Mathematical priming effect with different linguistic structures.

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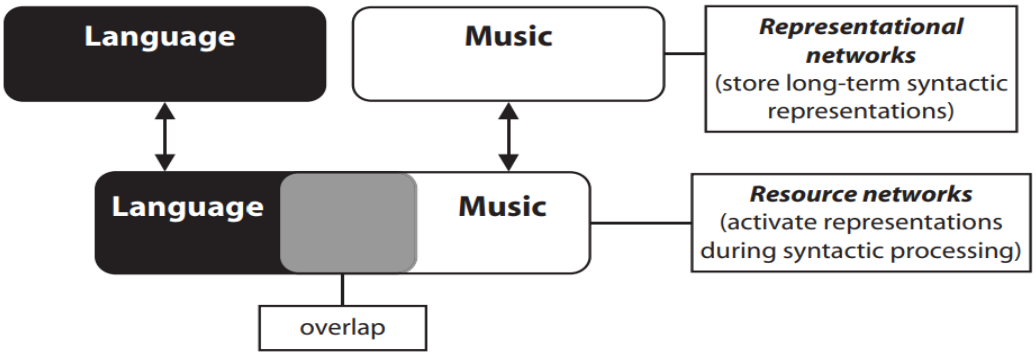
Introduction

The human language needs abstract structures to process and produce sentences that have never existed before. Other cognitive domains such as music or mathematics also relies on the same need for abstract structures. One question that remains unanswered is how unique and hermetic each cognitive domains are from both a behavioral and neuroscientific point of view. Do these domains share the same representations (structures & operations) and/or the same processing capacities (shared brain resources, i.e. same neural pathways, overlap in brain areas)? Two major theories were developed to answer such query: the *Sharing of structure building resources* addressed the question of common representations and the *Sharing of processing capacity* addressed the question of mutual cognitive resources.

Patel (2003), in favor of the same representations, proposed the *Shared syntactic resource hypothesis*. From the idea that both music and language need to integrate smaller and distinct units within a higher structure, they both demand syntactic rules for processing. Those rules may be specific to their domain, but their underlying foundation might rely on the same representation. Patel (2010) later sharpens his theory by saying that representation (long term memory) between language and music are separated but the active syntactic processing of those two can overlap in the resource networks (short-term memory involved in the parsing).



Kljajević et al. (2010), in favor of the same processing capacities, suggests that different cognitive domains like language and music might share the same syntactic working memory resources (processing relevant integration within sequences of structurally dependent elements). This theory tolerates both shared representations or absence of such. In the first case, underlying representation would be common for many cognitive domains; in the second case, a connection would be established across domains because it just shares resources: one operation for a given cognitive domain would impact the result of the next operation for an other cognitive domain. Each operation leaves a trace (bias) for the upcoming operation.

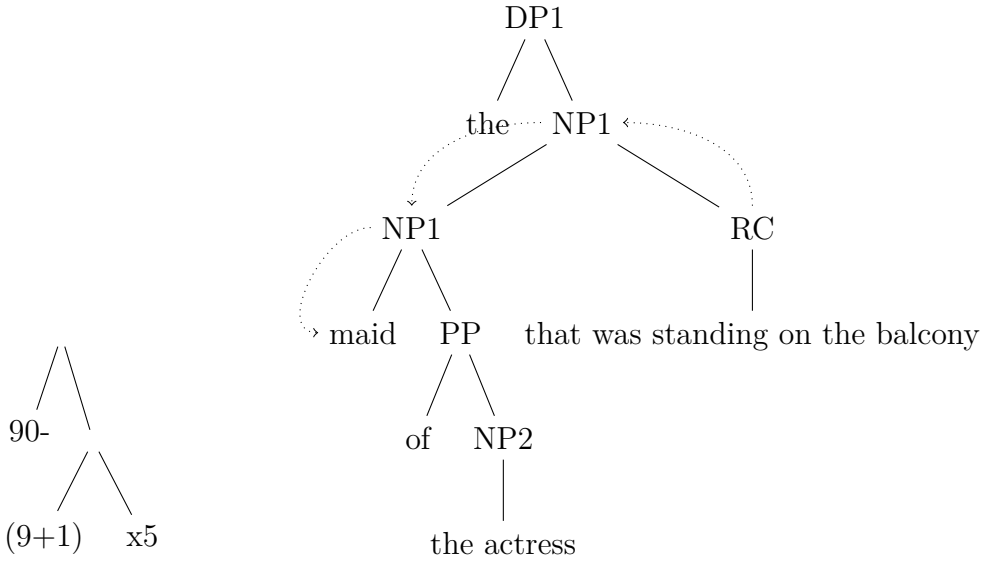
On more practical concerns, the brain imaging field failed to provide relevant results concerning the *Sharing of processing capacity*. Rogalsky, Rong, Saberi, and Hickok (2011) did not find overlap for language and music perception using fMRI imaging. They suggest that hierarchical processing (parsing) for music and speech use different cortical networks and previous claims for common brain areas are based on unsuitable design that stimulates higher-order cognitive process such as working memory or cognitive control, which are both present in speech and music. However, it is important to point out that the material used for music were piano melodies and it did not include sung speech whatsoever. Concerning mathematics, a strict separation have been suggested by Amalric and Dehaene (2016) for cross domain effect between language and mathematics. They found out that brain regions that were involved during mathematical thinking did not overlap with language areas. They concluded that mathematics and language did not rely on the same resources. Yet, their experimental design seems to emphasize mainly on the representation and storage of mathematical knowledge compared to more common knowledge. This study was, therefore, mostly related to long-term memory and semantics, it does not exclude interaction related to short-term memory and syntax.

