

Cross-linguistic structural priming in multilinguals: further evidence for shared  
syntax

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## Abstract

Four cross-linguistic structural priming experiments with multilinguals investigated whether syntactic representations for different languages are shared or separate and whether such representations in the first language are stored in a fundamentally different way from those in later acquired languages. The experiments tested whether structural priming within a language differs from priming between languages and whether priming between a first and second language differs from priming between two different second languages. Experiment 1 tested priming of relative clause attachment from Dutch (the subjects' first language), French, or English (two second languages) to Dutch. Experiments 2 and 3 were similar but had respectively French and English as the target language. Experiment 4 tested dative priming from Dutch, English, and German (another second language) to English. Structural priming was always as strong within- as between-languages and priming between a first and a second language was always as strong as priming between two second languages. These findings support accounts that assume syntax is shared across languages.

Keywords: Bilingualism; Multilingualism; Structural Priming; Sentence

Production

Worldwide it is the rule rather than the exception that people speak more than one language (Graddol, 2004; Grosjean, 1992); in some parts of the world most people even speak more than two languages. For instance, most people from the region of Flanders, Belgium, have Dutch as their first language (L1), but also know French, English and sometimes German as a second language (L2)<sup>1</sup>, which they typically started to learn towards the end of primary school, at the beginning of secondary school, and in the last years of secondary school respectively. Many studies on bilingualism have asked whether there are influences of L1 on processing an L2 (e.g., Thierry & Wu, 2007) or vice versa (e.g., Van Assche, Drieghe, Duyck, & Hartsuiker, 2009). Fewer studies have considered cross-language influences in speakers of more than two languages. However, multilingualism offers the possibility of comparing cross-linguistic influences between a first and second language with influences between two different second languages (see Lemhöfer, Dijkstra, & Michel, 2004; Van Hell & Dijkstra, 2002 for such studies in the lexical domain). This article will present such a comparison in the domain of sentence production in order to arbitrate between theories that assume syntactic representations are shared or separate across a multilingual's languages.

Although most cognitive-psychological studies on multilingualism have focused on the representation or processing of words, there is an increasing interest in research on syntactic processes in bilingual sentence production (e.g., Hartsuiker, Pickering, & Veltkamp, 2004; Kootstra, Van Hell, & Dijkstra, 2010; Loebell & Bock, 2003; Meyer & Fox Tree, 2003). Most of these studies use the *structural priming* paradigm, which is based on the phenomenon that the choice out of two alternative syntactic structures (e.g., an active instead of a passive

sentence) is influenced by having recently processed a prime sentence with that specific structure (Bock, 1986). In a series of seminal studies, Bock and colleagues ruled out that structural priming could be attributed to lexical factors, to overlap in thematic roles, or to overlap in prosody (Bock, 1989; Bock & Loebell, 1989), and thus is probably due to the overlap in syntactic structure *per se*. Structural priming has been found in several languages (e.g., Dutch: Hartsuiker & Kolk, 1998; English: Bock, 1986; German: Scheepers, 2003; Mandarin: Cai, Pickering, & Branigan, 2012; Swedish: Van Gompel & Kantola, 2011) and with many kinds of syntactic structures, such as the dative alternation (e.g., Bock, 1986; Pickering & Branigan, 1998), actives vs. passives (e.g., Bernolet, Hartsuiker, & Pickering, 2009; Bock, 1986), order of auxiliary and past participle (Hartsuiker & Westenberg, 2000), adjective + noun vs. noun + relative clause (Cleland & Pickering, 2003), omission vs. production of optional “that” (Ferreira, 2003), and low- or high attachment of relative clauses in a complex noun phrase (Scheepers, 2003). Several paradigms have been used, including picture description under the guise of a memory task (Bock, 1986), sentence completion (Pickering & Branigan, 1998), and a dialogue game paradigm where two subjects (a confederate of the experimenter and a naïve subject) alternate in describing each other pictures and verifying whether the other person’s description corresponds to their “matching picture” (Branigan, Pickering, & McLean, 2000).

Importantly, structural priming also takes place between languages. Hartsuiker et al. (2004), for example, showed that Spanish/English bilinguals described a picture more often with a passive sentence in English (“the church is hit by lightning”) when they were exposed to a passive sentence in Spanish immediately before (as opposed to an active sentence or a control sentence).

Cross-linguistic syntactic priming has also been found with other syntactic alternations and with different pairs of languages (e.g., Bernolet, Hartsuiker, & Pickering, 2007; 2009; 2012; 2013; Kantola & Van Gompel, 2011; Salamoura & Williams, 2006; Schoonbaert et al., 2007; see Hartsuiker & Pickering, 2008 and Bernolet & Hartsuiker, in press for reviews). Neuroimaging work found a neural analogue of structural priming across languages, namely decreased activation in certain brain areas in response to the second of two structurally similar sentences (repetition suppression). Specifically, Weber and Indefrey (2009) observed that left inferior frontal gyrus, left middle temporal gyrus, and left precentral gyrus were less active after repetition of syntax both within a second language and between a first and second language. Most importantly, cross-linguistic priming has also been found with respect to the attachment of relative clauses to the first or second noun in a complex noun phrase (e.g., *Claire visited the professor of the students who was/were...*) (De Smet and Declerq, 2006). Three of the experiments reported in this article used such attachment priming.

Cross-linguistic structural priming effects are compatible with two different ways of organizing syntactic information in multilinguals: Syntax could be shared across a multilingual's languages (shared-syntax accounts) or there could be separate, yet interacting syntactic representations (separate, interacting syntax accounts). First, according to shared-syntax accounts, syntactic representations and procedures would be shared across a multilingual's languages whenever the corresponding syntactic structures are similar enough (we address the issue of how similar structures need to be in order to be shared in the General Discussion). For instance, Hartsuiker et al.'s (2004) lexicalist shared syntax account assumed an integrated level of lexical

and syntactic representations in multilingualism, so that syntactic representations are shared between languages whenever possible. This model is a multilingual extension of Pickering and Branigan's (1998) model of the lexico-syntactic stratum in sentence production. Hartsuiker et al.'s model contains lexical representations for words in each language. These lemma nodes are connected to concept nodes, combinatorial nodes, and language nodes. It is assumed that the concept nodes and combinatorial nodes are shared across the different languages. Thus, there would be a single combinatorial node for the prepositional dative (e.g., *the soldier gave a flower to the nun*) that would become active when producing or comprehending this structure in English, but also in Dutch or German. Every verb that allows for this structure in every language the person knows would thus be connected to this node. Recently, Hartsuiker and Bernolet (in press) proposed an extended version of this account, which viewed fully shared syntax as the end point of a developmental trajectory. Learners of a second language would start out with separate representations for each language, but merge them across languages given sufficient exposure.

Additionally, non-lexicalist (i.e., implicit learning) accounts such as Chang, Bock, and Dell (2006) lend themselves well for an extension to multilingualism. After all, such accounts assume that syntax abstracts from lexical items, and so it is very much conceivable that in multilinguals syntax abstracts from language too, as long as the two or more languages have similar structures. Indeed, Chang et al. argue that cross-linguistic priming suggests that "adult syntax must involve some nonlexical abstractions" (p. 251). We return to the distinction between lexicalist and non-lexicalist shared-syntax accounts in the General Discussion.

Note that the syntactic alternation of interest in our first three experiments (i.e., high vs. low attachment of a relative clause) cannot be captured by combinatorial information attached to a lexical item (Scheepers, 2003) as both structures can be built by the same set of phrase structure rules. As a consequence, this type of priming cannot be accounted for in terms of a lexicalist model such as Hartsuiker et al. (2004). However, as the shared-syntax hypothesis is more general than that specific model one can still ask whether the more abstract representations or procedures involved in RC attachment priming are shared across languages.

A second account of syntactic organization in multilinguals is that multilinguals have separate syntactic representations for each of their languages, but that these representations interact with each other. For instance, De Bot (1992) proposed a bilingual version of Levelt's (1989, p. 6) blueprint of the speaker. Levelt distinguished a conceptualizer, a formulator, and an articulator and proposed a lexicon that is shared between production and comprehension. De Bot suggested that processing in L1 and L2 overlaps at the conceptual and lexical levels but that there are separate, interacting formulators for each language. The extent of this interaction would depend on variables like etymological relatedness of the languages (the more distant the languages, the smaller the cross-linguistic influence) and second-language proficiency (if speakers are more proficient in L2, they would be better able to separate their two languages and therefore cross-linguistic influences would decrease). Thus, on this account, the syntactic encoding processes and representations responsible for formulating a sentence in English are independent from the Dutch processes and representations, but these processes can prime each other.

Similarly, Kantola and Van Gompel (2011) raised the possibility of a lexicalist, separate but interacting syntax model: There would be separate combinatorial nodes for each language, but corresponding nodes would be connected and so can prime each other. A final model of this kind was proposed by Ullman (2001). According to that model, syntactic processing in L1 and L2 is carried out by two qualitatively different but connected systems, each with a different neural basis. In L1, syntactic processing would be carried out by procedural memory, similar to motor actions. In contrast, lexical and semantic processing would be carried out by declarative memory, the memory system for words and facts. The further assumption is that there is a sensitive period for the acquisition of syntax. If an L2 is acquired early enough (as in simultaneous bilinguals), then syntactic processing in a second language could be carried out by procedural memory. But if L2 is acquired too late, L2-syntactic processing will have to rely on declarative memory, for instance on explicit knowledge of grammatical rules. Thus, for the typical student in Flanders, who has acquired English around the age of 13, the production of a Dutch and English dative would be driven by fundamentally different (though possibly interacting) memory systems. In contrast, Ullman's model predicts that the production of an English and a German dative would be driven by the *same* memory system because both languages were acquired late.

