition with a temporal or causal connective and a pronoun that referred to one of the two noun phrases. The baseline condition remained identical to the one used in Experiment 1 and 2. An example of the primes in Dutch is given in (4).

- (4a) De politie ondervroeg de veroorzaakster van het ongeval alhoewel ze...  
[The police interrogated the causer of the accident although she...]
- (4b) De politie ondervroeg de veroorzaakster van het ongeval alhoewel het...  
[The police interrogated the causer of the accident although it...]
- (4c) De politie ondervroeg de veroorzaakster van het ongeval nadat...  
[The police interrogated the causer of the accident after...]

In the high referent (4a) condition, the pronoun that was used forced participants to refer to the first noun phrase and in the low referent condition (4b) the pronoun that was used forced participants to refer to the second noun phrase. However, in some of the items it was difficult to find pronouns that only referred to the first or second noun phrase. For instance, sometimes the pronoun could also refer to the noun phrase that was in the subject position of the main clause. Also, sometimes we used the personal pronoun “het [it]” to refer to one of the noun phrases even though this created the possibility to use this pronoun as a pleonastic pronoun (e.g. “The police interrogated the causer of the accident although it was clear nobody was to blame”). Because this was a control experiment for Experiment 2 we did not want to change the content of the prime fragments (e.g. by using a different noun phrases in order to avoid these ambiguities) even though we knew this meant that on some of the trials the intended pronoun manipulation would not work.

As a solution we simply ran more participants in this experiment (25% more than in Experiment 2) to ensure that the results for this experiment were based on the same number of observations overall. As in Experiment 2 the primes were in Dutch and the targets were in English. The targets were the same as in Experiment 2. All items can be found in Appendix C. On average, the participants took 45 minutes to complete the entire list of sentence beginnings.

***Procedure.*** The procedure was identical to that of Experiments 1 and 2.

## **Results**

First, we scored the prime continuations of the experimental trials. A total of 20% of the prime sentence beginnings were not completed as was intended by the pronoun manipulation and these were not further analyzed. As expected the number of incorrectly completed primes was higher than in Experiments 1 and 2, because in most incorrect cases the pronoun was used to refer to another entity than the two noun phrases or was used as a pleonastic pronoun. We had anticipated this and to avoid a lack of statistical power in our analyses – especially because we expected a null-effect as in Scheepers (2003) - we ran 25% more participants in this experiment compared to the previous one.

Of the remaining trials, the target sentence completions that were ambiguous in their attachment site were not further analyzed. This amounted to 13% for the high-attachment condition, 14% for the low-attachment condition and 10% for the baseline condition. This amount of undefined targets is similar to that in Experiment 2 and given that the same targets were used, it is most probably due to the same factors, most importantly the lack of overt number marking on most English verbs. A number of t-tests that were performed to examine whether the amount of undefined targets differed between the conditions showed that there were no significant

differences (all  $t$  values  $< 1.33$ , all  $p$  values  $> .19$ ). Because of these results, the percentages of high-attachment completions in the target were calculated relative to the sum of high-attachment and low-attachment completions, as in Experiments 1 and 2.

The average amount of high-attachment completions in the target sentences, as a function of prime type are represented in Table 1. As we expected on the basis of Scheepers' (2003) results, the percentage of high-attachment target completions was practically identical for the high referent and low referent prime conditions (48% and 47%, respectively). Table 2 shows that this 1% difference is not significant (95%CI = 14.68%). Also the baseline prime condition led to the same percentage of high attachment target continuations (47%) and did not differ significantly from either the high referent prime condition (95%CI = 11.70%) or the low referent prime condition (95%CI = 14.16%). Given that the difference between high-attachment prime and low-attachment prime continuations is numerically much smaller (an effect of 1%) than in Experiment 2 (an effect of 11%) and given that these means are actually based on more observations than those in Experiment 2 (the means in Table 1 are based on 478 trials for Experiment 2 and on 508 trials for Experiment 3), we are confident that this statistical null-effect is not due to a lack of power.

## **Discussion**

The results of Experiment 3 are consistent with the findings reported by Scheepers (2003) and show that the relative clause attachment priming effect is not due to priming of discourse-based representations such as anaphoric binding relations and the focus structure of the sentence. When these discourse factors are the same between prime and target but the syntactic structure between prime and target sentences is different the priming effect disappears completely. These results – together with those of the same control experiment conducted by Scheepers (2003) – strongly

support an explanation of the Dutch priming effect in Experiment 1 and the cross-linguistic priming effect in Experiment 2 (and the German priming effect) in terms of syntactic priming.

### **General Discussion**

In the present study we investigated a much studied syntactic ambiguity, namely the attachment of a relative clause to two possible noun phrases (e.g. Brysbaert & Mitchell, 1996; Cuetos & Mitchell, 1988; Desmet, Brysbaert, & De Baecke, 2002; Desmet, De Baecke, & Brysbaert, 2002; Desmet et al., 2005; De Vincenzi & Job, 1995; Fodor, 1998; Gilboy et al., 1995; Hemforth, Konieczny, & Scheepers, 2000; Mitchell, Cuetos, Corley, & Brysbaert, 1995; Scheepers, 2003; Traxler, Pickering, & Clifton, 1998; and see Desmet & Gibson, 2003; Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996; Gibson, Pearlmutter, & Torrens, 1999; Gibson & Schütze, 1999; Igoa, Carreiras, & Meseguer, 1998, for similar attachment ambiguities). In Experiment 1, it was shown that native Dutch speakers were more likely to produce a relative clause that attached to the higher noun phrase in the syntactic tree configuration when they had been induced to produce a high-attachment relative clause in the previous item compared to when they had been induced to produce a low-attachment relative clause in the previous item. This result replicates the finding presented by Scheepers (2003) in which the same relative clause attachment ambiguity was primed in speakers of German. In Experiment 2, priming of the relative clause attachment ambiguity was extended to a bilingual context. Native Dutch speakers with a high proficiency in English were more likely to produce high-attachment relative clauses in English sentences when they had to produce a Dutch high-attachment relative clause in the previous item compared to when they had to produce a Dutch low-attachment relative clause. The intra-linguistic priming effect in Experiment 1 (Dutch primes and targets) and the cross-linguistic priming effect in Experiment 2 (Dutch primes and English targets) were equally strong (a 10.57% priming effect within languages and a 10.73% priming effect between languages). Experiment 3