Despite the lack of results from brain imaging, evidence from behavioral tasks heavily suggests that cross domain effect are observed with both mathematics and music to

language. I will talk about the mathematical priming evidence found by Scheepers et al. (2011) later and will present evidence on music for now. Fedorenko, Patel, Casasanto, Winawer, and Gibson (2009) searched for common cognitive resources for structural processing between language and music. They manipulated within sung materials linguistic and musical complexity: subject/object extraction and in/out-of-key note. She found out that an interaction between linguistic and musical complexity is present: the difference between subject/object extraction was higher in the out-of-key condition. Her finding strongly indicates that language and music are heavily connected, at least at a behavorial level.

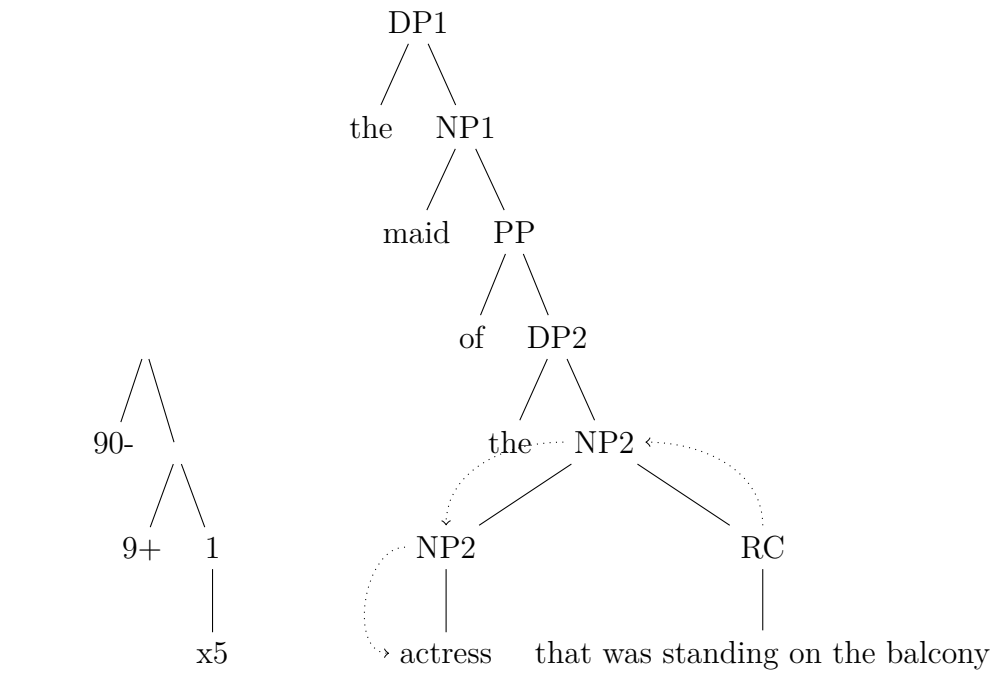
Such priming/interaction effect are yet never been tested on a specific topic, implicit causality (IC), which we will test in this paper. IC is, as Van Den Hoven and Ferstl (2018) described, a disambiguation phenomenon for incoming element (parser-wise): "Some interpersonal verbs show a bias in the proportion of times their subject and object arguments are rementioned in a sample of explanations for the eventuality the verb describes. This bias is known as Implicit Causality." Those verbs impute enough IC on a pragmatic/discourse level that the parsing of incoming elements is biased. Experiments that involves IC are influenced by many factors, but their conclusion in this paper is that lexical semantics have a stronger influence than world knowledge or discourse context. Those IC verbs impute a "coherent structure", it generates expectations and discourse bias from which the interlocutor draws inferences, it induces a causal relationship. Such expectations influence the syntactic parser as Rohde, Levy, and Kehler (2011) showed using a completion & a self-paced-reading experiment. They showed in the completion experiment that IC verbs that have an object bias for continuation are more subject to explanation, and overall, explanations refers more to the object (even from non-IC verbs). Their explanation is that IC verbs (object-biased) impute causality to the very next entity which creates a strong bias mentioning that entity again for ensuing explanation (the reader asks himself "why?").

