Cross-domain priming from mathematics to relative-clause attachment: A visual-world study in French

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Abstract

Human language processing must rely on a certain degree of abstraction, as we can produce and understand sentences that we have never produced or heard before. One way to establish abstraction in syntactic processing is by investigating structural priming. Structural priming is defined as the tendency to repeat aspects of syntactic structure from one trial to the next (see, e.g., Pickering & Ferreira, 2008). For example, after producing/understanding a double object sentence such as in [1], language users may find easier the production / comprehension of another sentence with the same structure as in [2] (Bock, 1986; Pickering & Branigan, 1998).

[1] Peter read the girl a book.
[2] Mary gave the dog a bone.

Thus, structural priming is efficient within a domain, that is to say the linguistic domain. But does priming still work across different domains?
In line with Scheepers et al. (2011), we decided to look at cross-domain structural priming from mathematical expressions to linguistic structures, particularly relative clause attachment.

Relative clause attachment : short story

[3] Algúien disparó contra **la criada** de **la actriz** [que estava en el balcón].
Low attachment
High attachment

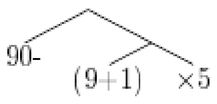
*Someone shot **the maid** of **the actress** [that was standing on the balcony]*
Low attachment
High attachment Cuetos & Mitchell (1988)

Several factors can explain relative clause attachment :
- anaphoric resolution (Hemforth et al, 2000)
- length (Hemforth et al, 2015)
- prosody (Fodor, 1998a;1998b;2002)
- syntactical (pseudo-relatives, e.g., Grillo & Costa, 2014)

Independent of these factors, is it possible to force the relative clause attachment ?

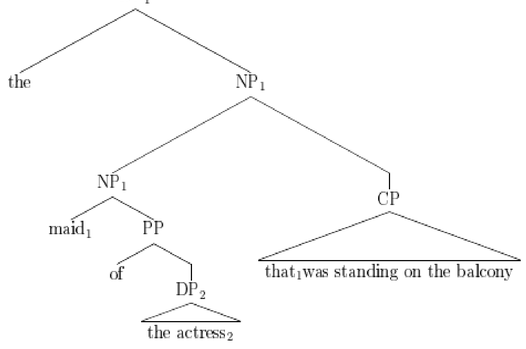
Relative clause attachment & mathematics

Mathematical expression with brackets

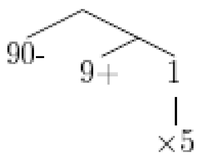


PRIMING

High attachment relative clause

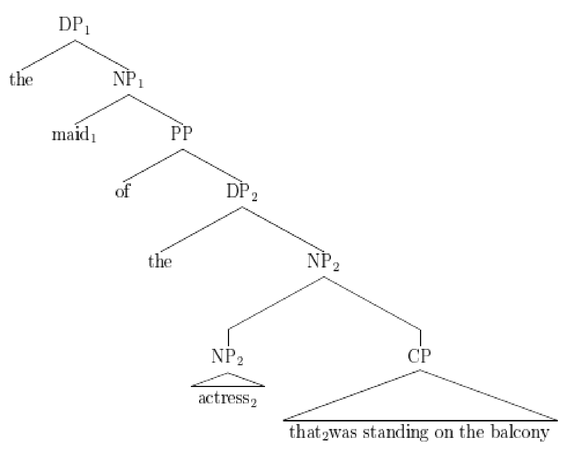


Mathematical expression without brackets



PRIMING

Low attachment relative clause



Previous offline experiments : Scheepers et al. (2011)

1. Experiment 1

- Completion tasks using a paper-and-pencil questionnaire
- 3 groups (mathematics, business, psychology)
- Materials : 8 items per condition, 51 fillers

CATEGORIE	ITEM
High attachment equation	90-(5+15)/15
Low attachment equation	90-5+15/15
Baseline equation	5+15
Sentence	The tourist guide mentioned the bells of the church that…

- Results :

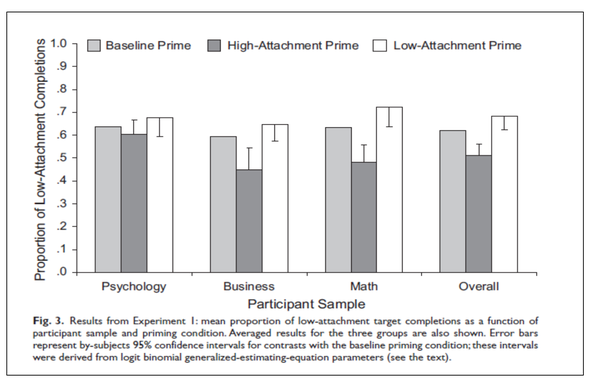


Fig. 3. Results from Experiment 1: mean proportion of low-attachment target completions as a function of participant sample and priming condition. Averaged results for the three groups are also shown. Error bars represent by-subjects 95% confidence intervals for contrasts with the baseline priming condition; these intervals were derived from logit binomial generalized-estimating-equation parameters (see the text).