excluded some alternative explanations of these priming effects in terms of discourse-based representations. In this experiment the anaphoric binding relations and the focus structure, but not the syntactic structure, were preserved between prime and target sentence fragments. Under these conditions no priming was observed, supporting the view that the priming effects found in Experiments 1 and 2 are syntactically driven. In the rest of the General Discussion section we will discuss the implications of these findings for several important issues in psycholinguistics.

### **Bilingual syntax**

The main goal of this study was to investigate the question of how bilinguals represent the linguistic knowledge of the languages they speak. As we discussed in the Introduction, this issue has received a lot of attention from psycholinguists interested in this question from a lexical point of view (e.g. Alvarez et al., 2003; Bloem & La Hey, 2003; Costa et al., 2000; Costa et al., 1999; Francis et al., 2003; Gollan et al., 1997; Grainger & Frenck-Mestre, 1998; Jian & Forster, 2001; Jiang, 2000; Kroll & Stewart, 1994; Scheutz & Eberhard, 2004; Sebastian-Galles et al., 2005; van Heuven et al., 1994). Within this domain the central question has been whether bilinguals have one integrated lexicon for both their languages (with direct connections between the lexical entries of words of both languages) or whether they have two separate lexica (with connections only through the conceptual level but not directly between the lexical entries of both lexica).

We were interested in the same question with respect to the syntactic level of language processing, rather than with respect to the representations within the mental lexicon. Following Hartsuiker et al. (2004), we discussed two theoretical accounts arguing for opposite views on bilingual syntax, the shared-syntax account and the separate-syntax account. The present study is the first study that tested these two accounts of bilingual syntactic processing by priming non-lexical syntactic information from the first language to the second language of bilinguals. We

think that the results of our study favor the shared-syntax account over the separate-syntax account of bilingualism. According to the latter view, the syntactic knowledge of the two languages of bilinguals is represented strictly separately. This corresponds to a language-selective view in which the grammatical knowledge of bilinguals is represented as two separate syntactic modules – one for each language – with each module being activated only when that specific language is being processed. Under this view it is difficult to explain how the syntactic representation for the relative clause attachment in the Dutch prime sentences influenced the relative clause attachment in the English target sentences. Given that the prime and target fragments described unrelated events involving different entities, there were no conceptual or lexical links through which the Dutch primes could have influenced the English targets. If the syntactic representation of high versus low attachment in Dutch is located in a syntactic module that is independent of the syntactic module which holds the representation of high versus low attachment in English, there is no straightforward explanation for why the use of the former should influence the activation of the latter.

Our results seem to be more in line with the predictions made by the shared-syntax account. This theory states that syntactic knowledge that is identical or similar between the languages of a bilingual is represented in a highly integrated way. This account corresponds to the view of psycholinguistic continuity according to which people who learn a second language extend their grammatical knowledge by integrating and connecting new grammatical knowledge with what they already knew of the syntax of their first language. Under this account there might actually be a single abstract syntactic representation for each of the alternative relative clause attachments, independent of the language. During sentence production or comprehension in a specific language context (Dutch or English) the same abstract syntactic representation may be driving sentence processing. It is easy to explain under such a view that activating one relative clause attachment alternative by using one language would prime the subsequent use of the

corresponding relative clause attachment alternative when using the other language: the underlying abstract representation is the same and it can be activated independent of the specific language that is used. This also elegantly explains why the priming effect is as strong between languages as within languages.

However, there are many different grammatical characteristics between any two languages, so even under the shared-syntax account it is necessary to allow for syntactic representations that are specific to one language. Even the relative clause attachment ambiguity, which structurally might look very similar between English and Dutch, could be subtly different between these two languages and both might be represented in a slightly different way in bilinguals. One subtle difference that comes to mind is the internal structure of the relative clause, which is verb-final in Dutch but verb-second in English. Subtle differences like this might actually preclude the existence of completely identical representations between languages. Nonetheless, our results suggest that even if this is the case, the relative clause attachment representations in both languages can have a substantial influence on each other's activation level. Therefore, they must be highly similar on some level of representation (i.e. it must be possible to generalize over some of the characteristics). A major challenge remains to find out what this common level of syntactic representation is. A lot of further psycholinguistic research – ideally driven by linguistic theories containing detailed hypotheses about how syntactic features might differ between languages – will be needed to find out in what way and how strongly the syntactic representations of the both languages of bilinguals are cognitively integrated. We will discuss a broad range of possible representations underlying the priming effects below. In any case, the opposite view – the separate-syntax account – seems much harder to reconcile with our data. The priming of abstract non-lexical information provides strong evidence against the idea that syntactic knowledge of the two languages of bilinguals is not integrated at any level of representation.