Relative clauses (RC) can be ambiguous if they follow a complex denominal phrase (DP). A DP is composed of two nominal phrases (NP), one is embedded in the other via a prepositional phrase (PP). The RC can have a non-local indexing referring to the first NP (high attachment) or have a local indexing referring to the second NP (low attachment). In fact Rohde et al. (2011) and Fedorenko et al. (2009) used RC ambiguity-attachment for their experimental design. Scheepers et al. (2011) also used RC ambiguity-attachment for their mathematical priming study. They found structural similarities between an equation and a complex DP.



High-Attachment-prompt *High Attachment: Sentence*

In the high attachment case, the "x5" applies to the operation of "9+1" which correlates with the structure of a non-local RC: "+1" is the embedded NP2 within the NP1, "9", and "x5" is the RC that applies to NP1.



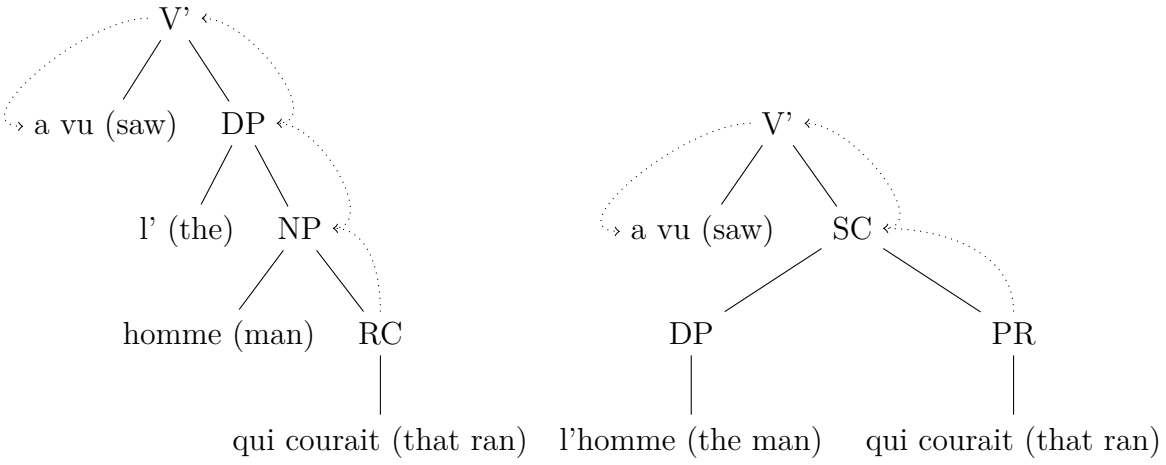
Low Attachment promt *Low Attachment: Sentence*

In the low attachment case, the "x5" only applies to "1". This simple operation shares similarities with the structure of a local RC: "x5", the RC, only applies to "1", the NP2. The RC is embedded in the NP2 which is himself embedded in NP1, "9".