2. Experiment 2

- Same as experiment 1
- Participants in psychology
- Materials : the same with redundant brackets, like 90-((5+15)/5) or 90-5+(15/5)

- Results :

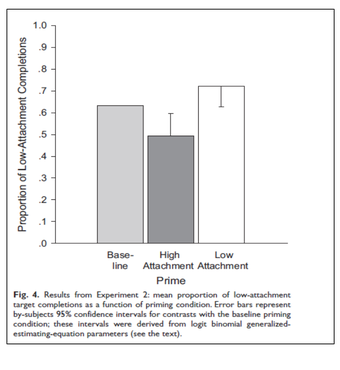


Fig. 4. Results from Experiment 2: mean proportion of low-attachment target completions as a function of priming condition. Error bars represent by-subjects 95% confidence intervals for contrasts with the baseline priming condition; these intervals were derived from logit binomial generalized-estimating-equation parameters (see the text).

Our experiment : online visual study in French

1. Participants

- 36 French native speakers, living in Paris

2. Material

- 30 items : pairs of equations & pictures with spoken sentences (ambiguous relatives)
- 2 conditions : high attachment (*90-(9+1)*5*) & low attachment (*90-9+1*5*
- 56 fillers (equations & pictures with spoken sentences)
- Pictures composed of 6 objects/characters : NP1 referent, NP2 referent, NP1-related target object, NP2-related target object and two distractors

3. Procedure

- Eye-Tracking with visual world paradigm
- Participants had to solve the equation first and then had to look at the picture and listen to the sentence, see Figure (1)
- Pretest (*1+2*3=?*) in order to constitute 2 groups : 18 participants knowing the priority rules (Group 1) and 18 participants ignoring the priority rules (Group 2)

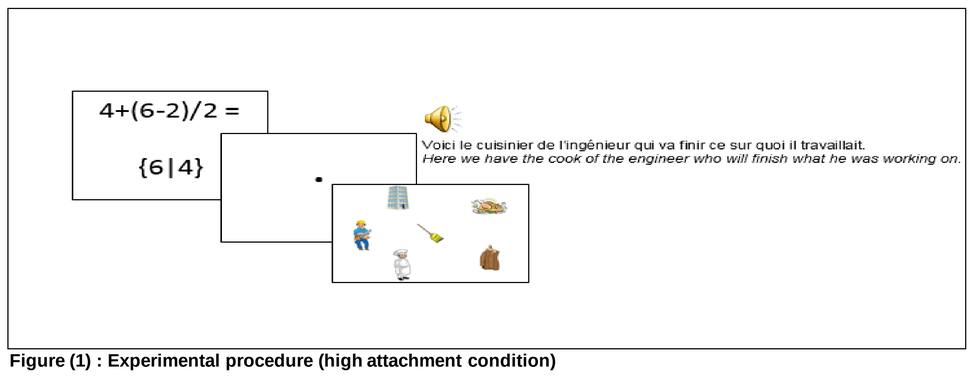


Figure (1) : Experimental procedure (high attachment condition)

4. Hypothesis

If mathematical domain and linguistic domain share aspects of syntactic structure at a high level of abstraction :
- Participants should be looking at the NP1-related target object after high- rather than low-attachment prime equations when they listen to the ambiguous relative.
- Participants should be looking at the NP2-related target object after low- rather than high-attachment prime equations when they listen to the ambiguous relative.
- This should work mainly for Group 1.

5. Results

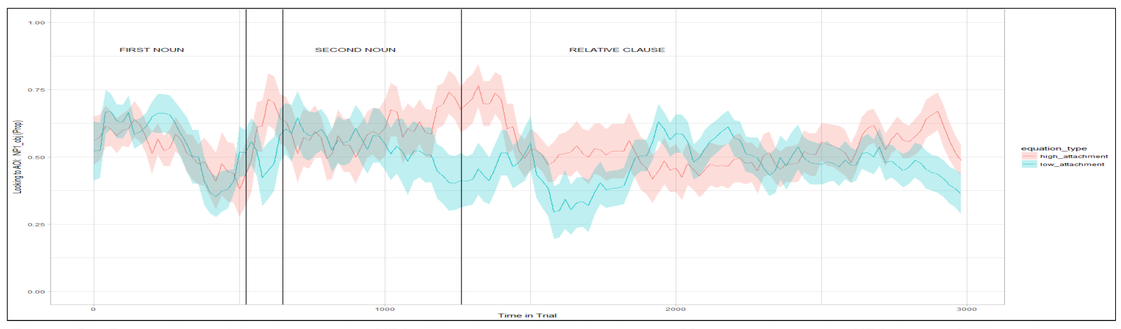


Figure (2) : Proportions of fixations on the NP1 object (roasted chicken) every 20ms starting at the NP1 (group 1)