The goal of this paper is to adjudicate between shared-syntax and separate, interacting syntax accounts. To do so, we will test two predictions having to do with the strength of between- vs. within-language structural priming, on the one hand, and the strength of between-language priming involving an L1 and L2 vs. involving different L2s, on the other hand.



First, separate, interacting syntax theories predict that within-language priming is stronger than between-language priming, because between-language influences rely on an interaction between memory systems or processing components. In contrast, shared-syntax accounts assume only a single, shared syntactic representation (provided sufficient proficiency in each language). Under the assumption that prime processing in each language activates the syntactic representation equally strongly, shared-syntax accounts predict in principle that between-language priming is just as strong as within-language priming. We do note that Cai, Pickering, Yan, and Branigan (2011) assume a shared-syntax account according to which within-language priming is stronger than between-language priming, as a result of a language node activating all verbs in the selected language. This would lead to strengthened connections between all verbs in the language and the syntactic representation that was just selected and therefore stronger within-language than between-language priming (we return to this account in the General Discussion).

A second prediction relates to the difference between priming from an L1 to an L2 or vice versa as compared to priming between two different L2s. One separate, interacting syntax account in particular (Ullman, 2001) assigns a special status to L1 as it would use a different memory system from all L2s. Because different L2s would use the same system, the prediction can be derived that priming between two L2s is stronger than that between an L1 and an L2 (under the assumption that representations within declarative memory are more likely to prime each other than a representation from procedural memory is likely to prime a representation in declarative memory).

In contrast, shared-syntax accounts and De Bot's (2001) separate, interacting syntax accounts assume respectively a single, shared syntactic representation for L1 and all L2's or separate, interacting representations for all languages. Therefore, such accounts predict equivalent structural priming between L1 and L2 and between two L2s.

These two sets of predictions follow from the models' core assumptions. Separate, but interactive models further make predictions about variables that modulate the extent of cross-linguistic syntactic interaction. For instance, De Bot (1992) suggested that the extent of interaction between each language's formulator is stronger for languages that are etymologically more closely related. This then predicts stronger priming between Germanic languages (e.g., English to Dutch) than priming between a Romance and Germanic language (e.g., French to Dutch). De Bot also suggested that cross-linguistic interactions between an L1 and an L2 become *weaker* with increasing proficiency in L2, as more proficient speakers would be better at keeping their languages separate. For our subjects, this predicts stronger priming between French and Dutch than between English and Dutch. Shared-syntax accounts predict no effect of proficiency or language relatedness, as long as the speaker has reached sufficient proficiency to share syntactic representations across languages.

Several earlier studies compared the strength of within-language vs. between-language priming, with mixed results. Schoonbaert et al. (2007) conducted a structural priming experiment involving double object datives (*the soldier is giving the nun a flower*) and prepositional object datives (*the soldier is giving a flower to the nun*) within and between English and Dutch. They also varied whether the verbs in prime and target utterances were related (identical

within-languages and translation equivalent between-languages) or unrelated. For our purposes, the most important effects are those in the unrelated conditions, which reflect syntactic effects in the absence of lexical or semantic influences. In these conditions, within-language priming was descriptively slightly larger than between-language priming, but this difference was not statistically significant. Note that a recent reanalysis of these data (reported in Hartsuiker & Bernolet, in press) showed that the difference between within-language and between-language depended on L2 proficiency, with a smaller difference for more proficient subjects.

Similarly, Kantola and Van Gompel (2011) reported two structural priming experiments using datives from L2 English and L1 Swedish to Swedish and English. They tested highly proficient subjects (master's students of English) and used a written sentence completion paradigm (Pickering & Branigan, 1998). Consistent with a shared-syntax account, there was equivalent within-language priming as between-language priming.

On the other hand, several studies found stronger within-language than between-language priming. Bernolet et al. (2007) reported a series of experiments with a word order alternation in noun phrases (e.g., the sheep that is red vs. the red sheep). Although there was clear priming within Dutch (L1) and within English (L2), there was no priming between these languages. This can be explained by the fact that Dutch and English have a different word order in the relative clause, so that these structures could not be shared across these languages. Consistent with that account, priming was obtained between Dutch and German, which have the same word order. Bernolet et al. (2013) observed that priming of genitive structures (the nun's hat vs. the hat of the nun) was

much stronger within-L2 than between L1 and L2. They argued that the English genitive, which differs from its Dutch counterpart in morphology and usage constraints, is learned rather late and so is not yet shared in the participants with relatively low proficiency. Indeed, in both experiments priming interacted with proficiency: Low-proficient subjects showed virtually no priming, whereas high-proficient subjects showed strong priming effects (note there was also a modulation with proficiency in the reanalysis of Schoonbaert et al., 2007, discussed above). Finally, Cai et al. (2011) conducted two experiments using dative structures in Cantonese and Mandarin. In Experiment 1 (Mandarin targets) there was a significant advantage for within-language over between-language priming. No such advantage was obtained in Experiment 2 (Cantonese targets), which the authors attributed to a ceiling effect. As described above, they interpreted the stronger within-language priming in Experiment 1 as the result of strengthened connections between all dative verbs in the prime language and the selected syntactic representation.

Summarizing, previous investigations contrasting within-language vs. between-language priming show a mixture of results. Within-language priming is stronger than between-language priming when the structure and its equivalent are so different that their syntactic representation cannot be shared (Bernolet et al., 2007) or is only shared in more proficient bilinguals (Bernolet et al., 2013). Several other cross-linguistic priming studies, all testing datives, found equivalent within- and between-language priming, with the exception of Cai et al. (2011) who observed stronger within-language priming in one of their two experiments. Because the shared syntax account essentially predicts a null effect and because there may be power issues with previous studies, a further

comparison of between-language and within-language priming is necessary. Furthermore, no previous study has compared priming between two second languages with priming between a first and second language. As argued above, the shared syntax hypothesis predicts no difference between these cases, but the theory that later acquired languages use a different memory system than the first language (Ullman, 2001) predicts stronger priming between two different second languages than between the first and a second language.

Below we report four cross-linguistic structural priming experiments. Three experiments used L1 Dutch and L2s English and French as the prime languages (within-subjects) and held the target language constant (Dutch, French, and English in Experiments 1, 2, and 3 respectively). These experiments tested for structural priming of the attachment of a relative clause to either the first noun (high attachment) or second noun (low attachment) of a complex noun phrase. It is important to note that attachment priming is different in important respects from priming of many other structures (e.g., datives, genitives) in which the syntactic alternation corresponds to a number of different argument structures of a verb or noun.

Similar to Desmet and Declercq (2006) and Scheepers (2003), we used a written completion paradigm. Each prime sentence fragment contained a complex noun phrase containing two number-marked nouns (with different number) and the beginning of a relative clause, namely a relative pronoun (ambiguous for number) and a number-marked verb (1a-b). Thus, noun-verb number agreement disambiguated attachment site. The target fragments were similar, but did not contain a relative clause verb (2). The sentence completion thus determined the attachment site. Note that Desmet and Declercq and

Scheepers used gender-marking on the pronoun to disambiguate attachment; because English and French do not have gender-marking on relative pronouns, we decided to use number.

(1a) Claire visited the students of the professor who were ...

(1b) Claire visited the students of the professor who was ...

(2) De storm vernielde de ramen van de bungalow die ...

(The storm destroyed the windows of the bungalow that ...)

In order to generalize the findings to an alternation that corresponds to a difference in verb argument structure, Experiment 4 elicited double object and prepositional object datives, as did Cai et al. (2011), Kantola and Van Gompel (2011), and Schoonbaert et al. (2007). The target language was English and the prime languages were Dutch, English, and German. German was used instead of French because French does not have the dative alternation.

In all experiments, the subjects were native-Dutch speaking Ghent University psychology students. They had learned French in primary school and English and German in secondary school. The order in which they had acquired their second languages was typically French, English, German, but their responses to the Language Experience and Proficiency Questionnaire (i.e., the LEAP-Q, Marian, Blumenfeld, & Kaushanskaya, 2007) indicated that they were more proficient in English than in French and least proficient in German. Their larger proficiency in English than in French may be related to the fact that Dutch and English are etymologically more closely related than Dutch and French, but also by the larger amount of exposure to English in daily life (English-language text books, music, film, and other media). All four experiments assessed whether within-language priming is stronger than between-language priming and three

experiments tested whether priming between two second languages is stronger than priming between a first and second language. Because participants indicated that they were more proficient in English than French or German and because French was the only Romance language of the ones tested here, the experiments could further indicate whether the strength of priming depends on proficiency or etymological relatedness.