Such trees illustrate that at an abstract level, mathematical and syntax structure share similarities between their structure. However, specific operations and the use of parentheses makes mathematical equation non-ambiguous whereas "the maid of the actress that was standing on the balcony" can have two interpretations. They tested their findings using a completion experiment, if equations could impact RC attachment (mathematical priming). They found a priming effect from mathematics to language, high-attachment-prompt yield more non-local RC and low-attachment-prompt yield more local RC. They also found a more proeminent interaction with mathematically-skilled participants. This may be due to the artificial complexity of equations, the first obligatory operation at the right in the low-attachment-prompt in only indicated by the multiplication sign. The use of redundant parentheses by Pozniak, Hemforth, and Scheepers (2018) showed less disparities between non and mathematically-skilled participants, she also gave

more evidence for mathematical priming with online data in an eye-tracking study.

To test if this mathematical priming effect is indeed due to similarities between structures, we will also test in this paper whether we still observe low and high attachment/prompt correlations with an other type of structure, the pseudo-relative (PR).



Because perceptual verbs can introduce both events or entities, there is an ambiguity whether the following element that comes after "qui" is a PR or a RC. To contrast with such verbs, we can use stative verbs that exclusively introduce entities. As we can see, the RC in embedded within the DP while the PR stands in a sisterhood relation with the DP, it never applies/modifies the DP. The RC is selected by the noun while the PR is selected by the verb. These structures are relatively simpler than relative clauses because of their structural and interpretive simplicity. To account for this facility, Grillo and Costa (2014) proposed the *PR-first Hypothesis*: PRs are easier to parse than RCs for structural, semantic and pragmatic reasons. Because they are easier to parse, they should be preferred by the parser. So, for French perceptual verbs, there is an ambiguity whether the incoming element is a RC or a PR, but the *PR-first Hypothesis* biases the parser to interpret more frequently the incoming element as a PR. As the examples suggested, PRs are available in French but not in English.

Experiments presented here investigate RC attachment preferences for different verbs

which bias the parser on a discourse level or suggest an other type of structure. It also continues the work on mathematical to language priming by indirectly suggesting an other type of structure that should not be subject to priming.

Experiment 1

This experiment aimed to replicate the completion experiment conducted by Rohde et al. (2011). Participants were asked to complete a sentence containing a complex DP (one NP embedded within a NP) in object position followed by "who". Therefore, they were forced to produce a RC that could either have a low (local) or high attachment (non-local), the only varying condition was the verb.

NON-IC-prompt: John babysits the children of the musician who ...

IC-prompt: John detests the children of the musician who ...

They found that IC verbs yield significantly more high attachments than non-biased verbs. Their explanation is that IC verbs impute/carry enough causality to force the participant to explain such causality for the object, and thus high attachment rises. If the French language works similarly as English, IC Verbs are supposed to yield more high attachments than non-biased verb. One important thing to mention is that English have a bias for NP2 (*Late closure*: Carreiras and Clifton (1999)) while the French have a bias for NP1 (*Early closure*: Zagar, Pynte, and Rativeau (1997)).

Participants

A total of 16 French native person have been selected for the experiment. One was dropped for not having French as native language. They were recruited via the RISC's platform (https://www.risc.cnrs.fr).

Material

For the experiment, 20 Items were used, they were essentially the uncompleted sentences of Rohde et al. (2011) (translated to French) but slightly more normalized

(suppression of adjectives and semantic adjustments). Sentences started with a proper noun followed by a verb, a complex DP that connects two NPS by "de" (or the contraction of "de" plus the determiner: "des" and "du") and "qui". This form forces the participant to produce a RC. Given the fact that a complex NP contains two NPs, the attachment of the following RC could be attached locally (NP2, low attachment) or non-locally (NP1, high attachment). Items were manipulated such as the two critical NPs differed in number, one was singular while the other was plural. The attachment of the RC was then defined by the number of the verb agreement. Both NPs denoted human entities to simplify the task for the participant.

NP1-biased-prompt: Carl a remarqué l'agent des chanteurs qui ...

Non-biased-prompt: Carl a accompagné l'agent des chanteurs qui ...

The varying condition was the verb, it was either an NP1-biased verb or a non-biased verb (40 critical trials). Because every languages are subject to different biases, we used completely new verbs. They were chosen using a list of verbs from a corpus study: Verbs that were object biased were considered as NP1-biased (the percentage of NP1 bias was higher than 80% compared to NP2) whereas verbs that showed no bias were considered as non-biased (the percentage of NP1 bias was less than 10% compared to NP2). All verbs were at the perfect tense (passé-composé). A total of 80 unrelated trials for an other experiment were added as fillers.