It is worth noting that our findings, which support the shared-syntax view, are also in line with the conclusions drawn in the only two other published studies on cross-linguistic syntactic priming. In these studies it was shown that the use of alternative ditransitive constructions can be primed between German and English (Loebell & Bock, 2003) and that the use of passives can be primed from Spanish to English (Hartsuiker et al., 2004). An important contribution of the present work lies in the notable difference in the type of syntactic information that was primed. As we argued in the Introduction, the syntactic information that was primed in Loebell and Bock's (2003) and Hartsuiker et al.'s (2004) study is closely related to the lexical entries of the verbs that were used. For instance, standard linguistic theories assume that in the dative constructions that were used by Loebell and Bock the grammatical requirement to use either two noun phrases or a noun phrase and a prepositional phrase is part of the lexical entry of the specific ditransitive verbs that are used. Also in the case of passives, Hartsuiker et al. (2004) – following Pickering and Branigan (1998), Levelt, Roelofs, and Meyer (1999), and Roelofs (1992, 1993) – argue that the choice between an active and a passive construction is represented at the lexical level, directly linked to specific verbal lexical entries. This is in line with a number of lexical accounts of passivization in linguistics (e.g. Bresnan, 1982; Grimshaw, 1991; Pollard & Sag, 1989, 1994). In contrast, the syntactic information that was shown to be prone to cross-linguistic priming in the present study is not closely tied to lexical entries and can only be represented at a fairly abstract syntactic level. To briefly summarize the argument, standard linguistic theories do not assume that the lexical entry of a noun contains the information that it can be modified by a relative clause, i.e. relative clauses are modifiers and are not part of the argument structure of lexical items. Moreover, it is impossible to distinguish the alternative relative clause attachments in terms of context-free phrase structure rules, because both alternatives are generated by the same rules. This means that the difference between the high-attachment construction and the low-attachment construction is related to how exactly the phrase structure rules are combined, i.e. with the hierarchical configuration of the phrase structure rules. In the high-attachment

construction the rule “NP → NP RC” is simply applied to a higher noun phrase than in the low-attachment construction. Our finding that this type of syntactic information, which is more abstract and remote from the specific lexical entries than any of the previous cross-linguistic syntactic priming studies, can be primed between two languages is strong evidence for the idea that purely syntactic representations can be shared between languages.

Incidentally, for these same reasons – namely that the syntactic information that is primed in this study is not related to lexical entries – our finding is also problematic for the cross-linguistic syntactic priming model of Hartsuiker et al. (2004) and the syntactic priming model of Pickering and Branigan (1998) on which it is based. In these models cross-linguistic priming is explained through activation of combinatorial nodes that are connected to specific words. The fact that the combinatorial nodes of the alternative relative clause attachment interpretations are both NP\_RC means that both models have no way to distinguish the alternative syntactic representations corresponding to high and low attachment. Consequently, this means that they cannot explain how the activation of one syntactic alternative in the prime influences the processing of the syntactic alternatives in the target. This is a general problem for all the sentence production models in the tradition of Levelt (1989), because these production models assume that syntactic information is represented at the lemma level. However, this ignores the fact that a lot of syntactic information is not immediately linked to lexical entries, such as the syntactic information related to the ambiguity under consideration here. In these sentence production models the building blocks of syntactic structure are represented (syntactic categories and at most combinatorial nodes), but it is left completely underspecified how the human sentence production system gets from these building blocks to the complete syntactic structure of the sentence. We are convinced that syntactic priming might be a very insightful and promising tool (1) for investigating exactly this question of what kinds of syntactic information might be represented and activated in

sentence production and (2) for extending current models of sentence production in order for them to be more specific about more complex syntactic information.

In relation to the question of bilingual syntactic representations it is important to note that some studies have looked at how bilinguals process very similar attachment ambiguities using other techniques than priming. First, Frenck-Mestre and Pynte (1997) studied prepositional phrases that could attach to a verb phrase or a noun phrase (e.g. “Brutus hit the gladiator with the shield...”) and looked at the influence of the main verb (verbs that accept two complements such as “accuse” elicit a stronger verb phrase attachment preference than verbs that accept only one complement such as “look”). They showed that during online processing second-language speakers (English-French bilinguals) were as sensitive to this verb manipulation as the monolingual speakers (French speakers). They conclude from this experiment that the data “do not provide evidence that non-native readers systematically engage in processing strategies that are qualitatively different from those of native readers”. They did find some indications that non-native speakers had more difficulty with the verb phrase attachment than native speakers. However, it is not clear whether this stems from preferences in their first language (their first language is not tested in this study) or from overall difficulty related to processing a second language. In sum, we think this study tell us more about the ability of the bilinguals to process their second language, rather than about how they represent the syntactic knowledge related to their two languages (i.e. how knowledge of the first language interferes with processing of the second language).

Second, a few papers have argued that the preference for resolving the relative clause attachment ambiguity is influenced by exposure to a second language, arguing that second language learning interferes with processing of the native language. For instance, Dussias (2003) and Fernandez (1998) showed that Spanish monolinguals had a higher attachment preference than Spanish-English bilinguals with the same Spanish relative clause ambiguities. The explanation they

provide is that Spanish monolinguals have only been exposed to Spanish which generally shows a high attachment bias, whereas Spanish-English bilinguals have also been exposed to English which generally shows a low attachment bias (see Cuetos & Mitchell, 1988, for a discussion of this cross-linguistic difference in relative clause attachment biases). However, the patterns in these studies are not in perfect alignment with what an exposure-based account and a shared-syntax account would predict. In Dussias' study, for instance, English-Spanish bilinguals had a higher attachment preference than the Spanish-English bilinguals, even though English-Spanish bilinguals must have had even more experience with English than the Spanish-English bilinguals. The main problem with this type of studies is that they forcibly rely on between-participants manipulations (a monolingual and a bilingual sample). This means that participants might differ on many other dimensions than exposure to a specific language, such as working-memory capacity, which has been shown to have an influence on relative clause attachment preferences (Swets, Desmet, Hambrick, & Ferreira, 2005). So, even though these studies are suggestive, it might be more insightful to experimentally manipulate exposure within the same participants using different languages, which is exactly what we did in the present study.

