Research Article

Cross-Structural Priming

Prepositional Phrase Attachment Primes Relative Clause Attachment

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Abstract. In this paper we show that attachment height (high vs. low attachment) of a modifier to a complex noun phrase (CNP; e.g., "the servant of the actress"), can be primed between dissimilar syntactic structures. In a sentence completion experiment, we found that the attachment height of a prepositional phrase (PP) in the prime sentence primed the attachment height of a relative clause (RC) in the target sentence. This cross-structural priming effect cannot be explained in terms of the priming of specific phrase-structure rules or even sequences of specific phrase-structure rules (Scheepers, 2003), because the attachment of a PP to a CNP is generated by a different phrase-structure rule than the attachment of an RC. However, the present data suggest that the location at which the RC is attached to the CNP is mentally represented, independent of the specific phrase-structure rule that is attached, or by extension, that the abstract hierarchical configuration of the full CNP and the attached RC is represented (Desmet & Declercq, 2006). This is the first demonstration of a cross-structural priming effect that cannot be captured by phrase-structure rules.

Keywords: sentence processing, syntactic representation, syntactic priming, attachment, relative clause, prepositional phrase

In a series of classic studies, Bock and colleagues (e.g., Bock, 1986, 1989; Bock & Loebell, 1990) observed that people are more likely to use a specific syntactic structure when that structure has been used in a preceding sentence. For example, after a sentence with a prepositional-object (PO) dative like "The girl gives the banana to the baby" people are more likely to describe a picture depicting a dative action with a PO-dative like "The client buys a newspaper for the waiter" than with a direct-object (DO) dative like "The client buys the waiter a newspaper." These syntactic priming effects suggest that the preceding or prime sentence activates a mental representation of the syntactic structure in question, which makes it more likely to use that same structure in the following or target sentence. Numerous studies following Bock (1986) have investigated which syntactic structures can be primed and syntactic priming has been proven a useful tool to gain insight into the mental representation of syntax (for a review article, see Pickering & Ferreira, 2008).

In the present paper, we focus on the observation that the attachment height of a relative clause (RC) to a complex noun phrase (CNP) can be primed (Desmet & Declercq, 2006; Scheepers, 2003). In a sentence like "Someone shot the butler of the actress who was on the balcony," the RC "who was on the balcony" can refer to the first noun phrase in the main clause (NP1) "the butler" as well as to the second noun phrase (NP2) "the actress." Consequently, the comprehender can interpret the RC as referring to the NP1 and thus attach the RC to the higher NP in the syntactic tree configuration (*high attachment*). Conversely, she or he can interpret the RC as referring to the NP2 and attach the RC to the lower NP in the syntactic tree configuration (*low attachment*).

A large body of research has shown that the attachment of the RC to one of the NPs in the CNP can be influenced by many factors, including lexical-semantic characteristics of the NPs (e.g., Desmet, Brysbaert, & De Baecke, 2002; Desmet, De Baecke, Drieghe, Brysbaert, & Vonk, 2006), the frequency with which the structural ambiguity has been resolved in favor of one or the other analysis in the past (Brysbaert & Mitchell, 1996; Mitchell, Cuetos, Corley, & Brysbaert, 1995), discourse context (Desmet, De Baecke, & Brysbaert, 2002), the prosodic patterns of the sentence (Frazier, Carlson, & Clifton, 2006), etc. In the present study, we focus on the observation that the attachment height of an RC in the prime sentence influences the attachment height of an RC in the target sentence. Such a priming effect was found in two sentence completion studies, one in German (Scheepers, 2003) and one in Dutch (Desmet & Declercq, 2006). These studies used prime sentence onsets like "Die Assistentin verlas den Punktestand$_{masc}$ der Kandidatin$_{fem}$, der$_{masc}$/die$_{fem}$ … [The assistant announced the score of the candidate that …]," in which the relative pronoun was marked for gender and thus referred uniquely to one of the two NPs in the main clause. As a consequence, participants were led to understand the attachment in an unambiguous way and as such were forced to complete the prime sentence with either a high- or a low-attached RC. Target sentence onsets, on the other hand, contained an ambiguous relative pronoun that could be interpreted to refer to either of the two NPs in the main clause. Depending on their understanding of the attachment, participants could thus choose to complete target sentences with a high- or with a low-attached RC. Both studies found priming of the attachment

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height of the RC, such that participants more often completed a target sentence with a high-attached RC after a high-attachment prime than after a low-attachment prime.