Procedure

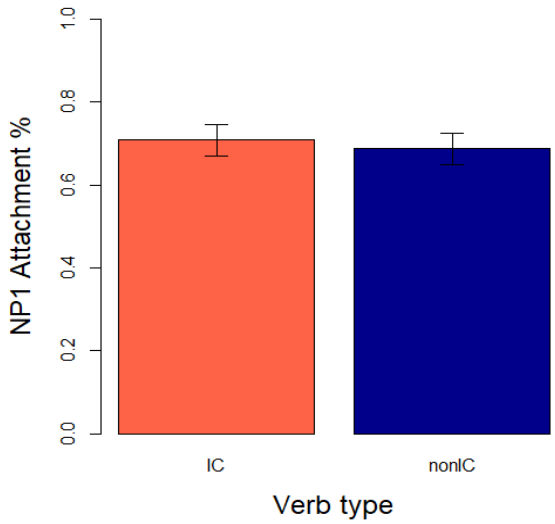
The experiment was hosted on a website called Ibex farm, Drummond (2013). Participants had access to the website from their own computers. For each item, they had to fill a text-box placed at the end of a non-finished sentence. They were asked to imagine a logic and natural continuation for every sentence. It took roughly 15 to 20 minutes to complete. Latin-squared lists were generated automatically by Ibex farm.

Prediction

We expect to see NP1 biased verbs to yield more high (non-local) attachment in completion than non-biased verbs.

Results

Results were annotated one by one by hand, there were 288 trials in total. One judge labelled whether the verb of the RC was singular or plural in order to determine the attachment of the RC. Every completion in this experiment was a valid relative clause.



The overall mean of NP1 attachment for NP1-biased verbs is at 70.83%. One the other hand, the mean for non-biased verbs is at 68.75%. We applied a Generalized Linear Mixed-Effects Models on annotated results, the formula was:
m1=glmer(Attachment vtype*(vtype||ID)+(1|Item),data=DON1,family=binomial)
The difference between the NP1-biased and the non-biased condition returned no correlation (Standard Error: 0.2911; z-value: -0.787; p: 0.4311).

Discussion

The very high NP1 attachment percentage is probably due to the design itself. This design biases completion by always wanting to explain what happened just before in the sentence, and thus be object biased, even for non-biased verbs.

Our results being so different than Rohde et al. (2011), we decided to replicate the experiment again but with more verb categories.

Experiment 2

The goal of this experiment was to add perception and stative verbs in the replicate study of Rohde et al. (2011). Indeed, Pozniak, Hemforth, Haendler, Santi, and Grillo (2019) revealed that French participants have NP1 bias for perception verbs (PR-first) and NP2 bias for stative verbs. The motivation for using such verbs was that both categories shows an explicit bias and one of them uses a different structure, perception verbs tend to facilitate the production of PR in French. The same item as in experiment 1 was used for NP1-biased and non-biased verb, we tried a second time to replicate results obtained on IC verbs in English but transposed to French.

Participants

A total of 25 French native participants were recruited for the experiment. They were recruited through the RISC's platform (https://www.risc.cnrs.fr) and via social networks.

Material

The same Items as in experiment 1 were used (with small adaptation) but two more conditions were added. We used the same verbs as Pozniak et al. (2019), plus other verbs to match the number of items, to create the new conditions: perception and stative verbs. 6 verbs of the stative condition were at the present tense, the others were at the perfect

tense (passé-composé). All perception verbs were at the perfect tense. Critical trials consisted of 20 items with 4 conditions (80 trials).

Non-biased-prompt:	Christophe a collaboré avec les sbires du dictateur qui ...
IC-prompt:	Christophe a hué les sbires du dictateur qui ...
Stative-prompt:	Christophe a pardonné les sbires du dictateur qui ...
Perceptual-prompt:	Christophe a entendu les sbires du dictateur qui ...

24 trials for another experiment and 10 unrelated completions were added as fillers.