### Experiment 1: Relative clause attachment with Dutch targets

#### *Method*

##### *Subjects*

Forty-eight Ghent University students (36 women and 12 men) participated in exchange for course credits. They had an average age of 18.33 years (range 17-21). All subjects filled in the LEAP-Q (Marian, et al., 2007). Table 1 reports self-rated proficiency in speaking, listening, reading, and writing from this questionnaire in the first three experiments. The full set of questionnaire data for this and all further experiments is available as supplementary material on <http://users.ugent.be/~rhartsui/SupMat.html>. For each of the experiments reported in this paper, we computed the participants' proficiency in the target language and the prime languages as the mean of their self-rated scores for speaking, listening, reading, and writing in these languages. Prime and target language proficiency were always included as covariates in the analyses (see Bernolet et al., 2012).

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Insert Table 1 About Here

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*Materials*

We constructed 30 sets of seven sentence fragments

(<http://users.ugent.be/~rhartsui/SupMat.html> for the full set of materials in this and all further experiments). Each set contained six prime sentence fragments in Dutch, French, or English that either forced a high attachment (3a, 3c, 3e) or low attachment (3b, 3d, 3f) completion, and one Dutch target fragment (2, repeated as 4) that could be completed using either high or low attachment. The Dutch, French, and English versions of each high-attachment prime and each low-attachment prime were translations of each other. Each Dutch target fragment was semantically and lexically unrelated to its prime fragments.

(3a) Claire bezocht de leerlingen van de professor die werden ...

(3b) Claire bezocht de leerlingen van de professor die werd ...

(3c) Claire a rendu visite aux élèves du professeur qui étaient ...

(3d) Claire a rendu visite aux élèves du professeur qui était ...

(3e) Claire visited the students of the professor who were ...

(3f) Claire visited the students of the professor who was ...

(4) De storm vernielde de ramen van de bungalow die ...

(translation: The storm destroyed the windows of the bungalow that ...)

Each prime sentence fragment contained two nouns, one with singular number (e.g., “professor”) and one with plural number (e.g., “students”). The second noun was followed by the beginning of a relative clause: a relative pronoun (e.g., “who”) and a number-marked verb. Thus, verb number disambiguated whether attachment was high or low. The target sentence fragment had a similar structure but ended after the relative pronoun and was thus ambiguous for relative clause attachment. The Dutch relative pronoun, as



opposed to its English and French counterparts, is gender-marked (“dat” for neuter gender, “die” for common gender). To ensure that only one pronoun was used in each language (and thus to maximize the comparability of conditions) all Dutch nouns had common gender.

There were as many prime sentences with a singular first noun (N1) and a plural second noun (N2) as there were prime sentences with plural N1 and singular N2. The order of number of N1 and N2 was the same in half of the prime-target pairs and different in the other half. In half the prime sentences and half of the target sentences both nouns were animate; in the other half of the materials both nouns were inanimate. Prime and target sentences were paired such that in half of the pairs all nouns were animate, in one quarter the prime nouns were animate and the target nouns inanimate, and in one quarter the prime nouns were inanimate but the target nouns animate. These steps were taken to prevent characteristics of the nouns to influence attachment decisions (Desmet, Brysbaert, & De Baecke, 2002). Additionally, there were 96 filler sentences that were structurally and semantically unrelated to the critical sentences.

These materials were used to construct six basic lists of items. Each list contained 5 prime-target pairs in each condition (30 prime-target pairs were presented in each list). A version of each prime-target pair occurred once in each list and across the six lists each experimental pair occurred once in each condition. The order of stimuli in each list was pseudo-random with the constraint that each list started with 6 filler items and that each pair of prime and target fragments was separated by two to four filler items from the next pair. Each list contained as many items in Dutch, English, and French. Finally, a

version was made of each list that inverted the sequence of stimuli, leading to 12 lists in total.

### *Procedure*

The subjects viewed each sentence fragment on a 17-inch monitor connected to a Pentium 4 personal computer. Each fragment was displayed, one at a time, on a single line and the cursor was located on the line below. The subjects typed their answer on a keyboard and pressed <ENTER> when ready. There were no constraints on time and content, except for the instruction to write grammatically correct and plausible sentences and to write down the first completion that came to mind. The experiment was controlled by E-prime (Schneider, Eschman, & Zuccolotto, 2002). A session lasted about one hour.

### *Scoring*

The second author, who is a native speaker of Dutch with high proficiency in English and French, determined the attachment site of each prime and target sentence; she was blind to the conditions and scored primes and targets separately. She considered both overt number marking on the relative clause verb and sentence semantics. Although in principle verb number marking forces low or high attachment in the primes and disambiguates attachment in the target fragments, completions were excluded when sentence semantics suggested a different site than did verb number (e.g., *The government financed the studies of the university that were participating in a global cooperation*) or when semantics left the attachment site ambiguous (e.g., the Dutch translation of *The cowboy was afraid of the chief of the Indians who were very angry*).

### *Data Analysis*

Because the data are binomial (valid completions have either low or high attachment), we fitted generalized linear mixed-effects models with the logit link function on the data (see Baayen, Davidson, & Bates, 2008), as recommended by Jaeger (2008). The models were implemented in the lme4 package (Bates, Maechler, & Dai, 2008) in R (R foundation for Statistical Computing, 2011). For this experiment and all the other experiments reported in this paper, we tried to keep the random effects structure maximal (Barr, Levy, Scheepers, & Tily, 2013): Apart from random intercepts for participants and items, the models included random slopes for the fixed effects whenever possible (i.e. when the models reached convergence). We applied Helmert contrasts in the analysis and always made the within-language priming condition the reference level. This way, the first contrast compared within-language priming (level 1) and between language priming (average of levels 2 and 3), while the second contrast compared the two between-language priming conditions (level 2 vs. level 3).

The fixed effects in the current model were attachment of prime (low vs. high), language of prime (Dutch, French, or English), and their interaction. In addition to random intercepts for participants and items, the model included random slopes for attachment of prime. Target language proficiency (proficiency in Dutch, in this case) and Prime language proficiency (proficiency in Dutch/English/French) were added as covariates, as were the interactions between attachment of prime and Target/Prime language proficiency and the three-way interaction between attachment of prime, language of prime, and Target language proficiency.

The models reported for our different experiments all include an interaction between attachment of prime and language of prime. As we predict a

null-effect for the interaction between attachment of prime and language of prime in all experiments, we used Bayes' information criterion (BIC) in order to compare the reported models containing this interaction ( $H_1$ ) with models without interactions between attachment of prime and language of prime ( $H_0$ ). As the difference between BIC values transforms to an approximation of the Bayes factor (see Wagenmakers, 2007), these comparisons indicate whether or not the models with the critical interaction ( $H_1$ ) are preferred above simpler models without this interaction ( $H_0$ ).

### *Results and Discussion*

The coded data and analysis scripts are available on the Open Science Framework:

[https://osf.io/xmhce/?view\\_only=5b31a0efdf2c423a935d93c0f2b8aba2](https://osf.io/xmhce/?view_only=5b31a0efdf2c423a935d93c0f2b8aba2)

We excluded completions that were semantically incompatible with the intended attachment locus in the prime trials (114 out of 1440 trials). The analyses reported below are based on the remaining 92.1% of the data. Among the 1326 trials that led to correct prime productions, 15 (1.1%) target responses were semantically ambiguous as to attachment locus in target completions, or were incorrect (e.g., missing completion, or completion that rendered the sentence ungrammatical) and were coded as 'other' responses. The remaining responses were coded as high attachment (565, 42.6%) or low attachment (761, 57.4%) responses.

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INSERT TABLE 2 ABOUT HERE  
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The proportions of high-attachment responses out of all low- and high-attachment responses in each condition of Experiments 1-3 are listed in Table 2, the results of the analysis are shown in Table 3. The model we fit to the data predicts the proportion of high attachment responses. The non-significant intercept, which represents the overall proportion of high attachment responses, indicates that, overall, there was no clear bias towards one of both response alternatives. The analyses showed a main effect of Prime Structure: The proportion of high attachment responses was significantly higher after high attachment primes (48.2%) than after low attachment primes (36.8%), resulting in an 11% effect of RC attachment priming. The overall distribution of target responses did not differ between the within-language and the between-language priming blocks (Prime language contrast 1), nor did it differ according to the L2 prime language that was used (Prime language contrast 2). Importantly, the priming effects did not differ for within- and between-language priming or according to the different L2 prime languages. Interestingly, we did obtain a marginally significant ( $p < .08$ ) main effect of Target Language proficiency: The higher the participants' self-reported proficiency in L1 Dutch, the higher the proportion of high attachment responses. Target Language proficiency showed significant interactions with PL contrasts 1 (within vs. between-language priming) and 2 (L2a vs. L2b). Additional analyses with dummy coding and alternating reference levels revealed that the overall response distribution (i.e., proportion of high attachment responses) was positively correlated with Target Language proficiency when the prime language was Dutch (Beta = 1.60, SD = 0.68, Wald's  $Z = 2.37$ ,  $p < .05$ ) or English (Beta = 1.29, SD = 0.63, Wald's  $Z = 2.06$ ,  $p < .05$ ), but not when the prime language was French ( $p > .1$ ).

The Bayes information criterion (BIC) of the model containing the interaction between attachment of prime and prime language and the three-way interaction between attachment of prime, prime language, and Target language proficiency was 1797.2; the BIC of the model without these interactions was 1769.7. Based on the approximation provided by Wagenmakers (2007), this yields a Bayes factor of  $\exp(\Delta\text{BIC}_{10}/2) \approx 34551.9$  in favor of the null hypothesis and a posterior probability of the null hypothesis of  $[1/(1+\exp(-\Delta\text{BIC}_{10}/2))] \approx 0.99$ .