### **Syntactic priming**

The argument that the priming effect in the present study was syntactically and not lexically driven is important in itself, i.e. independent of the question of how bilingual syntactic knowledge is organized. Some psycholinguists have argued that the persistence effects that have been called syntactic or structural priming are in reality lexically driven. One of the most important arguments has been the observation that syntactic priming is increased dramatically when the lexical items in the prime and target are repeated. This is the "lexical boost effect", which we mentioned in the Introduction. For instance, in the case of the most frequently studied syntactic construction in syntactic priming, namely double-object datives, there is a much stronger priming

effect when the verb in the prime and the target is the same compared to when the verb in the prime and the target are different (e.g. Pickering & Branigan, 1998). Some studies that claimed to investigate syntactic priming ignored this lexical boost effect and simply used the same verbs in the prime and target (e.g. Branigan et al., 1999; Pickering et al., 2002). Of course, in these specific studies it is very difficult to disentangle the contribution of lexical and syntactic information in the obtained priming effects. However, most structural priming studies do use different verbs in the prime and target sentences. The observation that these studies still show significant priming effects is taken to support the syntactic nature of the information that is primed. However, most of these structural priming studies have used a small number of different verbs which often have similar meanings (Branigan et al., 2000; Corley & Scheepers, 2002; Loebell & Bock, 2003; Pickering & Branigan, 1998; Schoonbaert et al., 2005). For instance, in the studies mentioned here the verbs that are repeatedly used are “give”, “hand”, “offer”, “lend”, “throw”, “toss”, “post”, “send”. These verbs all convey the transfer of some object from one person to the other. This is unavoidable when using ditransitive verbs because they typically carry this general meaning. Unfortunately this also means that, even when there is a significant priming effect without the same verb being used, in a lot of items the prime and target are strongly related conceptually, describing similar events. As a consequence, in a lot of studies that have investigated the persistence of structure use, it is difficult to entirely exclude that lexical, semantic or conceptual priming is underlying the priming effect.

In light of these confounds, the finding by Scheepers (2003), in which hierarchical configuration information was primed, is one of the strongest pieces of evidence in favor of syntactic priming. Our finding that this type of syntactic information can even be primed without specific language support is even stronger proof that abstract syntactic information can be primed. In both of these studies, there are no conceptual links between prime and target. Unrelated events involving different entities are used in the prime and target sentence fragments. The lexical items are all

dissimilar and don't have similar meanings. Thus it is highly unlikely that the current priming effects can be explained by invoking lexical or semantic factors.

The finding that the relative clause attachment ambiguity is subject to syntactic priming is also related to another important issue in the sentence processing literature, namely whether syntactic ambiguity resolution is exposure-based or not. Starting from the finding that attachment preferences for this particular ambiguity differ between languages (Cuetos & Mitchell, 1988), Mitchell and colleagues proposed the tuning hypothesis (e.g. Mitchell & Cuetos, 1991; Mitchell et al., 1995). According to this hypothesis people resolve syntactic ambiguities in favor of the structural interpretation that they encountered most often in the past. This means that people are strongly influenced by their past experience with similar syntactic structures. For some time, this account of syntactic ambiguity resolution was challenged by studies that pointed out that the online preferences of people did not correspond with the frequency pattern of the alternative interpretations in large text corpora for two attachment ambiguities, namely relative clause attachments in Dutch (Mitchell & Brysbaert, 1998) and noun phrase conjunction in English (Gibson & Schütze, 1999; Gibson, Schütze, & Salomon, 1996). Recently, however, Desmet and colleagues have argued that, when looking at a more detailed level of syntactic structure (a finer grain size), online attachment preferences and corpus frequencies do match, both for the relative clause attachments in Dutch (Desmet, Brysbaert, & De Baecke, 2002; Desmet et al., 2005) and for the noun phrase conjunction in English (Desmet & Gibson, 2003). This means that the empirical data are still compatible with an experience-based account of syntactic ambiguity resolution. The present findings and those before by Scheepers (2003) are further and more direct evidence in favor of the hypothesis that the way in which people resolve syntactic ambiguities is influenced by previous exposure to the same ambiguity.

However, to link the priming data to the tuning hypothesis (or any experience-based account) one has to assume that syntactic priming does not only involve a short-term activation of one specific syntactic structure over another, but that it actually has long-term effects. This is exactly what is claimed by Bock and Griffin (2000). Based on the finding that syntactic priming can occur over relatively long time intervals or the processing of other sentences (Bock & Griffin, 2000; Branigan, Pickering, Stewart, & McLean, 2000; Hartsuiker & Kolk, 1998), the finding that the syntactic priming effect is independent of explicit memory of the prime (Bock, Loebell, & Morey, 1992), and the finding that syntactic priming shows up in anterograde amnesia patients, Bock and Griffin have argued that syntactic priming is a form of implicit learning, which tunes the language processing system to previous experience. Moreover, in a very recent paper, Chang, Dell, & Bock (in press) tested the claim that syntactic priming is a form of implicit learning rather than activation of syntactic representations. In a connectionist model they treat syntactic priming as a form of error-based implicit learning, with the same learning mechanism underlying the training of the model and syntactic priming (changing weights between nodes through backpropagation). Treating syntactic priming this way (instead of through activation of specific nodes or groups of nodes) the model closely replicated a whole range of human syntactic priming results (e.g. Bock, 1989; Bock & Loebell, 1990; Bock & Griffin, 2000; Chang, Bock, & Goldberg, 2003; Pickering & Branigan, 1998). Especially telling is the finding that syntactic priming in the model is significant both in lag 0 and lag 10, just as in human data (Bock & Griffin, 2000).