This priming effect raises the question at which psycholinguistic level the information of the attachment height of the RC is mentally represented. First, the RC attachment information is unlikely to be tied to any information at the lexical level (cf. Pickering & Branigan, 1998). Unlike DO- and PO- dative alternatives, which are tied to specific verbs (e.g., "give", "hand", and "throw"), virtually any noun phrase can be modified by an RC. Moreover, the NPs in the prime and target sentences of Scheepers (2003) and Desmet and Declercq (2006) did not overlap lexically or semantically. Second, the attachment information is also unlikely to be tied to discourse information (cf. Desmet, De Baecke et al., 2002). More specifically, Scheepers (2003) showed that primes with an adverbial subclause, in which the pronoun referred to one of two NPs in the main clause (e.g., "Die Assistentin verlas den Punktestand$_{masc}$ der Kandidatin$_{fem}$, als dieser$_{masc}$/diese$_{fem}$ . . . [The assistant announced the score of the candidate when this . . .]"), did not prime attachment height in RC-targets. Unlike RCs, adverbial clauses do not attach to an NP in the main clause, but to the VP of the main clause. This suggests that it is not enough for primes and targets to share the same focus structure (i.e., which entity was elaborated upon) or anaphoric binding (i.e., the link between the pronoun and its antecedent), but that they have to share the same syntactic structure in order to obtain attachment priming (see Desmet & Declercq, 2006 for a replication).

These non-syntactic explanations being ruled out, the origin of the RC attachment priming effect most likely has to be situated at the level of syntactic representations. Apparently, the prime sentence activates an abstract mental representation of its syntactic structure, which influences the interpretation of the syntactic structure of the target sentence and hence of the attachment height of the ambiguous pronoun. As a consequence, the target sentence is more likely to be completed with an RC that is attached at the same height as the RC in the prime. In the present study, we want to explore how this syntactic representation looks like.

Pickering and Branigan (1998) have suggested that the representations identified by syntactic priming might be equated with representations assumed in formal linguistics. More specifically, they noticed that most syntactic priming effects that have been observed so far (e.g., priming of actives and passives, and priming of PO- and DO-datives, Bock, 1986; priming of locative to passive *by*-phrases, Bock & Loebell, 1990, Potter & Lombardi, 1998) can be explained by assuming representations at the level of phrase-structure rules (e.g., Frazier & Fodor, 1978). Phrase-structure rules are lexically independent rewrite rules that describe the structure of the sentence in terms of its constituents and the hierarchical relations between them. For example, the rule VP → V NP expresses that a verb phrase consists of a verb followed by an NP. In Pickering and Branigan's model, the choice for, for example, a PO- or DO-dative in the target sentence is driven by the recent activation of either the rule VP → V NP PP (for POs) or the rule VP → V NP NP (for DOs) in the prime sentence.

However, the priming of RC attachment height (Desmet & Declercq, 2006; Scheepers, 2003) cannot be explained by representations at the level of phrase-structure rules, because high and low RC attachments are generated by exactly the same set of rules (e.g., the rules "NP → NP PP," "NP → NP RC," and "PP → prep NP" would suffice to render both constructions). It thus seems that people represent attachment height at a different level than that of phrase-structure rules. Currently, there are two theoretical alternatives on how this representation might look like.

Scheepers (2003) noted that what differs between high- and low-attached RCs is not the phrase-structure rules themselves but the specific order in which the phrase-structure rules are being applied during structure building. For instance, assuming a top-down analysis (e.g., Yngve, 1960; but an analogous rationale holds for a bottom-up analysis), a high-attached RC would yield the sequence "NP → NP RC," "NP → NP PP," "PP → prep NP," whereas a low-attached RC would be analyzed as the sequence "NP → NP PP," "PP → prep NP," "NP → NP RC." Scheepers suggested that priming of RC attachment occurs because people have a procedural memory representation for the exact sequence in which the specific phrase-structure rules are applied during sentence processing.