Procedure

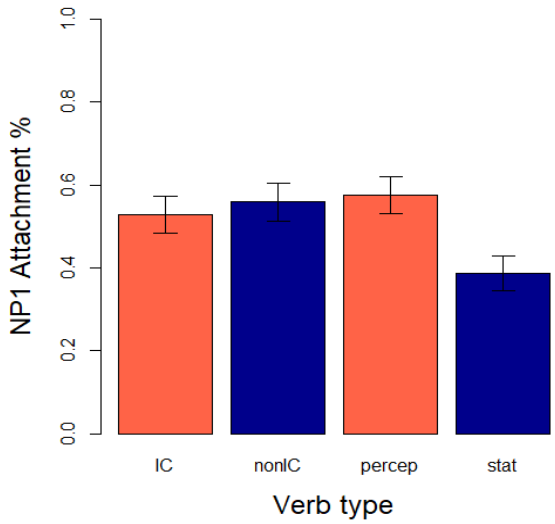
Sentence completions were conducted on a website called Ibex farm, Drummond (2013). Participants had access to the website from their own computers. For each item, they had to fill a text-box placed at the end of a non-finished sentence. They were asked to imagine a logic and natural continuation for every sentence. It took roughly 15 to 20 minutes to complete. Latin-squared lists were generated automatically by Ibex farm.

Prediction

We still expect, as in experiment 1, that NP1 biased verbs yield more high (non-local) attachment than non-biased verbs. We also expect perception verbs to yield more high attachment compared to stative verbs.

Results

Results were annotated one by one by hand, there were a total of 500 trials. One judge annotated whether the verb of the RC was singular or plural (to determine the attachment of the RC). Every completion was a valid relative clause.



The mean of NP1 attachment for NP1-biased verbs is at 52.8%, 55.93% for non-biased verbs, 38.63% for stative verbs and 57.6% for perception verbs. We applied a Generalized Linear Mixed-Effects Models on our results. Because the maximal model failed to converge, we used an intercept model with the stative condition as a baseline, the formula was: m2=glmer(Attachment cond1+cond2+cond4+(1|ID)+(1|Item),data=DON2,family= binomial)
("cond1" being the NP1-biased verb condition, "cond2" as non-biased and "cond4" as perception). All conditions compared to the stative condition showed a significative difference: NP1-biased to stative (standard error: 0.29122; z-value: -2.735; p: 0.00624), non-biased to stative (standard error: 0.30675; z-value: -2.186; p: 0.02878) and perception to stative (standard error: 0.30541; z-value: -2.766; p: 0.00567).

Discussion

The overall higher NP1 attachment percentage difference for NP1-biased, non-biased and perception compared to stative verbs can be explained for each condition. Stative verbs have a bias for NP2, that's why the mean of this condition is lower compared to other verbs that do no present this NP2 bias. NP1-biased verbs tend to force the

completion by explaining the reason of an event, and therefore to be object biased. Perception verbs biases the parser by preferring PR to RC for interpretation and structural reasons (*PR-first Hypothesis*). Finally, for non-biased verb, as experiment 1 previously suggested, this design is ideal to provide explanation for the quoted event, and thus be object biases for the completion of the RC that gives explanation or further details.

For the NP1-biased vs non-biased condition, the absence of results between the experiment of Rohde et al. (2011) and ours may reside in the verb choice for the task or the French language itself. They chose their verbs based on semantic property while we chose ours based on corpus studies. Also, French being an *Early Closure* language, it may be harder to study bias completion, especially for a phenomenon that selects the first NP. A cross-language experiment for this phenomenon may not be straightforward and may require further thinking for the choice of verbs/tense for the different conditions.

For the stative versus perception condition, biases observed by Pozniak et al. (2019) are confirmed again in our results. As predicted by the *PR-first Hypothesis*, we can see that perception verbs yield more high attachment completion for the need of the PR structure. The bias for NP2 is also observed for stative verbs.

The absence of apparent distinction of continuation between NP1-biased and non-biased but striking evidence between perception and stative verb made us solely focus on the last pair of verb categories for the last experiment which involves mathematical priming.