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INSERT TABLE 3 ABOUT HERE  
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Summarizing, this experiment showed structural priming of relative clause attachment from Dutch, English, and French to Dutch. Priming had a comparable magnitude in each language: We found no evidence that priming was stronger when the languages of the prime and target were identical (Dutch to Dutch) than when these languages were different (English to Dutch, French to Dutch). Furthermore, there was no indication that the extent of cross-linguistic priming was modulated by linguistic relatedness (which on De Bot's 1992 account would predict stronger priming from English than French). Proficiency in the target language influenced the response distributions (more high attachment responses with increasing proficiency in Dutch), but we did not find an effect of overall prime language proficiency: Priming was as strong with French primes as with English primes, even though our subjects were more

proficient in English. Note that in this experiment, etymological relatedness with the target language and proficiency in the prime language were confounded: both were higher in English than French. This issue is addressed at least partially in Experiment 4, which will present German primes; German is etymologically close to the target language used there (English) but our subjects had relatively low proficiency in German.

These results are consistent with shared syntax accounts, but not with separate, interacting syntax accounts. Next, we turn to French as the target language so as to strengthen the empirical basis for our claim that within- and between language priming do not differ, and to test whether priming between two later acquired languages differs from priming between a native language and a later acquired language.

#### Experiment 2: Relative clause attachment with French targets

Experiment 2 was identical to Experiment 1 except that the target fragments were now in French.

#### *Method*

##### *Subjects*

Forty-eight further Ghent University students (37 women and 11 men) participated in exchange for course credits. They had an average age of 18.73 years (range 18-41). All were native speakers of Dutch with English and French as second languages. Table 1 reports proficiency scores in Dutch, English, and French from the LEAP-Q.

*Materials, procedure, scoring, and data analysis*

The only difference with Experiment 1 was that the target fragments were now translated into French. To obtain an equal number of fragments overall in each language, the appropriate number of filler items were translated from French into Dutch.

*Results and Discussion*

As in Experiment 1, we excluded completions that were semantically incompatible with the intended attachment locus in the prime trials (42 out of 1440 trials). The analyses reported below are based on the remaining 97.1% of the data. Among the 1398 trials that led to correct prime productions, 42 (3%) target responses were semantically ambiguous as to attachment locus in target completions, or were incorrect (e.g., missing completion, or completion that rendered the sentence ungrammatical) and were coded as ‘other’ responses. The remaining responses were coded as high attachment (652, 46.6%) or low attachment (689, 49.3%) responses.

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INSERT TABLE 4 ABOUT HERE  
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The proportions of high-attachment responses out of all low- and high-attachment responses in each condition are listed in Table 2 the results of the analysis are shown in Table 4. The model used for the analyses is identical to that used for Experiment 1, except that for the current analyses the random slopes were not added to the model in order to reach model convergence. Like in



Experiment 1, the non-significant intercept indicates that, overall, there was no clear bias towards one of both response alternatives. The analyses showed a main effect of Prime Structure: The proportion of high attachment responses was significantly higher after high attachment primes (52.0%) than after low attachment primes (45.2%). This 7% effect of RC attachment priming did not interact with any of the other factors in the model. Most importantly, priming did not differ within- vs. between-languages and neither did it differ for priming between L1 and an L2 vs. priming between two L2's. Further, there were no effects or interactions involving proficiency.

The BIC of the model containing the interaction between attachment of prime and prime language and the three-way interaction between attachment of prime, prime language, and Target language proficiency was 1602.6; the BIC of the model without these interactions was 1577.1. This yields an approximated Bayes factor of 936589.2 in favor of the null hypothesis and a posterior probability of the null hypothesis of 0.99.

Summarizing, like in Experiment 1 we observed a structural priming effect of attachment site that did not depend on the language of the prime sentence: Within-language priming was not significantly stronger than between-language priming. Additionally, as far as we are aware, this is the first experiment to demonstrate cross-linguistic priming between two L2s. This allowed us to test whether cross-linguistic priming from L1 to L2 (Dutch to French) differs from priming between two L2s (English to French). In contrast to the predictions from accounts that argue syntactic processing in L1 and L2 is fundamentally different (Ullman, 2001), the magnitude of cross-linguistic priming was almost identical in these two situations (6.5% and 6.6%). Finally, it

appeared that priming overall was somewhat weaker here than in Experiment 1, suggesting an influence of *target* language on the strength of priming. We return to this issue after reporting Experiment 3, which aimed to replicate the current findings, but now with English as the target language.

### Experiment 3: Relative clause attachment with English targets

#### *Method*

##### *Subjects*

Forty-eight further Ghent University students (41 women and 7 men) participated in exchange for course credits. Their average age was 18.6 years (range 18 – 32). All were native speakers of Dutch with English and French as second languages. Table 1 reports proficiency scores in Dutch, English, and French from the LEAP-Q.

##### *Materials, procedure, scoring, and data analysis*

The only differences with Experiment 2 were that the target fragments were now translated into English and that the filler material was adapted to achieve equal numbers of fillers in each language.

#### *Results and Discussion*

As in Experiments 1 and 2, we first excluded fragment completions that were semantically incompatible with the intended attachment locus of the prime trials (72 out of 1440 trials). The analyses reported below are based on the remaining 95.0% of the data. Of these 1368 responses, 89 were coded as ‘others’ (6.5%), 549 as high attachment responses (40.1%) and 730 as low attachment responses (53.4%).

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INSERT TABLE 5 ABOUT HERE  
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The proportions of high-attachment responses out of all low- and high-attachment responses in each condition are listed in Table 2, the results of the analysis are shown in Table 5. The model used for the analysis is the same as for Experiment 2, without the three-way interaction between attachment of prime, language of prime and Target language proficiency, which was omitted in order to reach model convergence. For the current experiment, the intercept is marginally significant ( $p < .08$ ), indicating a general preference for low attachment responses (53.4%) over high attachment responses (40.1%) in English as an L2. The main effect for Prime Language Contrast 1 indicates that the overall proportion of high attachment responses is significantly higher in the within (47.7%) than in the between-language priming blocks (40.5%). But importantly, the strength of priming did not differ within and between languages. The absence of an interaction between Prime Structure and prime language Contrast 2 indicates that, also in this experiment, there was no difference in between-language priming caused by L1 (17% priming) or L2 primes (21% priming). Like in Experiment 1, the proportion of high attachment responses increased together with the participants' target language proficiency. In this experiment, however, the main effect of proficiency was only marginally significant.

The BIC of the model containing the interaction between attachment of prime and prime language was 1623.8; the BIC of the model without this interaction was 1610.0. This yields an approximated Bayes factor of 999.3 in

favor of the null hypothesis and a posterior probability of the null hypothesis of 0.99.

Summarizing, we again observed a structural priming effect of attachment site that did not depend on the language of the prime sentence. As in the previous experiments, within-language priming was not stronger than between-language priming. Similarly to Experiment 2, priming between an L1 and an L2 (Dutch to English) was as strong as priming between two different L2s (French to English). In contrast to the previous experiments, there was now an effect of prime language: Across the board, more high attachment responses were produced when the prime language was English. One possibility is that the subjects have different attachment preferences in their different languages and that a preference to attach high in English is stronger when the previous sentence was also in English. Finally, the overall priming effect appeared to be stronger here than in the previous experiments. We return to these findings in the General Discussion.

We have now reported three experiments that did not find any evidence that the strength of structural priming depends on the prime language, although the data do suggest that the strength of priming depends on the target language. Below, we report two analyses including the data from all 144 subjects tested in Experiments 1, 2, and 3. The first analysis investigated whether syntactic choices, and, consequently, the strength of priming vary according to target language, and whether within-language priming is stronger than between-language priming. As our participants were not only free to choose the syntactic structure, but also the content of their target completions, a second analysis investigated whether prime language and syntactic priming had an influence on

the syntactic complexity of the target completions. For this analysis, we used the length of the target sentences as a proxy for their complexity.

### Combined analyses of Experiments 1, 2, and 3

For the analysis of the syntactic choices, we computed a new variable (Within/Between) that indicated whether a specific prime-target language combination belonged to a within-language priming block or a between-language priming block. As we had three different target languages across the three experiments, Target Language was added as a factor as well. The data of the first three experiments were then fitted to a model with the fixed factors Prime Structure, Target Language, and Within/between and their interactions. Target Language proficiency and Prime language proficiency were added as covariates. As this model did not reach convergence with a full random effects structure, the model included only random intercepts for participants and items. Additionally, the final model only contained the interactions between attachment of prime and Target language, attachment of prime and within/between language priming, Target language and within/between language priming, and within/between language priming and Target language proficiency. The results of this combined analysis can be found in Table 6. We again used Helmert contrasts. The reference level for the factor Target Language is Dutch, so contrast 1 contrasts priming in native (level 1) and non-native languages (average of levels 2 and 3), while contrast 2 compares priming in two different L2s.