Desmet and Declercq (2006) formulated an alternative to this account and suggested that a more abstract representation of the structural skeleton of the CNP and the place of RC attachment might be primed. More specifically, they suggested that either the height or location at which the RC is attached to or inserted into the CNP is represented, independent of the specific phrase-structure rule that is inserted, or by extension, that the abstract hierarchical configuration of the full CNP and the attached RC is represented. Such an abstract representation is perfectly conceivable in a Tree Adjoining Grammar (Joshi, Levy, & Takahashi, 1975; Joshi & Schabes, 1997), for example, where the nodes of trees are rewritten as other trees. In such a grammar, the tree representing the RC would be adjoined at a higher point in the tree representation of the CNP in the case of a high-attachment RC than in the case of a low-attachment RC.

At this point, the available results from the RC attachment priming studies that were described above (Desmet & Declercq, 2006; Scheepers, 2003) are compatible with both accounts. The present experiment aimed to discriminate between them. The two views diverge on the point that the attachment information is either necessarily tied to specific phrase-structure rules (Scheepers, 2003) or not (Desmet & Declercq, 2006). Consequently, the accounts make different predictions about whether the attachment height of a certain modifier can prime the attachment height of another modifier into a CNP. For instance, just like an RC, a prepositional phrase (PP) is a modifier of NPs. In a sentence like "The maid of the actress with the white blouse was working in the kitchen," the PP "with the white blouse" can be attached to either of the NPs ("the maid" or "the actress"). However, the attachment of a PP is generated by a different phrase-structure rule (e.g., "NP → NP PP") than the attachment of an RC (e.g., "NP → NP RC"). The account of Desmet and

Declercq (2006) predicts that it does not matter which modifier is attached to the CNP, as long as the height or location of attachment is the same. Therefore, it predicts that the attachment height of a PP primes the attachment height of an RC. The account of Scheepers (2003), on the other hand, predicts that the attachment of a different modifier to the CNP alters the representation of the syntactic structure, because as soon as one phrase-structure rule alters, the full sequence of phrase-structure rules representing the attachment of the modifier to the CNP alters. Therefore, this theory predicts no priming of the attachment height between PPs and RCs.

In the present study, we investigated whether attachment height can be primed between PPs and RCs. As in the preceding studies (Desmet & Declercq, 2006; Scheepers, 2003), we used a sentence completion task. We presented four types of Dutch prime sentence onsets that either ended in a relative pronoun (e.g., "that") or in a preposition followed by a possessive pronoun (e.g., "with his"). Pronouns always unambiguously referred to either the NP1 or the NP2. As such, participants were forced to complete the prime with either an RC or a PP and to attach it either high or low. Target sentence onsets contained an ambiguous relative pronoun, and could thus be completed with a high- as well as a low-attached RC, depending on how the participant would interpret the attachment. In this way, we tested whether the attachment of an RC to one of two possible NPs in the target sentence could be primed by the attachment height of a PP (cross-structural priming) as well as by the attachment height of an RC (within-structural priming). This would then be the first demonstration of a cross-structural priming effect that cannot be captured by phrase-structure rules (cf. the priming of locative to passive *by*-phrases found by Bock and Loebell (1990), and Potter and Lombardi (1998), can still be captured by assuming representations at the level of phrase-structure rules).

It should be noted that the used sentence completion task requires both sentence comprehension (of the sentence onsets) and sentence production (of the completion). So far, it is still unclear whether data obtained within this paradigm (also those of Scheepers, 2003, and Desmet & Declercq, 2006) reflect representations underlying comprehension or production, or both (see also Pickering & Ferreira, 2008). In the present experiment, the presented sentence onsets of primes and targets all contain the CNP (including the potential attachment sites) and the beginning of the modifier (the relative pronoun or the preposition). So, both the attachment sites and the beginning of the to-be-attached segment are presented to the participant. The completion of the target will thus give us insight into how the onset of the sentence was interpreted, but does not entail the production of the syntactic attachment itself. Therefore, we think that in essence this task is about syntactic attachment comprehension rather than about syntactic attachment production. However, to answer this point with certainty, the processes underlying the sentence completion task will have to be investigated in further research. The aim of the present study is to investigate whether the mental representation of attachment height can be captured within phrase-structure rules or whether a more global representation is needed.