It should be noted that Scheepers (2003) looked at long term priming effects in his study by comparing the first half of trials with the second half of trials. He found no significant differences between these two halves and states that syntactic priming in relative clause attachment production might be a transient phenomenon. Even though this lack of an effect might be suggestive, we think it is likely that the manipulation in his experiments (and ours) might have

been too weak to find any long-term effects. At the second half of the experiment, participants had produced only 4 more high-attachment primes and 4 more low-attachment primes than in the first half of the experiment. The fact that there were only a few instances and that there were an equal amount of both types (not only four that went against the baseline, but also four that confirmed the baseline preference) might have made it very difficult to observe any effects. We think it might be a bit premature to reject the possibility of tuning on the basis of a post-hoc null effect in experiments that were not designed to test long-term effects. This is especially true given the studies that have shown syntactic priming over longer time intervals (e.g. Griffin & Bock, 2000) and the suggestive evidence that people's relative clause attachment preferences might shift when they get exposed to a language with a different attachment preference (e.g. Dussias, 2003; 2004; Fernandez, 1998). Further research is needed to figure out whether it is possible to find long-term effects on the basis of short-term priming manipulations. As for now, the first prerequisite for tuning, namely the activation of syntactic attachments on the basis of previous exposure seems to be a robust finding (found in German, Dutch, and cross-linguistically from Dutch to German).

### **Syntactic representations**

The discussion of the type of syntactic information that is primed in the present study also points to the usefulness of the syntactic priming technique. An interesting question in language processing research is how people represent the syntactic structures they build when they are reading or listening to sentences. This question has often been addressed indirectly by studying cases in which sentence processing is likely to fail, such as when processing syntactic ambiguities or complex syntactic structures. However, looking at syntactic priming is a more direct investigation of how people represent syntactic structures, because priming can only occur when the specific abstract structure under investigation is being represented. Studying which syntactic

structures are prone to priming and which are not is thus a very interesting way of investigating the representational aspect of sentence processing (see also the discussion of sentence production models above). The occurrence of this type of priming in a bilingual setting is a particularly strong case for representing syntactic structure, because it means that structures can be represented independent from the language that is used.

The main goal of the present study was to investigate whether purely syntactic information which is not directly connected to lexical entries could be primed between languages. Therefore, our study does not go beyond the findings presented by Scheepers (2003) in answering the question of what the exact nature of this syntactic information is. We can only speculate about the possible explanations and further research will have to clarify which of these options is most viable. One potential explanation is that people represent bigger chunks of syntax than phrase structure rules. This might seem somewhat unlikely within context-free grammars in light of the strong generativity hypothesis of language. It seems very redundant to represent both context-free phrase structure rules and in addition represent combinations of phrase structure rules. However, it is more likely in other grammar formalisms, such as Tree Adjoining Grammar (Joshi, Levy, & Takahashi, 1975; Joshi & Shabes, 1997), where the nodes of trees are rewritten as other trees. Within this formalism it is possible to represent larger chunks of syntax. So in the case of a high-attachment relative clause, the tree representing the relative clause would be adjoined at a higher point in the already existing syntactic tree than in the case of a low-attachment relative clause.

Another explanation – and the one that is favored by Scheepers (2003) – is an explanation in terms of sequences of syntactic rules. According to this explanation there is a mental record of the exact sequence in which the phrase structure rules are applied. Of course, this sequence will depend on the type of parser one assumes. A top-down parser (e.g. Yngve, 1960) will generate the phrase structure rules in a different sequence from a bottom-up parser. Crucially, however,

whatever type of parser one assumes the sequence for generating a high attachment relative clause will always differ from the sequence for generating a low attachment relative clause. For instance, assuming a top-down parser, high attachment would be generated by the following sequence of rules: “NP → NP RC”, “NP → NP PP”, “PP → prep NP”, whereas low attachment would be generated by the following sequence of rules: “NP → NP PP”, “PP → prep NP”, “NP → NP RC”. Under this explanation it is assumed that it is possible to activate such sequences and that this increases the likelihood of the subsequent use of the same sequence. This seems in line with the procedural view of syntactic priming. Bock (1986) for instance describes syntactic priming as the effect that the procedures responsible for the creation of a sentence’s structure can be activated or strengthened by use. This explanation also fits well with the assumption that syntactic priming is a form of implicit learning (Chang et al., 2000; Chang et al., in press), which was discussed before. This idea builds on a body of empirical evidence from the implicit learning literature, which shows that abstract sequence information can be learned implicitly and that this information can be activated in the brain without the participant’s awareness of there even being a sequence (see Seger, 1994, for a review article on implicit learning).

A final possible explanation that we would like to present – one that was not considered by Scheepers (2003) – is another explanation in terms of strengthening syntactic procedures (e.g. Bock, 1986; Bock & Loebell, 1990; Chang et al. 2000; Chang et al., in press) rather than syntactic representations (e.g. Hartsuiker et al., 2004; Pickering & Branigan, 1998): Maybe the syntactic priming effect in relative clause attachments can be explained through activation of general sentence processing principles. One relevant principle that has widely been argued to be active in sentence comprehension and sentence production is locality, which has also been referred to as late closure or recency (e.g. Bever, 1970; Desmet et al., in press; Frazier, 1979; Frazier & Fodor, 1978; Gibson, 1998; Gibson & Schütze, 1999; Hawkins, 1990, 1994; Kimball, 1973; Pearlmutter

