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How specific are linguistic structures? Mathematical priming on relative clause attachment in French

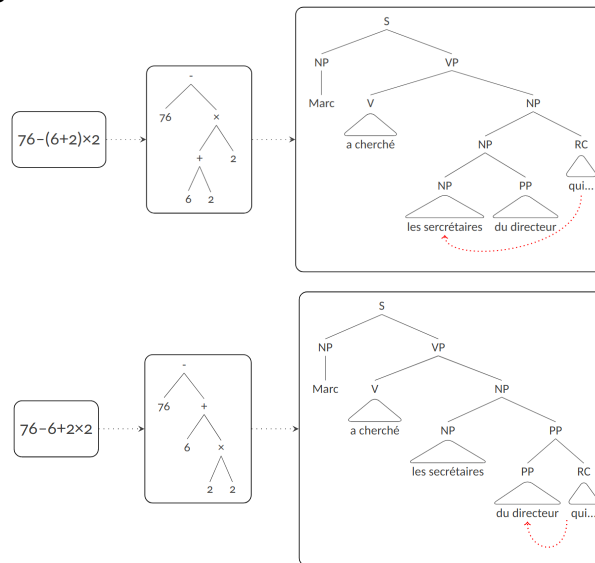
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The specificity of linguistic structures has been a central question in research related to questions on language universals and learnability. Scheepers et al. (2011) found that calculations like $76-(6+2)\times 2$ vs. $76-6+2\times 2$ respectively correspond to high and low attachment relative clause constructions. We report results from two production experiments further exploring the nature of mathematical priming on language. Contrary to Scheepers et al. (2011) and other previous studies, our results rather support relative clause attachment as association to thematic domains, as suggested for example by construal theory.

1 Introduction

The specificity of linguistic structures has been a central question in research related to questions on language universals and learnability. This question is still under debate (see Scheepers et al., 2019 for a review). Scheepers et al. (2011) suggested that calculations like $76-(6+2)\times 2$ structurally resemble a high-attachment RC construction (*[[the friend of a colleague] who lived in Spain]*) whereas calculations like $76-6+2\times 2$ are more similar to a low-attachment RC construction (*[[the friend of [a colleague who lived in Spain]]]*). This also applies for French as illustrated in Figure 1.

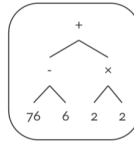
Figure 1. Calculations and relative clause attachment



Using a syntactic priming task, Scheepers et al. (2011) found that solving calculations like $76-(6+2)\times 2$ vs. $76-6+2\times 2$ (Figure 1) influenced high versus low relative clause (RC) attachment preferences in subsequently presented English sentences that participants had to complete (e.g. *The tourist guide mentioned the bells of the church that...*).

Although mathematical priming effects have been found based on this method, replicability issues are regularly raised. Hedier et al. (2020) and Hedier (2020) found that the calculation corresponding to low attachment was not correct. Indeed, for the calculation $76-6+2\times 2$, participants would rather start with $76-6$, calculate 2×2 , and then subtract the latter result from the first, leading to a different representation, as illustrated in Figure 2.

Figure 2. Real representation for $76-6+2\times 2$ (Hedier, 2020)



According to the authors, the correct calculation should be $76-(6+2\times 2)$. Therefore, we used the new calculation for low attachment from Hedier et al. (2020) in experiment 1 in French. Results from the first experiment suggest that priming may not be structural but based on associations to thematic domains. We test predictions for more adequate calculations in experiment 2 for high and low attachment primes.

2 Experiment 1 One variable was manipulated: prime (low vs. high). Primes consisted in calculations whose structure was equivalent to either that of a low attachment or of a high attachment of a RC. Items (N=12) were preceded by two structurally similar calculations, and consisted of structurally ambiguous target sentences containing complex NPs of the form *NP1 of NP2*, half of them singular-plural, half plural-singular, followed by the relativizer “qui” (Table 1). We used non-perceptual verbs in the main clause so as to avoid pseudo-RCs (Grillo & Costa, 2014), which have a different syntactic structure (Hedier et al. 2020).

Table 1. Example of two items in all conditions

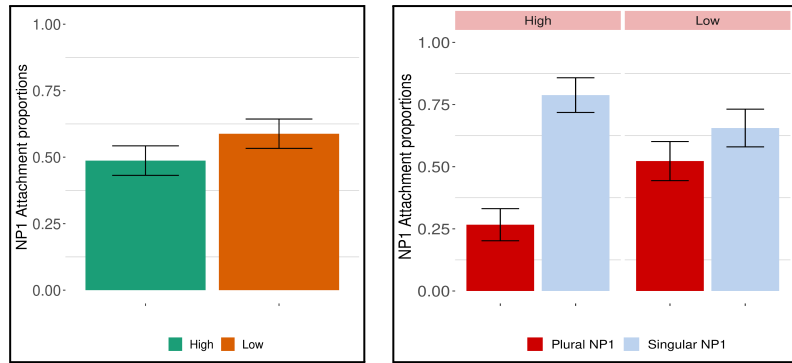
Item	NP1	Prime	Sentence
1	Plural	High	$76-(6+2)\times 2=$
		Low	$76-(6+2\times 2)=$
2	Singular	High	$8 - (6 - 2) / 2 =$
		Low	$8 - (6 - 2 / 2) =$

2.1 Prediction If shared structural representations between mathematics and language exist that trigger priming (Scheepers et al., 2011), high attachment calculations should prime RC high attachment, and low attachment calculations should prime RC low attachment.