Method

Participants

Sixty-eight students from Ghent University participated in exchange for money or course credits. All participants were native Dutch speakers and were unaware of the purpose of the study.

Design and Materials

Target stimuli (see Appendix) were 24 Dutch main clauses that ended in the relative pronoun "die [that/who]" and thus had to be completed with an RC (e.g., "De rechtbank veroordeelde de ontvoerders van de prins die … [The court sentenced the kidnappers of the prince who …]"). The relative pronoun was grammatically compatible with both the NP1 and the NP2 of the main clause. Participants could thus choose to complete the sentence with either a high- or a low-attached RC. NP1 and NP2 always differed in number (either NP1 was singular and NP2 plural or vice versa), so that, as a consequence of the Dutch grammatical rules, the number of the verb in the attached RC would uniquely refer to one of the two NPs. This provided us afterward with an objective, grammatical criterion to code whether the participant completed the sentence with a high- or low-attached RC. Half of the NP1s were plural and half were singular, and the same applied for the NP2s. As animacy has been found to influence attachment (Desmet, Brysbaert, & De Baecke, 2002), the NPs in a target stimulus were always both animate or both inanimate.

Prime stimuli (see Appendix) were Dutch NP constructions of the form "NP1 – van [of] – NP2 – pronoun – …" that had to be completed with an attachment that was determined by the characteristics of the pronoun. Required attachment was manipulated in a 2 × 2 orthogonal design crossing Prime Attachment Height (high vs. low) with Prime Attachment Structure (RC vs. PP). This yielded 24 prime quartets, each consisting of four types of primes, as in (1).

(1a) De vrouw van het schoolhoofd dat …
[The wife$_{\text{non-neuter}}$ of the principal$_{\text{neuter}}$ who$_{\text{neuter}}$ …]
(1b) De vrouw van het schoolhoofd die …
[The wife$_{\text{non-neuter}}$ of the principal$_{\text{neuter}}$ who$_{\text{non-neuter}}$ …]
(1c) De vrouw van het schoolhoofd met zijn …
[The wife of the principal with his …]
(1d) De vrouw van het schoolhoofd met haar …
[The wife of the principal with her …]

RC-primes ended in the relative pronoun "dat [that/who]" (1a), referring to the NP with the definite article "het" (i.e., a neuter, singular NP, like in "het schoolhoofd dat [the principal who]," or a diminutive), or "die [that/who]" (1b), referring to the NP with the definite article "de" (i.e., a non-neuter, singular NP like in "de vrouw die [the woman who]," or a plural NP, like in "de tafels die [the tables that]"), and had to be completed with an

appropriate RC. PP-primes ended in the beginning of a prepositional phrase, consisting of the preposition "met [with]" followed by a possessive pronoun "zijn [his]" (1c), "haar [her]" (1d), or "hun [their]" and had to be completed with an appropriate prepositional phrase. The possessive or relative pronoun in the prime uniquely referred to either NP1 or NP2, forcing participants to complete the sentence with either a high or a low attachment, respectively. As attachment height of the PP or RC in the prime sentences was thus forced by the characteristics of the pronoun, there was no need to control the animacy of the NPs in the prime stimuli, as was the case in the target stimuli. A prime sentence could thus contain two animate NPs, two inanimate NPs, or one animate and one inanimate NP. The NPs in the primes and targets did not overlap lexically or semantically.

Prime type was manipulated within-items and within-participants. Each participant only saw one of the four primes of a quartet; the primes within a quartet were counterbalanced over participants. This rendered four lists, in which a target was preceded by only one of the four primes of a quartet. Each participant saw six instances of each of the four prime types (24 primes in total).