& Gibson, 2001; Stevenson, 1994). Assuming that syntactic principles like this are part of the procedures responsible for the creation of a sentence's structure, these principles might also be activated or strengthened by use. The application of locality in the prime sentence fragment (i.e. reading the sentence beginning and interpreting the relative pronoun as the beginning of a low attachment relative clause) might have increased the likelihood of applying locality in the target sentence fragment (i.e. interpreting the ambiguous relative pronoun as the beginning of a low attachment relative clause). Interestingly, this explanation makes different predictions than the account proposed by Scheepers in which sequences of phrase-structure rules are being primed. If the priming of general processing principles underlies the relative clause attachment priming effect, then the application of these principles in other syntactic structures, such as prepositional phrase attachment (e.g. "John saw the letter of the teacher to..." which would force high attachment of the prepositional phrase to "the letter") might actually prime relative clause attachments. Note that such a priming effect between different syntactic ambiguities is not predicted by the previous accounts, because the bigger chunks of tree representations or the sequences of phrase-structure rules in prime and target would involve completely different phrase-structure rules in the prime and target ("NP → NP + PP" in the prepositional phrase attachment ambiguity and "NP → NP + RC" in the relative clause attachment ambiguity). The idea of general principles influencing different syntactic structures is also in line with the neural network of Sturt, Costa, Lombardo, and Frasconi (2003). They use a hybrid model in which a dynamic grammar is used to generate and represent syntactic structures and in which a recursive neural network ranks these syntactic structure on the basis of the models experience. This experience-based model, which can deal with complex hierarchical structures produced by the dynamic grammar, was able to generalize relative clause attachment preferences from experience with other syntactic attachment structures, without ever being presented with relative clause attachments during the learning phase. This means that the model had to abstract syntactic

attachment decisions regarding the hierarchical tree configuration from experience with different syntactic structures. Of course, the Sturt et al. model generalized on the basis of a lot of previous experience and is a good model for long-term effects on sentence processing. However, it is possible that the underlying generalized representations that were built by the model are could be informative about the representations that are underlying the priming effect in our study. Sturt et al. acknowledge that the exact nature of the syntactic generalization is a topic that requires further investigation. Studies using priming techniques like those used in the present study might be a very interesting avenue for further research into these general representations that can influence different types of attachment structures. Priming studies looking at the priming effects between different syntactic structures (such as between prepositional phrase and relative clause attachments) might be a good place to start.

## **Conclusion**

The present study has shown that the alternative structures of the relative clause attachment ambiguity can be primed from Dutch to English in proficient Dutch-English bilinguals. This cross-linguistic priming effect was as strong as the priming effect within Dutch and was not due to priming of discourse-based representations. We have argued that these findings favor a shared-syntax account, where the syntactic information of the two languages of bilinguals is represented in a highly integrated way, over a separate-syntax account, where the syntactic information of the two languages of bilinguals is represented in distinct, independent syntactic modules. We have argued that these findings are further evidence for priming of syntactic information that is not related to lexical entries. These findings are also more direct evidence for an experience-based account of syntactic ambiguity resolution. Finally, we have pointed out the importance of syntactic priming studies for investigating how people represent syntactic knowledge. We hope that we also made clear that a lot of further research on syntactic priming would be desirable,

because it could reveal important insight into the nature of the syntactic representations that people use both in sentence comprehension and production.

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## Appendix A

Appendix A contains the prime (a) and target (b) pairs used in Experiment 1. The primes were also used in Experiment 2. The three versions of the primes (a) were constructed by using one of the three words between brackets. The first word between brackets is the relative pronoun that was used for the high-attachment prime condition because it can only refer to the first noun phrase. The second word between brackets is the relative pronoun that was used for the low-attachment prime condition because it can only refer to the second noun phrase. The relative pronoun “die” can only refer to words that take the determiner “de” (non-neuter and plural nouns), whereas the relative pronoun “dat” can only refer to words that take the determiner “het” (neuter words). The third word between brackets is the adverb that was used in the baseline prime condition. Each prime (a) and target (b) sentence beginning is followed by its English translation (between square brackets).

- 1a. Gabriel bekrabbelde de cover van het tijdschrift (die/dat/toen)  
[Gabriel scratched on the cover of the magazine (that/that/when)]
- 1b. De boer voederde de kalfjes van de koe die  
[The farmer fed the calves of the cow that]
- 2a. Maria troostte het kindje van de medebewoonster (dat/die/nadat)  
[Maria consoled the child of the roommate (that/that/after)]
- 2b. De concertmanager wachtte op de muzikanten van de band die  
[The concert manager waited for the musicians of the band that]
- 3a. Alle mensen staarden naar het herenhuis van de miljonair (dat/die/omdat)  
[Everyone stared at the mansion of the millionaire (that/who/because)]
- 3b. De docent adviseerde de leerlingen van de lerares die  
[The lecturer advised the students of the teacher who]

- 4a. Peter hoorde de kanarie van het buurmeisje (die/dat/nadat)  
[Peter heard the canary of the girl next door (that/who/after)]
- 4b. Klara bezocht de studenten van de pianolerares die  
[Klara visited the students of the piano teacher who]
- 5a. De getuige herkende de bestuurder van het voertuig (die/dat/toen)  
[The witness recognized the driver of the vehicle (who/that/when)]
- 5b. De priester sprak met de leidster van de scouts die  
[The priest spoke to the leader of the scouts who]
- 6a. De politie ondervroeg de veroorzaakster van het ongeval (die/dat/nadat)  
[The police interrogated the causer of the accident (who/that/after)]
- 6b. Klaas ontmoette de bazin van de bediendes die  
[Klaas met the boss of the employees who]
- 7a. De assistent declameerde het puntentotaal van de candidate (dat/die/alvorens)  
[The assistant announced the score of the candidate (that/who/before)]
- 7b. De gepensioneerde beledigde de uitgeefster van de brochures die  
[The pensioner insulted the editor of the leaflets that]
- 8a. Judith vervolgde de eigenares van het dier (die/dat/alhoewel)  
[Judith prosecuted the owner of the animal (who/that/even though)]
- 8b. De welzijnswerker begroette de verpleegster van de bejaarden die  
[The social worker greeted the nurse of the elderly who]
- 9a. We consulteerden de bediende van het bankkantoor (die/dat/omdat)  
[We consulted the employee of the bank office (who/that/because)]
- 9b. Kurt controleerde de uittreksels van de secretaresse die  
[Kurt controlled the tickets of the secretary that]
- 10a. Helmut gebruikte het printtoestel van de afdeling (dat/die/hoewel)  
[Helmut used the printer of the department (that/that/even though)]