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INSERT TABLE 6 ABOUT HERE  
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The analysis showed main effects of Prime Structure and Within/between language block. The main effect for Within/between language block indicates that the proportion of high attachment responses was higher in within-language (46.6%) than in between-language priming blocks (43.7%). The significant interaction between attachment of prime and Target language contrast 1 indicates that the priming effects observed in Experiment 1, where the target language was the participants' L1, were significantly stronger than the average priming effects observed when the target language was a non-native language. This interaction is probably due to the weak effects observed in Experiment 2, for a significant interaction between prime Structure and Target language contrast 2 (L2a vs. L2b) reveals that the priming effects observed in Experiment 2, in which French was the target language, were significantly weaker than the effects observed in Experiment 3, in which English was the target language. Importantly, the interaction between attachment of prime and within/between language priming was not significant, indicating that, across the three experiments, within-language priming was not stronger than priming between languages.

The BIC of the model containing the interaction between attachment of prime and within/between language priming was 4867.8; the BIC of the model without this interaction was 4859.9. This yields an approximated Bayes factor of 51.9 in favor of the null hypothesis and a posterior probability of the null hypothesis of 0.98.

The regression analyses with target length as dependent variable featured prime language, target-prime structure match, and their interaction as predictors and random intercepts for participants and items showed no effects

of prime language on target length ( $ps >.1$ ) and no effects of prime-target match ( $ps >.1$ ), suggesting that the completions were equally complex for the different prime languages in all experiments and that target complexity was not different when structures were repeated vs. when they were not. There were differences in target length according to the target language: In Experiment 1 (L1 Dutch), the average length (including spaces and typos) was 29.8 characters, in Experiment 2 (L2 French) 22.4 characters, and in Experiment 3 (L2 English) 23.9 characters, suggesting that the targets were more complex in the L1 than in the L2s.

Summarizing, the cross-experiment comparison confirmed the results of the individual experiments: there was a clear structural priming effect that did not depend on the prime language. Within-language priming was as strong as between-language priming, and between-language priming was as strong between L1 and L2 as between two different L2s. The cross-experiment comparison also showed that the strength of priming varied with L2 target language: It was stronger in English than in French. Apart from the strength of priming, the overall complexity of the target sentences also differed between the different target languages: Target completions were longer in the L1 than in the L2s. Prime language did, however, not influence sentence complexity. Finally, there were some indications that subjects had a stronger preference for high-attachment in the within-language condition. This effect seems to be driven mostly by the English to English condition; we return to this in the General Discussion.

The findings so far are very much compatible with a shared-syntax account. However, it is possible that the syntactic processes involved in deciding whether to attach a relative clause high or low are qualitatively different from

the processes involved in deciding, for instance, between alternative argument structures for a verb. As we already noted, priming of attachment cannot be easily captured by a lexicalist model. Further, several recent studies have shown that relative clause attachment makes a demand on very domain-general machinery. Thus, Scheepers, Sturt, Martin, Myachykov, Teevan, and Viskupova (2011) demonstrated priming between the solving of arithmetic sums in which an operand had scope over only the last element of the sum (low attachment) or over a larger part of the sum (high attachment) and RC attachment in sentence completion. Van de Cavey and Hartsuiker (2016) replicated such priming from arithmetic, but further observed priming from musical sequences and from descriptions of action sequences which were analogous to high- or low attachment sentences. The fact that attachment priming occurs across such different domains leaves open the possibility that a shared syntax account holds for relative clause attachment, but not for other alternations.

We therefore found it important to also have a test case where the syntactic alternations did correspond to different argument structures. To do so, we next turned to datives, similarly to the experiments reported by Cai et al. (2011), Kantola and Van Gompel (2011), and Schoonbaert et al. (2007). Because French does not have the dative alternation, we now used primes in German instead.

#### Experiment 4: Datives with English targets

This experiment investigated structural priming from Dutch, English, and German to English. German is clearly the weakest language of our subjects, but they still reported to have moderate reading skills in that language (2.8 on a scale from 1-5, see Table 7). The current experiment used the dative alternation.



Dutch and English have a similar double object dative (5a and 6a) and prepositional dative (5b and 6b). German has a similar double object dative (7a) but also a scrambled version of the double object dative with the direct and indirect object swapped (and with syntactic function marked by case on the determiner). For many German verbs the prepositional dative is unacceptable, but other verbs do allow this structure (7b). Here, we used six verbs that allow prepositional object datives. These verbs were also used by Loebell and Bock (2003).

(5a) De clown schrijft de inbreker een brief

(5b) De clown schrijft een brief aan de inbreker

(6a) The clown writes the burglar a letter

(6b) The clown writes a letter to the burglar

(7a) Der Clown schreibt dem Einbrecher einen Brief

(7b) Der Clown schreibt einen Brief an den Einbrecher

A further change from Experiments 1 – 3 concerned the experimental paradigm. Although sentence completion studies eliciting datives have been done in the past (e.g., Corley & Scheepers, 2002; Kantola & Van Gompel, 2011; Pickering & Branigan, 1998), that paradigm typically leads to a considerable loss of data. Kantola and Van Gompel suggested that Swedish speakers are more likely to use ditransitive verbs transitively or intransitively than English speakers. Pilot testing in our lab suggested that Dutch speakers are like the Swedish speakers in this respect. Therefore, we decided to use a version of the confederate scripting paradigm (Branigan et al., 2000; Hartsuiker et al., 2008; Schoonbaert et al., 2007), which typically shows clear effects and in which data loss is usually limited. Here we used Hartsuiker et al.'s "chatting" version of this

paradigm: The subjects used a simulated computer chatting environment and were under the impression of alternating with a chatting partner in describing each other pictures and verifying whether that description corresponded to one's own picture. In reality, the responses of the chatting partner were computer-generated. In this way, the computer's descriptions could serve as primes for the real subject's target responses.

### *Method*

#### *Subjects*

Forty-eight further students (37 women and 11 men) from Ghent University and other institutes of higher education in the Ghent area participated in exchange for course credits or 10 Euro. Average age was 20.0 years (range 18-24). All were native speakers of Dutch and had learned English and German in school. The subjects began to learn German later than English (14.7 vs. 10.7 years) and were less proficient in German (reading skills 4.3 vs. 2.8 on a scale from 1-5). Detailed self-ratings of proficiency in each of the three prime languages are provided in Table 7. Like for the previous experiments, we computed the participants' proficiency in the target language as the mean of their self-rated scores for speaking, listening, reading, and writing in this language. Target and Prime language language proficiency were included as covariates in the analyses.

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INSERT TABLE 7 ABOUT HERE

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#### *Materials*

The prime sentences used the six verbs that Loebell and Bock (2003) also used in cross-linguistic priming experiments between English and German (*to buy, to write, to sew, to make, to build, and to bake*). Each verb was used in five sentences and each sentence had six versions: the double object or prepositional object dative in Dutch, English, or German as in (5)-(7) above.

We also selected 30 target pictures from Schoonbaert et al.'s (2007) materials. These were line drawings that showed an agent, a theme, and a recipient (e.g., a pirate giving a banana to a cowboy). Underneath each picture an English verb was shown: *to throw, to offer, to give, to hand, or to show*; there were six pictures with each verb. There were also 96 filler pictures that could not be described using a dative (e.g., a doctor tickling a waitress), 126 pictures for a cover task of sentence-picture matching (see below), and 96 filler sentences. In 50% of all picture materials the direction of the action was from left to right and in 50% it was from right to left. Materials were organized into 126 triplets consisting of a prime sentence (allegedly generated by the chatting partner), a matching picture, and a description picture. There were 30 critical triplets and 96 filler triplets (32 per language). In all critical triplets and in 50% of all triplets the sentence was a correct description of the matching picture. The pairing of prime sentences and target pictures in each triplet was such that all combinations of prime verb and target verb occurred exactly once and so that there was never overlap in the content words of prime and expected target sentence.

We constructed a pseudo random order of the 126 triplets, with the constraints that the first six triplets were fillers and that all critical triplets were separated by between two and four filler triplets. This order was the basis for six

stimulus lists, so that there were five prime sentences in each of the six conditions and that across the six lists each prime sentence occurred once in each condition. A further six lists had the reverse order of stimuli.

### *Procedure*

The experiment used Hartsuiker et al.'s (2008) simulated chatting environment on a personal computer.<sup>2</sup> The subjects were told that they would be playing a dialogue game with another subject in a different room via a computer chatting system; the chatting partners would alternate in describing each other pictures and comparing each other's descriptions against a matching picture.

Unbeknownst to the subjects, their chatting partner was in reality a computer program. To make the computer-generated sentences sound natural, we deliberately put in occasional spelling errors. Further, the time interval during which the chatting partner appeared to be thinking or writing was variable. To avoid subjects initiating task-unrelated chat and to avoid them expecting this of their partner, the instructions emphasized that it was important to only work on the task and to ignore any unrelated comments their partner might make. The instructions mentioned that the verb underneath the picture should be used. Furthermore, the subject was told to describe the pictures in English but that their chatting partner was assigned to a different condition and would describe a given picture in either Dutch, English, or German.