Within a list, targets followed primes immediately. The presentation of the 24 prime-target pairs was interspersed with the presentation of 96 filler sentences, which were structurally and semantically unrelated to the critical stimuli. Fillers were onsets of main clauses that did not contain a CNP, like "Het zou moeten verboden zijn … [It ought to be prohibited …]" or "Intelligentie is het onderwerp van veel discussies onder … [Intelligence is a much debated topic among …]." Each list started with 4 or 5 filler sentences. Prime-target pairs were separated by 2–6 filler sentences.

Procedure

Stimuli were presented as a list on paper. They had to be completed on paper in the order they were listed in. Each stimulus started on a new line and was followed by a dotted line. Participants were asked to complete each sentence in the way that first came to mind.

Results

Completions were rated by a rater who was blind to the conditions. Also, primes and targets were scored separately. All ambiguous cases, which are described in the next paragraph, were double-checked by a second blind rater.

The grammatical features of the pronoun at the end of the prime forced participants to attach the completion to only one of both NPs. However, in 7.41% of the completed primes, the semantics of the completion clearly referred to the NP to which the pronoun did not refer. This was the case in a sentence like "Het neefje van de muzikante dat net optrad, komt met een spaarpotje rond. [The $\text{nephew}_{\text{neuter}}$ of the $\text{musician}_{\text{non-neuter}}$ $\text{who}_{\text{neuter}}$ has just given a performance, is collecting money]," where the semantics of the completed RC refer to the NP2, whereas the grammatical features of the pronoun refer to the NP1. These primes, as well as their corresponding targets, were excluded from the analyses. Besides, 3.00% of the primes were completed in a way that semantically did not uniquely refer to either of the NPs, like in "De vader van het meisje die ziek was. [The father of the girl that was ill.]." In these cases, we cannot be sure that the participant actually meant the completion to refer to the intended NP. These primes, as well as their corresponding targets, were therefore excluded from the analyses. Attachment height of the completion in the target could be inferred from the number of the verb in the attached RC, as the NP1 and NP2 in the target always differed in number. However, in 1.29% of the targets, either the number of the verb did not uniquely refer to either of the NPs, like in "Vandaag verjaren de zussen van de jongen die ik gisteren tegenkwam. [Today is the birthday of the sisters of the boy who I met yesterday.]," or the semantics referred to one NP and the number of the verb to the other one. These ambiguous targets were left out of the analyses. The resulting descriptive statistics are shown in Table 1.

We fitted generalized linear mixed-effects models[1] with the logit link function on the data (see Baayen et al., 2008) using the lme4 package (Bates, Maechler, & Dai, 2008) from R (R development core team, 2008), with Target Attachment Height (high vs. low) as the dependent variable and Participants and Items as crossed random effects. The contribution of the fixed effects of Prime Attachment Height (high vs. low), Prime Attachment Structure (RC vs. PP), and their interaction was tested with likelihood ratio tests with Type II Sum of Squares. Neither Prime Attachment Structure ($\chi^2(1) = 0.002$, $p = .968$) nor the interaction of Prime Attachment Structure and Prime Attachment Height ($\chi^2(1) = 0.05$, $p = .826$) improved the model's fit. Only Prime Attachment Height did ($\chi^2(1) = 10.69$, $p = .001$). Therefore, we refitted the model with Prime Attachment Height as the sole fixed effect. In this model (log-likelihood = –654.3), Prime Attachment Height was a significant predictor of Target Attachment Height: the estimated odds of producing a low attachment RC in the target were 1.62 times higher after a low-attachment prime than after a high-attachment prime (Wald's $Z = 3.34$, $p < .001$).

[1] In psycholinguistics the more traditional (see Raaijmakers, Schrijnemakers, & Gremmen, 1999 for an overview) – but less appropriate, see Baayen, Davidson, and Bates (2008) – analyses of these kinds of data have been the repeated measures 2 × 2 analyses of variance on the means for participants ($F1$) and items ($F2$). We obtained a similar pattern of results with these traditional ANOVAs: Target Attachment Height was influenced by Prime Attachment Height, $F1(1, 67) = 5.94$, $p = .017$; $F2(1, 23) = 14.84$, $p = .001$, but not by Prime Attachment Structure, $Fs < 1$. There was no interaction between Prime Attachment Height and Prime Attachment Structure, $Fs < 1$. Separate analyses on the two prime structure conditions confirmed that the Attachment Height of a PP-prime predicted the Attachment Height of an RC-target, $F1(1, 67) = 3.73$, $p = .058$; $F2(1, 23) = 8.96$, $p = .006$, and so did the Attachment Height of an RC-prime, $F1(1, 67) = 4.17$, $p = .045$; $F2(1, 23) = 5.43$, $p = .029$.