- 10b. We amuseerden ons met de artikels van de verslaggeefster die  
[We were amused by the articles of the journalist that]
- 11a. Martine streeelde het huisdier van de schoolvriend (dat/die/omdat)  
[Martine caressed the pet of the school friend (that/who/because)]
- 11b. Dieter glimlachte om de schetsen van de ontwerpster die  
[Dieter laughed at the etches of the designer that]
- 12a. Iemand schoot op het lief van de filmdiva (dat/die/nadat)  
[Someone shot the lover of the film diva (who/who/after)]
- 12b. Francesca corrigeerde de manuscripten van de schrijfster die  
[Franceska corrected the manuscripts of the author that]
- 13a. De storm verwoestte de veranda van het huis (die/dat/hoewel)  
[The storm destroyed the porch of the house (that/that/even though)]
- 13b. De expert loofde de firma van de jonge ondernemers die  
[The expert praised the firm of the young entrepreneurs that]
- 14a. Frits klaagde bij het slagersmeisje van de supermarkt (dat/die/nadat)  
[Frits complained to the butcher of the supermarket (who/that/after)]
- 14b. De huisbaas herstelde de deurbel van de huurders die  
[The landlord repaired the door bell of the tenants that]
- 15a. Hans poetste het uitstalraam van de apotheek (dat/die/zodat)  
[Hans cleaned the window of the pharmacy (that/that/so)]
- 15b. De vorst vernielde de oogst van de fruitboeren die  
[The frost destroyed the harvest of the fruit farmers that]
- 16a. De tuinier maaide de weide van het park (die/dat/alhoewel)  
[The gardener mowed the meadow of the park (that/that/even though)]
- 16b. De commissie verwees naar de bron van de donaties die  
[The commission referred to the source of the donations that]

- 17a. De jongen plaagde de hamster van het meisje (die/dat/omdat)  
[The boy teased the hamster of the girl (that/who/because)]
- 17b. De verhuizer verzekerde de meubels van de opdrachtgeefster die  
[The mover insured the furniture of the customer that]
- 18a. De patiënt consulteerde de hoofddarts van het ziekenhuis (die/dat/omdat)  
[The patient consulted the head physician of the hospital (who/that/because)]
- 18b. De meid staarde naar de juwelen van de gravin die  
[The girl stared at the jewels of the duchess that]
- 19a. Francine herinnerde zich het broertje van de vriendin (dat/die/toen)  
[Francine recalled the brother of the friend (who/who/when)]
- 19b. De reisleader vernoemde de klokken van de kerk die  
[The guide mentioned the bells of the church that]
- 20a. Leo wees naar het prentje van de oude man (dat/die/toen)  
[Leo pointed to the print of the old man (that/who/when)]
- 20b. De geheime dienst legde beslag op de documenten van de overheid die  
[The secret service confiscated the documents of the government that]
- 21a. De kardinaal bekritiseerde het beleid van de politicus (dat/die/hoewel)  
[The cardinal criticized the policy of the politician (that/who/even though)]
- 21b. De geleerde bestudeerde de taal van de oerbewoners die  
[The scholar studied the language of the aborigines that]
- 22a. De portrettist schilderde het neefje van de gravin (dat/die/omdat)  
[The portraitist painted the nephew of the duchess (who/who/because)]
- 22b. De mecanicien controleerde de auto van de diplomaten die  
[The mechanic controlled the car of the diplomats that]
- 23a. De brandweer redde de bewoonster van het dakappartement (die/dat/zodat)  
[The firemen saved the occupant of the penthouse (who/that/so)]

- 23b. De chauffeur poetste de limousine van de staatsgasten die  
[The chauffeur cleaned the limo of the official guests who]
- 24a. De douanebeambte fouilleerde het gezelschap van de toerist (dat/die/omdat)  
[The immigration officer searched the company of the tourist (that/who/because)]
- 24b. Het sportnieuws prees de defensieformatie van de Rode Duivels die  
[The sports news praised the defense of the soccer players that]

## Appendix B

Appendix B contains the English target sentence beginnings that were used in Experiment 2. The Dutch primes for Experiment 2 were the same as in Experiment 1 (see Appendix 1).

1. The farmer fed the calves of the cow that
2. The concert manager waited for the musicians of the pop star that
3. The tutor advised the students of the schoolmistress that
4. Klara visited the students of the piano teacher that
5. The pastor talked to the leader of the scouts that
6. John met the boss of the employees that
7. The pensioner complained about the content of the fliers that
8. The civilian service worker greeted the nurse of the seniors that
9. Kurt checked the payment slips of the company that
10. We were amused about the articles of the newspaper that
11. Dieter smiled at the children of the secretary that
12. Francesca corrected the manuscripts of the publisher that
13. The expert called the help desk of the companies that
14. The janitor greeted the maid of the tenants that
15. The frost ruined the harvest of the fruit farms that
16. The commission referred to the source of the donations that
17. The remover insured the furniture of the apartment that
18. The maid looked at the children of the countess that
19. The tourist guide mentioned the bells of the church that
20. The secret service confiscated the files of the office that
21. The scholar investigated the language of the countries that

22. The flight engineer saw the bodyguard of the diplomats that
23. The chauffeur met the representative of the state guests that
24. The sport news praised the defense formation of the soccer teams that

## Appendix C

Appendix C contains the prime sentence beginnings used in Experiment 3. The targets in Experiment 3 were the same as in Experiment 2 (see Appendix 2). The first word between brackets is the pronoun that was used for the high-attachment prime condition because it can only refer to the first noun phrase. The second word between brackets is the pronoun that was used for the low-attachment prime condition because it can only refer to the second noun phrase. The baseline condition was the same as in Experiment 1 and 2. Each prime sentence beginning is followed by its English translation (between square brackets).