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INSERT FIGURE 1 ABOUT HERE  
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Figure 1 shows a screenshot of the chatting environment, taken while the subject is typing in a picture description. The computer always had the first turn. Each trial consisted of the following events: (1) a matching picture appeared on the right hand side of the screen; (2) simultaneously, the message “your partner is typing” was displayed for a duration drawn from a Gaussian distribution (M: 6 secs, SD: 1 sec); (3) the computer-generated sentence appeared on the screen; (4) the subject decided whether that sentence and the matching picture did or did not correspond by either pressing a key labeled with a green or a red sticker; (5) the picture was replaced by the subject’s description picture; simultaneously, an input text field and ‘send’ button became active; (6) the subject typed the picture description and when ready sent it off by either clicking the “send” button or by pressing the <ENTER> key; (7) The sentence appeared on the left side of the screen, underneath the computer’s previous sentence. At the same time, the message “your partner is thinking” appeared on the screen, which indicated that the chatting partner was busy with the sentence-picture matching task; (8) After a time interval drawn from a Gaussian distribution (M: 3 secs, SD: 1 sec) the picture was replaced with a new matching picture and the next trial started. The experiment lasted about 50 minutes.

### *Scoring and analysis*

The computer program wrote the subjects’ picture descriptions to a file. The responses were then manually categorized (by the second author) into double object datives, prepositional datives, or “other responses”. A response was scored as a double-object dative if it used the verb underneath the picture and if the verb was followed by the indirect object (recipient) and the direct object

(theme). A response was scored as a prepositional object dative if the correct verb was followed by the direct object (theme), which was then followed by a prepositional phrase consisting of the preposition “to” or “at” and a noun phrase containing the recipient. A response was scored as “other” if an incorrect verb was used or if a particle was added to the verb (e.g., hand *over* instead of hand), or if the sentence had a different structure from a canonical double object or prepositional object dative (e.g., “the boxer is being shown a mug by the pirate”). As in the previous experiments, the data were analyzed with generalized linear mixed-effects models with the logit link function.

#### *Results and discussion*

Of the 1440 trials, 31 were coded as ‘other’ responses (2,2%). The remaining responses were coded as double object datives (671, 46.6%) or prepositional object datives (738, 51.3%). The proportions of double object responses out of all double object and prepositional object responses in each condition are listed in Table 8.

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INSERT TABLE 8 ABOUT HERE  
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Like the models we fitted for Experiments 1-3, the current model included Prime Structure and Prime Language as fixed factors. Target and Prime Language proficiency were included as covariates. In order to reach model convergence, the final model only included random intercepts for participants and items. Additionally, it only included interactions between attachment of prime and language of prime and attachment of prime and Target language proficiency. Again, we applied Helmert contrast coding. The model predicted the

odds for a DO dative response, the results of the analysis are mentioned in table 9.

The non-significant intercept indicates that, for English datives, there was no overall bias towards one of both response alternatives. The analysis show a significant effect of Prime Structure: The overall proportion of DO datives was higher after DO primes (53.4%) than after PO primes (41.9%), resulting in a 11.5% priming effect for datives. This priming effect did not interact with any of the other factors in the model.

The BIC of the model containing the interaction between attachment of prime and prime language was 1527.4; the BIC of the model without this interaction was 1514.5. This yields an approximated Bayes factor of 632.7 in favor of the null hypothesis and a posterior probability of the null hypothesis of 0.99.

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INSERT TABLE 9 ABOUT HERE  
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Summarizing, we again observed a structural priming effect, this time with datives, which did not depend on the language of the prime sentence. As in the previous experiments, within-language priming was not stronger than between-language priming, and between-language priming involving an L1 and an L2 (Dutch to English) was as strong as between-language priming involving two different L2s (German to English).

## General Discussion

All four experiments found clear structural priming effects that were not modulated by the prime language. Experiment 1 tested priming of low and high attachment primes in Dutch, English, and French with Dutch as the target language. Priming from English to Dutch and French to Dutch was as strong as priming from Dutch to Dutch. Experiment 2 had French as the target language. Again, within-language priming and between-language priming did not differ, and neither did priming between an L1 and L2 (Dutch to French) and between two different L2s (English to French). Comparable results were obtained in Experiment 3 that had English as the target language. Finally, Experiment 4 generalized the findings to datives and to German as a prime language. German, (unlike French) has the dative alternation, it is etymologically similar to the target language English, and our subjects are relatively low-proficient in it. The latter two properties helped us to tease apart effects of language similarity and proficiency. As in the previous experiments within-language priming (English to English) did not differ from between-language priming (Dutch to English or German to English), and priming between L1 and L2 (Dutch to English) did not differ from priming between two L2s (German to English). Summarizing, within-language priming was never stronger than between-language priming, and priming between two second languages was never stronger than priming between a first and second language. Additionally, we note that strength of priming was affected by the target language. There was also some indication that the overall preference for high attachment was stronger in within-language conditions (especially English to English).

*Within vs. Between-language priming*



Similar to our findings, Schoonbaert et al. (2007) and Kantola and Van Gompel (2011), also found no difference between the strength of within-language and between-language structural priming. We note that traditional logic in psychology states that a null hypothesis can never be proven. However, we agree with the view of Erdfelder (2010) and others that if a theory predicts no difference between conditions, the investigator must have options to corroborate that prediction. These options include having large sample sizes, relaxing the traditional alpha-level of .05, or adopting a Bayesian framework. In this respect, it is noteworthy that equivalent within- and between-language priming has now been found in one study comparing four experiments, with priming direction manipulated between-subjects (Schoonbaert et al., 2007) and in six further experiments manipulating priming direction within-subjects (the present study and Kantola & Van Gompel, 2011). The total number of subjects tested in these studies exceeds 400. Further, even with a very much relaxed alpha-level, the crucial prime language x prime structure interaction would still never have been significant. Finally, an approximation of Bayes Factors showed very strong evidence for the null hypothesis in all of our experiments.

We thus take the comparable effect of within- and between-language priming found here and elsewhere as support for a shared syntax model. If there is one syntactic representation for a given syntactic option that is shared between different languages, then it should not matter by which language that node is activated. In contrast, “separate syntax” models always predict stronger within-language than between-language priming. Assuming a shared syntax model, the question arises how similar structures need to be before they can be shared across languages. Cross-linguistic priming effects have been shown

between structures that are somewhat different in their morphology and pragmatics, such as the genitive in English (*the nun's hat*) and Dutch (*de non haer hoed*, lit. *the nun her hat*; Bernolet et al., 2013). However, there seems to be no cross-linguistic syntactic priming for studies priming constructions differing in word order: Bernolet et al. (2007) observed no priming between Dutch and English for constructions like "*het schaap dat wit is*" (*the sheep that is white*), which have verb-final word order in Dutch but not English. In contrast, there was priming of such structures between Dutch and German, which do have the same word order. These findings suggest that representations at the syntactic level can be shared across languages despite differences in morphology or pragmatics, but that such sharing requires word order to be identical.

Importantly, Cai et al. (2011) pointed out that a version of Hartsuiker et al.'s lexicalist, shared-syntax model can predict stronger within- than between-language priming. On that account, when a prime sentence is processed (e.g., a double object dative in English), activation of the "language node" would indiscriminately activate all lexical nodes in that language. The combinatorial node for the double-object dative would be active too. Because of this coactivation, the links between *all* English verbs allowing the double-object dative and the corresponding combinatorial node would be strengthened to some extent. If the target sentence is then in English, the node for the double-object dative would have an additional advantage because of the strengthened links with English verbs. The present data are not consistent with this view. We note that this view relies on an assumption that has been challenged in independent work. In particular, the notion of a language node that activates the lexical level has been rejected by Dijkstra and Van Heuven (2002) (at least in

comprehension) on the basis of several studies indicating that language information becomes available too late to affect the word selection process.

An alternative account for the comparable within-language and between-language priming is that the participants always generated target sentences in L1 and then translated them into L2. If that were the case, L1 to L2 priming would effectively be the same as priming from L1 to L1. However, that account is incompatible with the results of our earlier syntactic priming experiments with multilinguals, in which noun phrases (the red sheep vs. the sheep that is red) were primed (Bernolet, Hartsuiker & Pickering, 2007). Participants in that study showed no between-language priming from Dutch to English (L1 to L2), whereas they did show priming for the same structures within English as an L2 and between Dutch and German (L1 to L2). If participants would generate target sentences in their L1 first, one would not expect a null effect when priming from Dutch to English.

A further alternative account for the comparable effect of within- and between-language priming might be that in principle, within-language priming is stronger than between-language priming; however, stimuli in L1 would always exert a stronger effect on L2 processing than L2 stimuli on L1 processing and so priming in the L1 to L2 direction would be affected by two opposing forces and end up being about as strong as priming in the L2 to L2 direction (Kantola & Van Gompel, 2011). It is indeed the case that studies using masked translation priming and masked cross-linguistic semantic priming tend to find stronger effects from L1 to L2 than vice versa (Schoonbaert, Duyck, Brysbaert, & Hartsuiker, 2009). However, the present data and those of Kantola and Van

Gompel are not consistent with this account, because it incorrectly predicts much stronger priming in the L1 to L1 direction than the L2 to L1 direction.

*Priming between L1 and L2 vs. priming between L2a and L2b*

As far as we are aware, the present study is the first to demonstrate priming between two different second languages and, more importantly, to establish that such priming is as strong as priming between an L1 and L2. This finding too is compatible with a shared syntax account. Given that there is only one syntactic representation for a given structure, it does not matter whether that structure is activated by an L1 or an L2. In contrast, the finding is inconsistent with the hypothesis that later-acquired second languages use the declarative memory system for syntactic processing while the first language uses the procedural memory system (Ullman, 2001). This hypothesis predicts that priming between two second languages is stronger than priming between a first and second language, a prediction that was contradicted by the present findings. It should be acknowledged that the prediction derived from Ullman's account is based on the assumption that two representations within the declarative system will interact more strongly than a representation in the declarative system with a representation in the procedural system. Although this assumption seems plausible, it is possible of course that it does not hold, in which case the prediction no longer follows.