Experiment 3

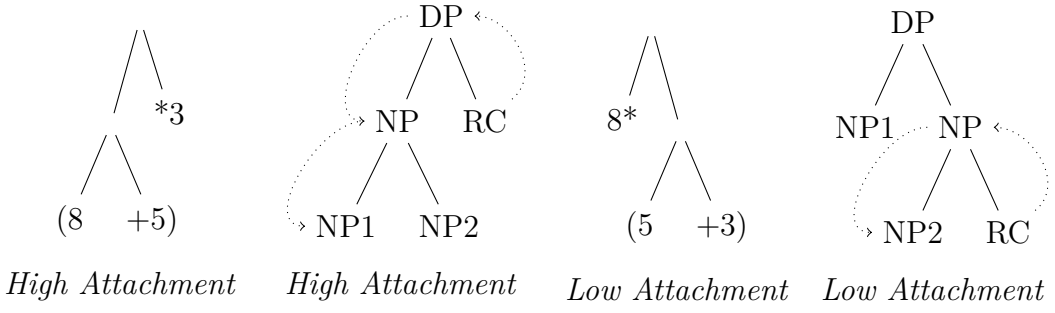
The goal of the experiment was to compare the effect of mathematical priming on two structures, standard RC and PR, through the use of two class of verbs, stative and perception verbs. Indeed, stative verbs exhibits a NP2 bias and prohibits PR while perception verbs exhibits a NP1 bias and allows PR (the nature of the bias).

Participants

54 French participants participated for the experiment. They were recruited with the RISC (https://www.risc.cnrs.fr) and social networks. It is important to note that participant (via social networks) were targeted for their supposedly greater mathematics knowledge which enhances the priming effect.

Material

The same items from experiment 2 were used but only the stative and perception verb conditions remained (40 trials). The task remained the same, participants had to complete a sentence with a RC that follows a complex DP. Every trial had an equation before which is suppposed to prime the completion: one half of the items had an equation similar to a high attachment structure "(x+y)*z"; the other half had an equation similar to a low attachment "x*(y+z)". The first type of equation shares common structural properties with non-local RC (high attachment) while the second equation shares common structural properties with a local RC (low attachment).



Equations were simpler compared to Pozniak et al. (2018) or Scheepers et al. (2011), they had only two operations (three numbers) and start order was indicated by parentheses. Numbers of equations were randomly generated with LibreOffice Calc. 20 fillers were added, one half was unrelated equations and the other half was unrelated uncompleted sentences. These two types of fillers were not paired unlike critical trials.

Procedure

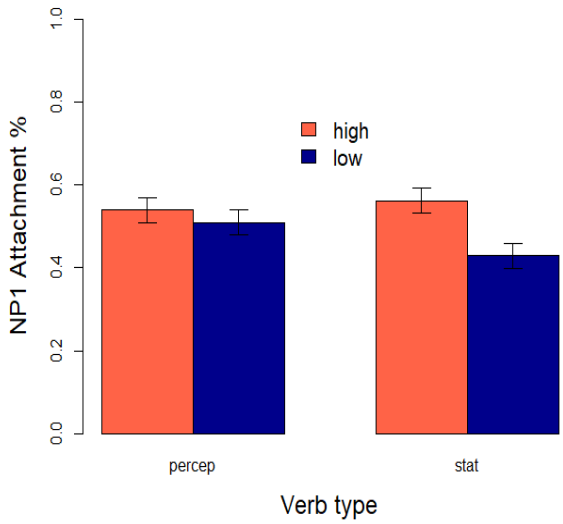
Sentence completions were conducted with the help of a website called Ibex farm, Drummond (2013). Participants had access to the website from their own computers. For each item, they had to fill a text-box placed at the end of a non-finished sentence. They were asked to imagine a logic and natural continuation for every sentence. They were also asked to calculate each equation. It took roughly 25 minutes to complete. Latin-squared lists were generated automatically by Ibex farm.

Prediction

We expect to see a difference of RC-attachment for the stative verbs: more local RCs for low-attachment-prompt and more non-local RCs for high-attachment. We expect to see no difference of RC-attachment for perception verbs.

Results

1100 equations in total were presented. 5 of them were abandoned by participants (letter in the completion) and 69 had the wrong answer leading to an overall 6.73% of wrong answer. All participants had above 50% correct answers. The 1100 trials were then annotated by one judge, the task was to specify if the verb was singular or plural (to determine the attachment of the RC). 33 completions presented no verbs and were not kept for the analysis, there were 1067 valid completion.