2.2 Procedure Inspired by Scheepers et al. (2019), participants were reminded before the experiment of the arithmetic operator-precedence rules. Then, they solved calculations, read and continued sentences in writing (see Table 1). Eighty native speakers of French (recruited on Prolific) participated. We present the results from monolingual participants who correctly answered the prime calculations in the critical trials (N=618 observations).

2.3 Results As seen in Figure 3 (left), contrary to our expectations, Bayesian analyses showed that after a low calculation prime, continuations referred more to high attachment than low attachment ($\beta=-0.53$, CrI[-1.47,0.36], $P(\beta)>0=0.88$). In post hoc analyses, taking number marking into account (Figure 3, right) we found an interaction between NP1 number and prime ($\beta=2.69$, CrI[0.30,5.19], $P(\beta)>0=0.99$), meaning that there was a higher proportion of high attachment continuations with a singular NP1 than with a plural NP1, in the high prime condition. The preference for high attachment with singular NP1 persisted to a lower degree after low attachment calculations.

Figure 3. Results from Experiment 1



2.4 Discussion Calculations did not prime the expected structure of RC attachment and, moreover, we found a strong interaction with number marking. Reanalyses of previous experiments with different materials and participants in French showed the same pattern regarding NP1 number which seems thus to be a robust effect. We suggest that the calculations primed RC construal to thematic domains (TD) as it has been suggested in *Construal Theory* (Frazier & Clifton, 1997, see also Keller, 1995, or Crysmann, 2005, for corresponding analyses in HPSG). According to construal theory, RCs (as other non-primary relations) are associated to a thematic domain in a first step (Figure 4). The antecedent of the RC is then chosen within the thematic domain based on a variety of factors (e.g. number). Priming of association to thematic domains could lead to the observed effects with our “high attachment” calculations priming a thematic domain above the complex NP (with a free choice of antecedents based on non-structural factors) and the “low attachment” calculations priming a thematic domain defined by NP1 (Table 2). We tested the robustness of thematic domain priming with the adequate calculations experiment 2. If shared representations triggering thematic domain priming do exist, the high attachment calculations should prime RC high attachment, and the low attachment calculations should prime RC low attachment (Table 2, Primes 2 and 3).

Figure 4. Association to thematic domains

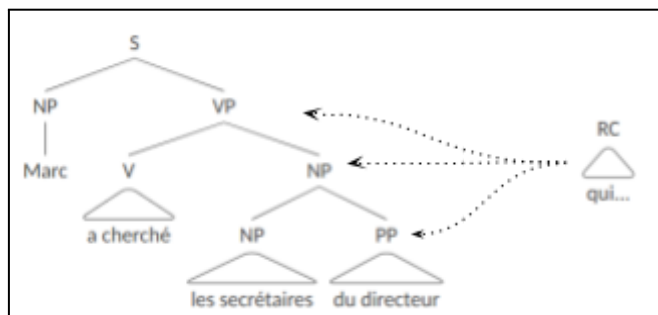


Table 2. Nature of priming for the calculations

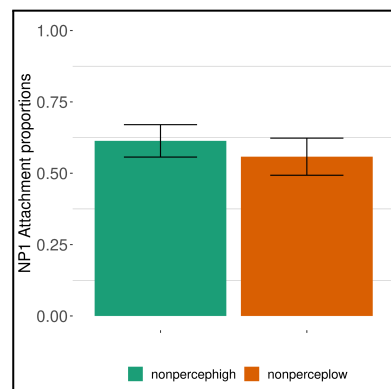
Prime	Calculation	Structural Priming	Thematic Domain Priming
1	76-(6+2)×2	High attachment (NP1)	Thematic domain defined by the main verb (NP1 or NP2 equally accessible)
2	76-(6+2×2)	Low attachment (NP2)	Thematic domain: Complex NP, defined by NP1, so high attachment (NP1)
3	76-6+(2×2)	Low attachment (NP2)	Thematic domain: Last NP, so low attachment (NP2)

3 Experiment 2

3.1 Design & procedure Design and procedure are the same as Experiment 1 except that the calculations were different (primes 2 and 3 in table 1). We present the results from participants who correctly answered the prime calculations (N=506 observations).

3.2 Results & Conclusion As seen in Figure 5, continuations referred more to high attachment than low attachment after a high attachment prime ($\beta=0.57$, CrI[-0.6,1.7], $P(\beta)>0=0.84$). Our results support the hypothesis of shared representations between mathematics and language. However, it seems that structural priming may not be at stake here, but rather thematic domain priming, suggesting that relative clauses as non-primary relations are associated to a thematic domain. This would explain replicability issues from previous studies, especially in French since the calculations were rather structural and not linked to thematic domain (see Hedier et al., 2020 for the calculations). A better analysis of the number effect, especially regarding the semantic particularity of singulars, is also necessary to understand the nature of priming. Finally, our results support relative clause attachment as association to thematic domains, as suggested by construal theory.

Figure 5. Results from Experiment 2



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