*Effects of proficiency and linguistic relatedness*

Cross-linguistic priming experiments differ with respect to the bilinguals' age of second language acquisition, immersion, and proficiency, but it is clear that cross-linguistic priming can be observed in late, non-immersed bilinguals with moderate to high proficiency such as the subjects tested here. Does the

*strength* of cross-linguistic priming depend on the relative proficiency in the different languages of a multilingual? Our Experiment 1 provided a good test of this possibility, because it presented a comparison involving the same participants and same target items of priming from a language in which participants were more proficient (English) with one in which they were considerably less proficient (French). However, priming from English to Dutch was as strong as priming from French to Dutch. This is consistent with a shared syntax model, which predicts equivalent priming from all languages, as long as the subject knows the second language well enough to share the critical syntactic representation with his or her other languages. Another way of testing for proficiency effects is by considering individual differences in the strength of priming. Thus, Bernolet et al. (2013) observed stronger priming with genitives the more proficient the subjects were. Additionally, Hartsuiker and Bernolet (in press) reanalyzed the data of Schoonbaert et al. (2007) and observed a similar modulation of priming by proficiency in cross-linguistic priming with dative sentences. In the current experiments, however, no modulation of priming by proficiency was observed. It is possible that effects of proficiency in the current design are complicated by the fact that each experiment involved *two* second languages and that the proficiency in both of these languages mattered. All in all, the current results are in line with a shared-syntax account, but they are hard to reconcile with a separate, interacting syntax account like De Bot (1992) according to which newly learned languages strongly overlap with the first language at first, but become more separated as the learner becomes more proficient.

De Bot (1992) also suggested that linguistic relatedness determines the strength of cross-linguistic interactions, with more closely related languages showing stronger interactions. Contrary to our results, this would always predict stronger priming effects between Dutch and English or vice versa than between Dutch and French or English and French (because Dutch and English are Germanic languages and French is a Romance language). Further evidence against De Bot's suggestion is Shin and Christianson's (2009) finding of cross-linguistic structural priming between a much more distant language pair namely Korean and English.

*Why does priming depend on the target language?*

Even though language of the prime never mattered for the strength of the priming effect, language of the target utterance did. Priming was weakest in French. The fact that priming was different in the three target languages might be an effect of individual differences of the subjects (target language was manipulated between-subjects). It is also possible that there were differences in the extent to which other constraints than priming determined syntactic choices in the different languages. The stronger the influence of such other constraints (e.g., overall attachment preferences, effects related to animacy or number, pragmatic feasibility; see Desmet et al., 2002) the weaker any influence of priming can be.

*The locus of priming*

In three of these experiments the syntactic alternation (high- vs. low attachment) changed the meaning of the sentence. A possibility therefore is that one component of such priming is located at the semantic level (Pickering & Ferreira, 2008). We think this possibility is rather unlikely, given that both

Scheepers (2003) and Desmet and Declercq (2006) report control experiments with adverbial clauses that are not syntactically attached to either the first or second noun, but contain a pronoun that refers to either of these nouns. Those control experiments found no evidence for a semantic component to attachment priming. Additionally, a semantic account seems to be ruled out by findings that arithmetic problems and musical sequences can prime RC attachment, as it would be hard to argue that such sequences share semantics with sentences.

An interesting precondition for this type of priming however is that the syntactic decision to attach high or low drives the sentence completion, rather than the semantic decision to elaborate on the first or second noun. Like Pickering and Ferreira, we assume that syntax-driven completion is particularly likely in a sentence completion task where the productions do not follow from any particular communicative intention. It is important to note that Experiment 4 yielded converging data with the previous experiments, using a task that clearly involves concept-driven production (i.e., describing a picture). A further advantage of the picture naming paradigm used there is that there is a clear separation between a comprehension component (reading the prime sentence) and a production component (describing the picture); these components are more strongly intertwined in the sentence completion task, where both prime and target processing involve both comprehension and production.

As noted above, the currently most elaborated shared-syntax account (Hartsuiker et al., 2004) cannot explain structural priming of relative clause attachment, because the distinction between high- and a low attachment sentences concerns the global syntactic configuration of the complex noun phrase and is unrelated to any specific lexical item. A number of non-lexical

accounts of attachment priming have been proposed in the literature. Scheepers proposed that priming affects the representation of a sequence of grammatical rules in procedural memory, given that complex noun phrases with low-attachment or high-attachment can be derived from the same set of grammatical rules but applied in a different order. In contrast, Desmet and Declercq suggested that either the global syntactic configuration of the noun phrase is primed or the specific attachment site in the syntactic tree. Consistent with these latter possibilities, Loncke, Van Laere, and Desmet (2011) demonstrated that attachment priming across two different structures (attachment of a prepositional phrase [PP] to attachment of a relative clause) was as strong as attachment priming involving the same structure. This is hard to reconcile with priming of a rule sequence, because PP-attachment involves different syntactic rules as RC-attachment, but does involve the same positions in the complex noun phrase and the same global configuration. The same argument can be made, of course, on the basis of the studies showing structural priming of RC-attachment across different cognitive domains (Scheepers et al., 2011; Van De Cavey & Hartsuiker, 2016). Whatever the precise characterization of RC-attachment priming, we argue that the relevant procedures are shared across languages.

#### *Lexicalist vs. nonlexicalist accounts*

Our experiments support a shared-syntax account, but they were not designed to arbitrate between alternative shared-syntax accounts such as the lexicalist model of Hartsuiker et al. (2004) or a possible extension to multilingualism of an abstract syntax (implicit learning model) such as Chang et al. (2006). The latter type of model predicts that priming effects are sensitive to the extent to which the prime structure is unexpected; thus, a highly infrequent



(and hence unexpected) prime structure would lead to stronger priming than a highly frequent structure, the so-called inverse frequency effect (Ferreira & Bock, 2006). It is possible that multilinguals have different expectations about the distribution of structures in their different languages (e.g., they might, implicitly, consider English a “low attachment language” and Dutch a “high attachment language”). If that were true, the prediction follows that a high attachment prime would lead to stronger priming in English than Dutch (relative to a baseline prime). As we did not include a baseline in the current experiments, we leave such an experiment for future work.

### *Conclusion*

To conclude, our experiments find no evidence that priming within-languages differ from priming between languages, supporting theories according to which syntax is shared across languages. We also observed that priming between a first and second language was as strong as priming between two different second languages. Again, this supports a shared-syntax account, but not accounts that assume fundamentally different representations of first language and second language syntax. Although more work is needed to precisely characterize the mechanisms underlying priming of relative clause attachment, our findings show that a shared-syntax account holds both in this case as when priming lexically-based syntactic alternations, showing the generality of this principle.

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## Footnotes

1. We will use the term L2 to refer to *any* second language, irrespective of differences in the age of acquisition or proficiency of these second languages. Note that most of our subjects acquired French somewhat earlier than English, but rated themselves as more proficient in English than French; they acquired German latest and are least proficient in German.

2. The software and user manual can be downloaded from <http://users.ugent.be/~rhartsui/chatter/chatter.htm>. The author of the software, user manual, and webpage is Dieter Vanderelst.

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Author notes

The experiments reported in this paper were conducted in partial fulfillment of the requirements of the second author's master's degree.

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Table 1: LEAP-Q self-ratings of proficiency in Dutch, French, and English in Experiments 1, 2, and 3.

	Dutch (L1)	French (L2)	English (L2)
Experiment 1			
Speaking	4.78 (.40)	2.98 (.81)	3.83 (.69)
Listening	4.66 (.51)	3.14 (.93)	3.97 (.71)
Writing	4.53 (.61)	2.78 (.85)	3.42 (.70)
Reading	4.80 (.45)	3.39 (.74)	4.07 (.64)
Experiment 2			
Speaking	4.69 (.62)	2.90 (.83)	3.60 (.79)
Listening	4.67 (.66)	3.08 (.82)	3.92 (.79)
Writing	4.46 (.77)	2.77 (.81)	3.46 (.68)
Reading	4.77 (.42)	3.44 (.85)	3.96 (.71)
Experiment 3			
Speaking	4.65 (.53)	2.85 (.80)	3.56 (.71)
Listening	4.63 (.57)	2.96 (.77)	3.69 (.80)
Writing	4.23 (.78)	2.79 (.90)	3.33 (.75)
Reading	4.69 (.51)	3.38 (.79)	3.85 (.59)

Note. Scale from 1-5 with higher numbers denoting higher proficiency

Table 2. Percentage of high-attachment completions out of all valid completions for each condition of Experiments 1-3.