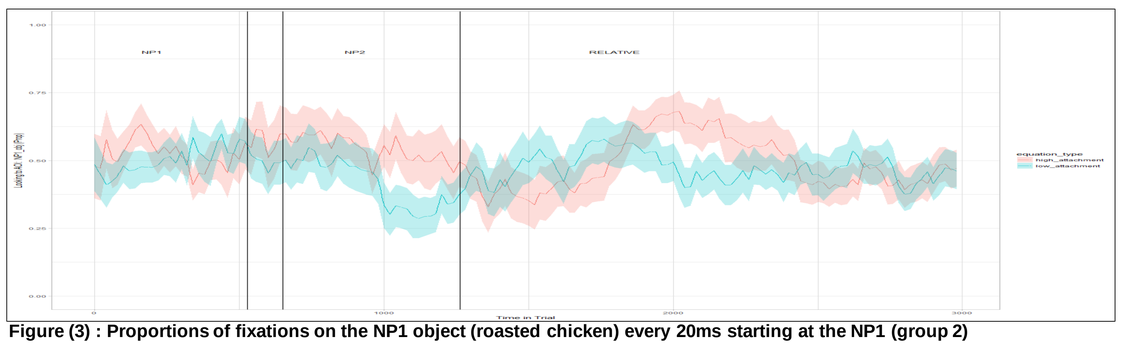


Figure (3) : Proportions of fixations on the NP1 object (roasted chicken) every 20ms starting at the NP1 (group 2)

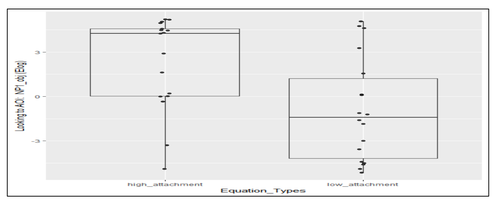


Figure (4a): Logits for looks to NP1_object (roasted chicken) bw. 1200-1380ms (Group 1)

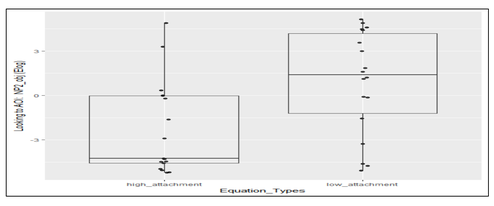


Figure (4b): Logits for looks to NP2_object (building) bw. 1200-1380ms (Group 1)

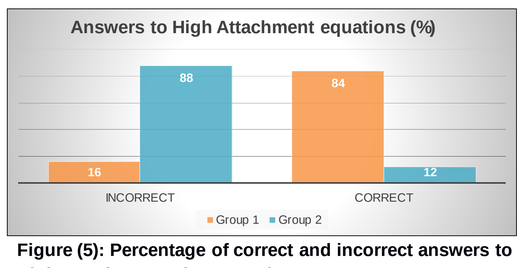


Figure (5): Percentage of correct and incorrect answers to High Attachment prime equations

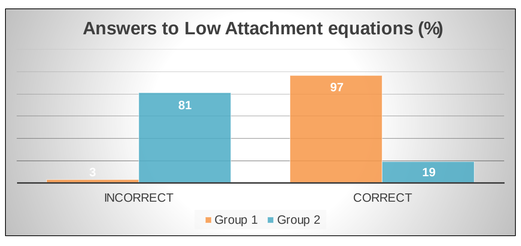


Figure (6): Percentage of correct and incorrect answers to Low Attachment prime equations

Conclusion

- In line with Scheepers et al. (2011), our experiment suggests that mathematics and language share aspects of syntactic structure at a very high level of abstraction.
- Importantly, we can see this cross-domain structural priming in direct processing.
- Again, mathematically less adept participants did not seem to be influenced by this mathematical priming.
- Finally, for mathematically skilled participants (Group 1), our experiment appears to indicate that mathematical priming influences the very earliest stages of integrating a relative clause into the prior sentence context.

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