Mathematical to language priming: New evidence from French

Antoine Hedier, Céliné Pozniak, Barbara Hemforth (Université de Paris, LLF-CNRS)
antoinehdr@gmx.fr

The role of common representations or operations between language and mathematics still remains under discussion to this day. A paradigm first proposed by Scheepers et al. (2011)[1] was to use mathematical equations as a prime and attachment ambiguities as a target, the only common similarity being the structure. Priming effects have been shown based on this method (e.g. see Scheepers, Galkina, Shtyrov, and Myachykov (2019)[2]), but reproducibility issues are regularly raised by researchers (unfortunately usually not published). We here report our analysis for two mathematical to language priming experiments in French where prime exposition lead to different results.

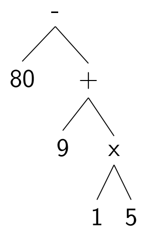
The first experiment (28 items, 36 part.) tested high and low attachment priming of relative clauses (RCs) (coded as h:1, l:0) by mathematical equations, high vs. low priming (h:-1, l:1) and stative vs. perception verbs (s:1, p:-1) (table 1). Participants had to solve a given equation and then complete an unfinished sentence. Equations were of the same format as Scheepers et al. (2011), resembling either a low or high RC attachment structure. Sentence preambles consisted of a proper noun, a verb, a complex noun-phrase (NP) and the word "qui" that forces a RC. NPs within the complex noun phrase differed in number so that the attachment of the RC intended by participants could be determined by number marking on the verb. We included perception verbs because they can lead to a different type of structure, the pseudo-relative (PR) in French, which resembles a small clause interpretation with only the first NP as a possible antecedent of the relative pronoun (fig 5). Although this structure is always ambiguous between an RC and a PR reading, PRs have been shown to be preferred over RCs (Pozniak, Hemforth, Haendler, Santi, and Grillo (2019)[3]). No or smaller priming effects were expected for PRs. **For the second Experiment** (20 items, 36 part.), we only kept stative verbs and high vs. low mathematical priming (table 2). We modified the format of the equation using redundant parentheses (as Scheepers et al. (2011), Exp2) and simplified equations.

Results: For this paper, we only included participants in the analyses who solved more than two-thirds of the equations correctly (Exp1:14, Exp2:22; no priming effects were observed for low-performing participants compatible with earlier work). We also distinguished fast and slow resolution of equations by median split on a trial basis (fast:-1, slow: 1). Bayesian analyses (BRMS package by Bürkner (2018)[4] , binomial, weakly informative prior, 4 chains, 3000 iterations per chain) showed priming effects only for slow calculations (3-way interactions prime*verb*equation-time in Exp1, $\hat{\beta}$ =-0.66, 95% CrI=[-1.47, -0.03], P(β)<0=0.98,2-way interaction prime*equation-time for Exp2, $\hat{\beta}$ =-0.26, 95% CrI=[-0.62, 0.08], P(β)<0=0.93). In Exp1, surprisingly, the high attachment or PR interpretation in the perception verb condition was primed most by a low attachment prime. In Exp2, high attachment was primed by high attachment primes as expected. Both experiments suggest that within the mathematically skilled group, only if the time to solve an equation (prime exposition) is consequent enough, we observe a priming effect (fig 3 & 4).

Discussion: Our results rely on fairly small numbers of participants in the relevant conditions and have therefore be to be taken with a grain of salt. The surprising priming effect for the PR interpretation with low attachment priming in the perception verb condition in Exp1 might be explained by the fact that participants have to resolve the low attachment equations as (80-9) + (1*5) to arrive at the correct result (fig 2). This does not correspond to the representation typically given in the mathematical priming literature (fig 1), which does actually not give the expected result for 80-9+1*5=76. The structure in (fig 2) may be more in line with a small clause (PR) structure than a low attachment structure, which could explain the unexpected priming effect. Taken together, these experiments highlight problems with current paradigms: participants have to be skillful in mathematics but not too high-performing because otherwise they will solve equations too rapidly, thus reducing their exposure to the prime. Also, the equations traditionally used in the literature to represent low relative clause attachments may not be fully adequate.

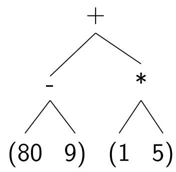
Stative verbs	high priming: 80-(9+1)*5	Carl a connu l'agent des chanteurs qui ... Carl knew the manager of the singers that ...
Stative verbs	low priming: 80-9+1*5	Carl a connu l'agent des chanteurs qui ... Carl knew the manager of the singers that ...
Perception verbs	high priming: 80-(9+1)*5	Carl a vu l'agent des chanteurs qui ... Carl saw the manager of the singers that ...
Perception verbs	low priming: 80-9+1*5	Carl a vu l'agent des chanteurs qui ... Carl saw the manager of the singers that ...

Table 1: Experiment 1 Design



80-(9+(1*5)) = 66

Figure 1: Low attachment prime structure representation following Scheepers & al.(2011)



(80-9)+(1*5) = 76

Figure 2: Adequate low attachment prime structure representation following our interpretation

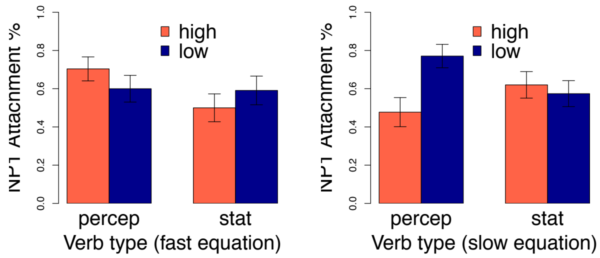


Figure 3: Verb Type, median-split by quickness in equations within the mathematically skilled group. (experiment 1)

high priming: 80-((2+3)*4)	Carl a connu l'agent des chanteurs qui ... Carl knew the manager of the singers that ...
low priming: 80-2+(3*4)	Carl a connu l'agent des chanteurs qui ... Carl knew the manager of the singers that ...

Table 2: Experiment 2 Design

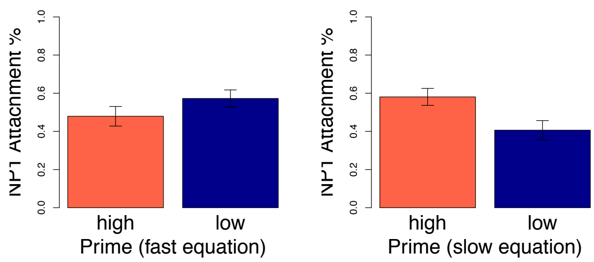


Figure 4: Prime, median-split by quickness in equations within the mathematically skilled group. (experiment 2)

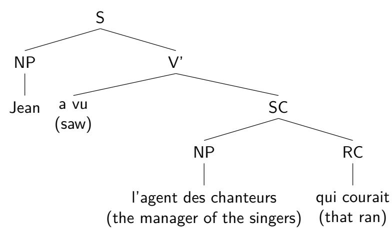


Figure 5: Pseudo-relative