Experiment	Prime Attachment	Prime Language		
		Dutch	English	French
1: Target language Dutch	High	49.1	47.4	48.1
	Low	36.9	38.4	34.9
	Priming effect	12.2	9.0	13.2
2: Target language French	High	49.8	53.5	52.8
	Low	43.3	46.9	45.5
	Priming effect	6.5	6.6	7.3
3: Target language English	High	49.8	58.3	50
	Low	33.3	37	28.9
	Priming effect	16.5	21.3	21.1

Table 3. Results model Experiment 1

Summary of the fixed effects in the mixed logit model ( $N=1326$ ; log-likelihood = -729.4)				
Predictor	Coefficient	<i>SE</i>	Wald <i>Z</i>	<i>p</i>
Intercept	0.42	(0.283)	1.50	>.1
Prime Structure	0.28	(0.080)	3.51	<.001
Prime language (PL) contrast 1: within vs. between-language priming blocks	0.03	(0.117)	0.29	>.1
Prime language (PL) contrast 2: between-language priming from L2a vs L2b	0.04	(0.089)	0.45	>.1
Target Language Proficiency (L1 Dutch)	0.84	(0.464)	1.81	<.1
Prime Language Proficiency (Dutch/English/French)	0.09	(0.194)	0.48	>.1
Interaction = <i>Prime &amp; PL Contrast 1 (within vs. between)</i>	-0.13	(0.106)	-1.21	>.1
Interaction = <i>Prime &amp; PL Contrast 2 (L2a vs L2b)</i>	-0.05	(0.077)	-0.68	>.1
Interaction = <i>Prime &amp; Target language proficiency</i>	-0.25	(0.221)	-1.12	>.1
Interaction = <i>Prime &amp; Prime language proficiency</i>	-0.12	(0.155)	-0.77	>.1
Interaction = <i>PL Contrast 1 &amp; Target language Proficiency</i>	-0.50	(0.237)	-2.13	<.05
Interaction = <i>PL Contrast 2 &amp; Target language Proficiency</i>	-0.40	(0.148)	-2.69	<.01
Interaction = <i>Prime &amp; PL Contrast 1 &amp; Target language proficiency</i>	-0.35	(0.235)	-1.50	>.1
Interaction = <i>Prime &amp; PL Contrast 2 &amp; Target language proficiency</i>	-0.04	(0.145)	-0.28	>.1

Table 4. Results model Experiment 2

Summary of the fixed effects in the mixed logit model ( $N= 1341$ ; log-likelihood = -841.0)				
Predictor	Coefficient	SE	Wald Z	$p$
Intercept	0.07	(0.193)	0.36	>.1
Prime Structure	0.15	(0.061)	2.53	<.05
Prime language (PL) contrast 1: within vs. between-language priming blocks	0.15	(0.159)	0.92	>.1
Prime language (PL) contrast 2: between-language priming from L1 vs L2	-0.04	(0.043)	-0.91	>.1
Target Language Proficiency (L2 French)	-0.08	(0.184)	-0.47	>.1
Prime Language Proficiency (Dutch/English/French)	-0.08	(0.177)	-0.48	>.1
Interaction = Prime & PL Contrast 1 (within vs. between)	0.16	(0.142)	1.12	>.1
Interaction = Prime & PL Contrast 2 (L1 vs L2)	-0.01	(0.043)	-0.31	>.1
Interaction = Prime & Target language proficiency	0.06	(0.131)	0.51	>.1
Interaction = Prime & Prime language proficiency	-0.21	(0.152)	-1.40	>.1
Interaction = PL Contrast 1 & Target language Proficiency	-0.13	(0.134)	-0.95	>.1
Interaction = PL Contrast 2 & Target language Proficiency	0.04	(0.067)	0.59	>.1
Interaction = Prime & PL Contrast 1 & Target language proficiency	-0.07	(0.130)	-0.54	>.1
Interaction = Prime & PL Contrast 2 & Target language proficiency	-0.01	(0.067)	-0.22	>.1

Table 5. Results model Experiment 3.

Summary of the fixed effects in the mixed logit model ( $N= 1279$ ; log-likelihood = -769.0)				
Predictor	Coefficient	SE	Wald Z	<i>p</i>
Intercept	0.35	(0.194)	1.80	<.1
Prime Structure	0.47	(0.065)	7.25	<.001
Prime language (PL) contrast 1: within vs. between-language priming blocks	0.25	(0.113)	2.21	<.05
Prime language (PL) contrast 2: between-language priming from L1 vs L2	0.03	(0.079)	0.38	>.1
Target Language Proficiency (L2 English)	0.45	(0.230)	1.94	<.1
Prime Language Proficiency (Dutch/English/French)	-0.17	(0.181)	-0.92	>.1
Interaction = <i>Prime &amp; PL Contrast 1 (within vs. between)</i>	-0.08	(0.108)	-0.72	>.1
Interaction = <i>Prime &amp; PL Contrast 2 (L1 vs L2)</i>	0.04	(0.074)	0.51	>.1
Interaction = <i>Prime &amp; Target language proficiency</i>	-0.01	(0.167)	-0.06	>.1
Interaction = <i>Prime &amp; Prime language proficiency</i>	0.05	(0.164)	0.33	>.1

Table 6. Results combined analysis Experiments 1-3.

Summary of the fixed effects in the mixed logit model ( $N= 3946$ ; log-likelihood = -2371.8)				
Predictor	Coefficient	SE	Wald Z	$p$
Intercept	0.32	(0.178)	1.80	<.1
Prime Structure	0.27	(0.045)	6.16	<.001
Target language (TL) contrast 1: native (L1) vs. non-native (L2a & L2b)	0.11	(0.119)	0.94	>.1
Target language (TL) contrast 2: L2a vs. L2b	-0.09	(0.075)	-1.18	>.1
Within vs. between language priming	-0.16	(0.077)	-2.02	<.05
Target Language Proficiency	0.09	(0.141)	0.67	>.1
Prime Language Proficiency	0.04	(0.064)	0.62	>.1
Interaction = Prime & TL Contrast 1 (native vs. non-native)	0.11	(0.045)	2.39	<.05
Interaction = Prime & TL Contrast 2 (L2a vs L2b)	-0.07	(0.025)	-2.73	<.01
Interaction = Prime & Within/between language priming	0.05	(0.077)	0.60	>.1
Interaction = TL Contrast 1 & Within/between language priming	-0.07	(0.126)	-0.56	>.1
Interaction = TL Contrast 2 & Within/between language priming	0.13	(0.080)	1.63	>.1
Interaction = Within/between language priming & Target language Proficiency	0.17	(0.154)	1.09	>.1



Table 7. LEAP-Q self-ratings of proficiency in Dutch, English, and German in Experiment 4.

	Dutch (L1)	English (L2)	German (L2)
Speaking	4.83 (.43)	3.85 (.71)	1.77 (.75)
Listening	4.85 (.41)	4.15 (.77)	2.69 (1.03)
Writing	4.75 (.53)	3.40 (.84)	1.63 (.70)
Reading	4.96 (.20)	4.31 (.80)	2.75 (.96)

Note. Scale from 1-5 with higher numbers denoting higher proficiency

Table 8. Percentage of double object dative responses out of all valid responses for each condition of Experiment 4 (target language is English).

Prime Attachment	Prime Language		
	Dutch	English	German
Double Object	54.5	51.5	54.2
Prepositional Object	43.6	41.9	40.1
Priming effect	10.9	9.6	14.1

Table 9. Results model Experiment 4

Summary of the fixed effects in the mixed logit model ( $N= 1409$ ; log-likelihood = $-723.8$ )				
Predictor	Coefficient	SE	Wald Z	$p$
Intercept	0.22	(0.310)	0.72	>.1
Prime Structure	0.37	(0.070)	5.34	<.001
Prime language (PL) contrast 1: within vs. between-language priming blocks	0.13	(0.161)	0.82	>.1
Prime language (PL) contrast 2: between-language priming from L1 vs L2	-0.15	(0.107)	-1.36	>.1
Target Language Proficiency (L2 English)	-0.18	(0.481)	-0.37	>.1
Prime Language Proficiency (Dutch/English/French)	0.18	(0.159)	1.11	>.1
Interaction = <i>Prime &amp; PL Contrast 1 (within vs. between)</i>	0.10	(0.084)	1.24	>.1
Interaction = <i>Prime &amp; PL Contrast 2 (L1 vs L2)</i>	-0.01	(0.049)	-0.23	>.1
Interaction = <i>Prime &amp; Target language proficiency</i>	-0.15	(0.123)	-1.20	>.1

Figure Caption

Figure 1. Screenshot of the chatting environment, at the moment the subject is typing a picture description (i.e. target sentence).

tk

De bokser raakt de dokter aan

>>Jij zegt:  
The cook shoots the jar

>>Je partner zegt:  
De cowboy slaat de matroos

>>Jij zegt:  
The pirate holds the gun

>>Je partner zegt:  
De schilder kietelt de serveerster

>>Jij zegt:  
The painter shoots the mug

>>Je partner zegt:  
The clown pushes the nun

>>Jij zegt:  
The sailor pushes the cowboy

>>Je partner zegt:  
De matroos slaat de dokter

>>Jij zegt:  
The nun pushes the swimmer


>>Je partner zegt:  
Der Koch schiebt den Soldat

>>Jij zegt:  
The waitress tickles the doctor

>>Je partner zegt:  
The dancer buys a newspaper for the boxer

▼

The nun throws a mug to the swimmer



**TO THROW**

Beschrijf dit plaatje aan je partner.

Voortgang  
4  
|

<<<<<<>>>>>>

Zend