Table 1. Numbers (and relative frequencies in parentheses) of high-attachment (HA) and low-attachment (LA) target completions (rows) by levels of prime type (columns)

	RC-prime		PP-prime	
RC-target	HA	LA	HA	LA
HA	104 (32%)	87 (24%)	111 (30%)	93 (24%)
LA	218 (68%)	271 (76%)	254 (70%)	299 (76%)
Total	322	358	365	392

Separate analyses on the two prime structure conditions confirmed that the Attachment Height of a PP-prime significantly predicted the Attachment Height of an RC-target (log-likelihood = –343.2, Wald's $Z = 2.67$, $p = .008$), and so did the Attachment Height of an RC-prime (log-likelihood = –338.8, Wald's $Z = 2.40$, $p = .016$).

General Discussion

In the present study, we investigated whether the attachment height of a modifier to a CNP can be primed between dissimilar syntactic structures. In a sentence completion experiment, we found that the attachment of an RC to one of two possible NPs in the target sentence could be primed by the attachment height of a PP as well as by the attachment height of an RC. Not only did we thus replicate the finding that the syntactic information of attachment height can be primed *within* the same structure (RC-RC; Desmet & Declercq, 2006; Scheepers, 2003), but we also observed that it can be primed *between* two different structures (PP-RC).

The NPs in the primes and targets did not overlap lexically or semantically and their lexical characteristics were carefully controlled. Therefore, it is highly improbable that the attachment priming effect could be attributed to representations at the lexical level. Also, as discussed in the Introduction, Scheepers (2003) showed that the attachment effect is unlikely to be situated at the discourse level, for instance by focusing one of the NPs through modification. He showed that the attachment height of adverbial subclauses did not prime the attachment height of RCs, even though these adverbial subclauses also focus one of the NPs.

The attachment priming effect is thus most likely due to the activation of a syntactic representation. Scheepers (2003) suggested an explanation in terms of the activation of sequences of phrase-structure rules. However, this account is ruled out by the cross-structural priming effect observed in the present study. The attachments of PPs and of RCs are generated by different phrase-structure rules ("NP → NP PP" vs. "NP → NP RC"). As a consequence, the sequence of phrase-structure rules that represents the attachment of the modifier to the CNP differs between PP-primes and RC-targets.

A viable explanation for the cross-structural priming effect is the suggestion made by Desmet and Declercq (2006). They stated that the RC attachment priming effect could be explained in terms of the activation of a representation of the height or location at which the modifier is attached to or inserted into the CNP, independent of the specific phrase-structure rule that is attached, or by the activation of a representation of the abstract hierarchical configuration of the full CNP. The activation of such a representation could also account for the cross-structural priming effect in the present study.

The configuration of the stimuli in the present study even permits us to further specify this account. Primes and targets differed in their global syntactic structure: primes merely consisted of a CNP (e.g., "De vrouw van het schoolhoofd dat … [The $\text{wife}_{\text{non-neuter}}$ of the $\text{principal}_{\text{neuter}}$ $\text{who}_{\text{neuter}}$ …]"), and as such, the CNP functioned as the subject of the to-be-completed main clause; the CNP in the targets, on the other hand, functioned as the object of the main clause (e.g., "De rechtbank veroordeelde de ontvoerders van de prins die … [The court sentenced the kidnappers of the prince who …]"). The attachment height of a modifier in the subject NP thus primed the attachment height of a modifier in the object NP. This suggests that the attachment priming effect has to be located at or within the level of the CNP. More specifically, either the height or location of the attachment in the CNP or the configuration of the whole CNP must be primed. The global syntactic configuration in which this NP is embedded does not seem to matter. The evidence thus suggests that the structural attachment information that is being primed is more global than phrase-structure rules, but also more local than the representation of the full sentence. On the one hand, this finding is in line with the study of Branigan, Pickering, McLean, and Stewart (2006), who showed that priming of the POs and DOs occurs irrespective of the global structure of the sentence. Crucially, however, the priming of dative structures can still be explained at the level of phrase-structure rules, whereas the priming of attachment height observed in the present study (and in Desmet & Declercq, 2006 and Scheepers, 2003) suggests that more global structures are also represented.