1. Gabriel bekrabbelde de cover van het tijdschrift omdat (deze/het)  
[Gabriel scratched on the cover of the magazine because (it/it)]
2. Maria troostte het kindje van de medebewoonster wanneer (het/zij)  
[Maria consoled the child of the roommate when (it/she)]
3. Alle mensen staarden naar het herenhuis van de miljonair alhoewel (het/hij)  
[Everyone stared at the mansion of the millionaire even though (it/he)]
4. Peter hoorde de kanarie van het buurmeisje wanneer (deze/zij)  
[Peter heard the canary of the girl next door when (it/she)]
5. De getuige herkende de bestuurder van het voertuig toen (die/het)  
[The witness recognized the driver of the vehicle when (he/it)]
6. De politie ondervroeg de veroorzaakster van het ongeval alhoewel (ze/het)  
[The police interrogated the causer of the accident even though (she/it)]
7. De assistent declameerde het puntentotaal van de kandidate alhoewel (het/ze)  
[The assistant announced the score of the candidate even though (it/she)]
8. Judith vervolgde de eigenares van het dier omdat (ze/het)  
[Judith prosecuted the owner of the animal because (she/it)]

9. We consulteerden de bediende van het bankkantoor aangezien (hij/it)  
[We consulted the employee of the bank office given that (he/it)]
10. Helmut gebruikte het printtoestel van de afdeling omdat (het/ze)  
[Helmut used the printer of the department because (it/it)]
11. Martine streelde het huisdier van de schoolvriend toen (het/hij)  
[Martine caressed the pet of the school friend when (it/he)]
12. Iemand schoot op het lief van de filmdiva toen (hij/zij)  
[Someone shot the lover of the film diva when (he/she)]
13. De storm verwoestte de veranda van het huis alhoewel (die/het)  
[The storm destroyed the porch of the house even though (it/it)]
14. Frits klaagde bij het slagersmeisje van de supermarkt omdat (zij/die)  
[Frits complained to the butcher girl of the supermarket because (she/it)]
15. Hans poetste het uitstalraam van de apotheek omdat (het/die)  
[Hans cleaned the window of the pharmacy because (it/it)]
16. De tuinier maaide de weide van het park zodat (die/het)  
[The gardener mowed the meadow of the park so (it/it)]
17. De jongen plaagde de hamster van het meisje omdat (die/zij)  
[The boy teased the hamster of the girl because (it/she)]
18. De patiënt consulteerde de hoofddarts van het ziekenhuis omdat (die/het)  
[The patient consulted the head physician of the hospital because (he/it)]
19. Francine herinnerde zich het broertje van de vriendin omdat (het/hij)  
[Francine recalled the brother of the friend because (he/he)]
20. Leo wees naar het prentje van de oude man omdat (het/hij)  
[Leo pointed to the print of the old man because (it/he)]
21. De kardinaal bekritiseerde het beleid van de politicus omdat (het/die)  
[The cardinal criticized the policy of the politician because (it/he)]

22. De portrettist schilderde het neefje van de gravin toen (het/zij)  
[The portraitist painted the nephew of the duchess when (he/she)]
23. De brandweer redde de bewoonster van het dakappartement alvorens (zij/het)  
[The firemen saved the occupant of the penthouse before (she/it)]
24. De douanebeambte fouilleerde het gezelschap van de toeriste omdat (het/zij)  
[The immigration officer searched the company of the tourist because (they/she)]

Table 1. Mean percentage of high attachment continuations in the target sentence beginnings, as a function of prime type (HA, LA, BL), and the mean priming effect (high attachments following the HA versus LA prime) for Experiments 1, 2, and 3.

	Prime Type			Priming Effect
	HA	LA	BL	
Experiment 1	45.57	35.00	42.86	10.57
Experiment 2	42.41	31.68	36.48	10.73
Experiment 3	48.31	46.55	46.73	1.76

Table 2. Analysis of variance results for Experiments 1, 2, and 3

Exp.	Effect	By participants			By items			MinF'		
		<i>df</i>	F1	p	<i>df</i>	F2	p	<i>df</i>	MinF'	p
1	HA – LA	1,29	7.39*	.011	1,23	6.25*	.020	1,50	3.39	.072
	BL – HA	1,29	< 1	.618	1,23	< 1	.552	1,52	< 1	.701
	BL – LA	1,29	3.90	.058	1,23	3.57	.071	1,51	1.86	.178
2	HA – LA	1,23	6.43*	.018	1,23	6.30*	.020	1,46	3.18	.081
	BL – HA	1,23	5.73*	.025	1,23	< 1	.436	1,28	< 1	.458
	BL – LA	1,23	1.64	.214	1,23	1.04	.318	1,44	< 1	.429
3	HA – LA	1,29	< 1	.585	1,23	< 1	.399	1,48	< 1	.645
	BL – HA	1,29	< 1	.722	1,23	< 1	.858	1,34	< 1	.873
	BL – LA	1,29	< 1	.392	1,23	< 1	.704	1,32	< 1	.727