The idea of a phrase-structure independent representation of the attachment height within the CNP is also in line with the results obtained with the Recursive Neural Network of Sturt, Costa, Lombardo, and Frasconi (2003). This experience-based model forms its own representations of the abstract structural features that are relevant for ambiguity resolution and comes up with the representation of the relative positions of different attachment sites in the incremental tree. Most relevant to our study, preliminary results show that the model's experience with RC attachment in a training phase had a reliable effect on its preference for PP attachment in the test phase even though the model had not encountered PP attachment in the training phase. This finding suggests that the effect of cross-structural priming of PP-attachment to RC-attachment that we observed in real sentence processing could be due to the activation of a representation of the height or location at which the RC/PP is inserted in the CNP.

To summarize, in the present study we found that the syntactic information of attachment height can be primed *between* two different structures (PP-RC) and this to the same extent as the priming of attachment height *within* the

same structure (RC-RC). This cross-structural priming effect cannot be explained by representations of the sequence of applied phrase-structure rules (Scheepers, 2003), but it can be accounted for by representations of the height or location at which the modifier is attached to the CNP, or of the abstract hierarchical configuration of the full CNP (Desmet & Declercq, 2006). This study offers the first demonstration of a cross-structural priming effect that cannot be captured by phrase-structure rules.

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Appendix

This appendix contains the experimental stimuli, ordered per prime-target pair. For each pair, version a is the prime sentence onset, and version b is the target sentence onset. The order of the pairs was counterbalanced over the four lists. In the prime sentences, the first and third pronoun are referring to the NP1, and the second and the fourth are referring to the NP2. English translations are given between square brackets.

1a. De vrouw van het schoolhoofd met haar/met zijn/die/dat . . . [The wife of the principal with her/with his/who/who . . .]

1b. De rechtbank veroordeelde de ontvoerders van de prins die . . . [The court sentenced the kidnappers of the prince who . . .]
2a. De tafels van het restaurant met hun/met zijn/die/dat . . . [The tables of the restaurant with their/with its/that/that . . .]
2b. De ontsnapte gek schoot op de kinderen van de buurman die . . . [The escaped fool fired at the children of the neighbor who . . .]
3a. Het broertje van haar beste vriendin met zijn/met haar/dat/die . . . [The brother of her best friend with his/with her/who/who . . .]
3b. Mama verstopte de speelgoedautootjes van de winkel die . . . [Mama hid the toy cars of the shop that . . .]
4a. Het bureau van de assistenten met zijn/met hun/dat/die . . . [The office of the assistants with its/with their/that/that . . .]
4b. Iemand waarschuwde de familie van de kinderen die . . . [Someone warned the family of the children who . . .]
5a. Het neefje van de muzikante met zijn/met haar/dat/die . . . [The nephew of the musician with his/with her/who/who . . .]
5b. De detective volgde al de minnaars van de vrouw die . . . [The detective shadowed all the lovers of the woman who . . .]
6a. Het galabal van de verenigingen met zijn/met hun/dat/die . . . [The grand ball of the societies with its/with their/that/that . . .]
6b. De technicus herstelde de internetkabel van de computers die . . . [The mechanic repaired the internet cable of the computers that . . .]
7a. De echtgenoot van het meisje met zijn/met haar/die/dat . . . [The husband of the girl with his/with her/who/who . . .]
7b. De overheid financiert de onderzoeken van de universiteit die . . . [The government finances the studies of the university that . . .]
8a. De bedden van het ziekenhuis met hun/met zijn/die/dat . . . [The beds of the hospital with their/with its/that/that . . .]
8b. De brandweer redde de twee katten van de oude vrouw die . . . [The fire department saved the two cats of the old lady that/who . . .]
9a. Het zoontje van de buurvrouw met zijn/met haar/dat/die . . . [The son of the woman next door with his/with her/who/who . . .]
9b. Gisteren zag ik de manager van de muzikanten die . . . [Yesterday, I saw the manager of the musicians who . . .]
10a. De computers van het bedrijf met hun/met zijn/die/dat . . . [The computers of the company with their/with its/that/that . . .]
10b. De architect tekende de plannen van de nieuwe school die . . . [The architect drew the plans for the new school that . . .]
11a. De vader van het meisje met zijn/met haar/die/dat . . . [The father of the girl with his/with her/who/who . . .]
11b. De arbeiders staken voor de poorten van de fabriek die . . . [The workers are on strike in front of the gates of the factory that . . .]
12a. Het vliegtuig van de voetballers met zijn/met hun/dat/die . . . [The plane of the football players with its/with their/that/who . . .]
12b. Ik dans graag op de muziek van de jaren negentig die . . . [I love to dance to the music of the nineties that . . .]
13a. Het vriendinnetje van de jongen met haar/met zijn/dat/die . . . [The girlfriend of the boy with her/with his/who/who . . .]
13b. Bush negeert de nabestaanden van de soldaat die . . . [Bush disregards the relatives of the soldier who . . .]
14a. Het hotel van de rijke vrouw met zijn/met haar/dat/die . . . [The hotel of the rich woman with its/with her/that/who . . .]
14b. Vandaag verjaren de zussen van de jongen die . . . [Today is the birthday of the sisters of the boy who . . .]
15a. De verpleegster van het oude mannetje met haar/met zijn/die/dat . . . [The nurse of the old man with her/with his/who/who . . .]
15b. De geleerde bestudeerde de architectuur van de oude gebouwen die . . . [The scholar studied the architecture of the old buildings that . . .]
16a. De matrozen van het schip met hun/met zijn/die/dat . . . [The sailors of the ship with their/with its/who/that . . .]
16b. Isabelle ziet graag de standbeelden van de kathedraal die . . . [Isabelle likes the statues of the cathedral that . . .]
17a. De kinderen van het dagverblijf met hun/met zijn/die/dat . . . [The children of the day-care center with their/with its/who/that . . .]
17b. Toeristen bezoeken de musea in de stad die . . . [Tourists visit the museums of the city that . . .]
18a. De moeder van het gezin met haar/met zijn/die/dat . . . [The mother of the family with her/with its/who/that . . .]
18b. In de herfst vallen de bladeren van de boom die . . . [In autumn the leaves of the tree that . . . fall off.]
19a. Het vriendje van de verkoopster met zijn/met haar/dat/die . . . [The boyfriend of the saleswoman with his/with her/who/who . . .]
19b. Jan verwijderde de achterzetels van de auto die . . . [Jan removed the back seats of the car that . . .]
20a. De attracties van het pretpark met hun/met zijn/die/dat . . . [The attractions of the amusement park with their/with its/that/that . . .]
20b. De getuige is de beste vriend van de verloofden die . . . [The witness is the best friend of the fiances who . . .]
21a. Het zusje van de puber met haar/met zijn/dat/die . . . [The sister of the adolescent with her/with his/who/who . . .]

21b. Er lag bloed op de vloer van de kamers die . . . [There was blood on the floor of the rooms that . . .]
22a. Het opperhoofd van de indianen met zijn/met hun/dat/die . . . [The chief of the Indians with his/with their/who/who . . .]
22b. De welzijnswerker begroette de verpleegster van de bejaarden die . . . [The social worker greeted the nurse of the elderly who . . .]
23a. Het huis van de actrice met zijn/met haar/dat/die . . . [The house of the actress with its/with her/that/who . . .]
23b. Klaas ontmoette de bazin van de bediendes die . . . [Klaas met the boss of the employees who . . .]
24a. De zus van het jongentje met haar/met zijn/die/dat . . . [The sister of the boy with her/with his/who/who . . .]
24b. De meid kuiste de kamer van de twee broers die . . . [The maid cleaned the room of the two brothers that/who . . .]