The mean of NP1 attachment for perception verbs is at 52,36% for high-attachment-prompt and 49,45% for low-attachment-prompt. For stative verbs, the mean for high-attachment-prompt is at 54,55% and 41,82% for low-attachment-prompt. We applied a Generalized Linear Mixed Effects Models but due to an error in the design (the latin-square was not respected, every items did not have all the same conditions), we had to adapt the model to incomplete data, the formula was: m3=glmer(Attachment vtype*equation+(vtype||ID)+(1|Item),data=DON3,family=binomial) Difference between verb type is not significative (standard error: 0.16292; z-value: 1.698; p: 0.0896) and the difference between verb type interacting with equation prompt is not significative either (standard error: 0.28175; z-value: -1.785; p: 0.0743).

Discussion

It is important to note that even if there were 69 wrong answers to equations, the mathematical priming could have occurred: the use of parentheses to indicate the start of the equation is a mathematical property that can be assumed to be known for every participant (in respect to their high response rate). We think that our absence of significative results is essentially due to the design, it lacks conditions for every items.

Nevertheless, our results being so close to a significative difference, we'll still consider that there is an interaction between both verb condition and equation prompt, this interaction being a mathematical priming effect.

General discussion

As for IC and continuation bias, the lack of results may come from many factors. The fact that Rohde et al. (2011) relied on semantic categories of verbs while we relied on continuation bias based on corpus may be the source of our problems. They used "psych" (non-eventive state) and judgement verb for the IC condition and for the non-IC verbs, they chose verbs that do not express an action or a property of an iniator, from McKoon, Greene, and Ratcliff (1993). The choice of tense may have also impacted the cross-language comparison. All their "psych" verbs were at the present tense while just some of our stative verbs were at the perfect tense. But the most likely explanation to our absence of result could be the target language. French follows the rule of *Early closure*, so any phenomenon that tend to rise the percentage of NP1 attachment would lie behind this major parsing preference. To verify such explanation, it requires experiments in a *Late closure* language that would test if a NP2 bias can be modulated. Cross-language comparison for IC may indeed need a stricter design for adaptation of a given language: that could either be done indirectly by using verb biases from corpus study; or further semantic analysis between these two languages, also involving their tense modification. Both methods are not optimal. The first is putting to test IC indirectly via corpus statistics. The second may be subject to too much language variance because, as Van Den Hoven and Ferstl (2018) suggests, IC for a verb is encoded lexically. This difference lying in the lexicon makes cross-language comparison much harder.

One analysis that can be interesting to do would be to annotate whether NP1-biased verbs yielded more explanation RCs than non-biased verbs. This would investigate the link between NP1-biased and IC verbs we assumed.

Results obtained in experiment 3 constitute an additional advance for the *Sharing of structure building resources*. The cross-domain priming effect is observed when structures share similarities (RC) and is absent when structures differ (PR). Indeed, the fact that PRs were not sensible to priming prompts designed for RCs highlight their distinction (the phrase is embedded by the verb, not the NP). It also implies that mental representation is a key feature for this interaction and so the work of Scheepers et al. (2011) and Pozniak et al. (2018) can be now adapted to the model, originally for music, of Patel (2010), The early integration and predetermined attachment for a RC and the impossibility to prime the PR into a RC suggest that resource networks overlap for language and mathematics syntactic processing. As for the representational networks, Amalric and Dehaene (2016) suggested that language and mathematics representations and storage of knowledge are located in different brains area. This goes in the direction of Patel who proposed that long-term syntactic representations for mathematics and language do not encroach.

This cross-domain interaction can be tested behaviorally in both offline and online experiment, but explaining the source of this interaction is actually a really strong challenge. Brain imaging fails to provide evidence for common resources, even electroencephalography experiments suggest different mechanisms for language and mathematics. A study conducted by Martín-Loeches, Casado, Gonzalo, De Heras, and Fernández-Frías (2006) found that violations to equations modulate event-related-potentials that were not found for linguistic violation. These interactions and priming effects may lie in memory as Patel proposed: long-term memory for the representational networks and short-term memory for the Resource networks. This would explain why all previous brain imaging and EEG studies failed to provide evidence, they maybe all searched for commonly known computational systems such as the Broca's area. More online and offline work have to be done to pinpoint which representations and/or resources it elicits, whether it is underlying rules/operations, neural mechanisms or working memory.

For later work involving mathematics to language priming, we suggest to keep

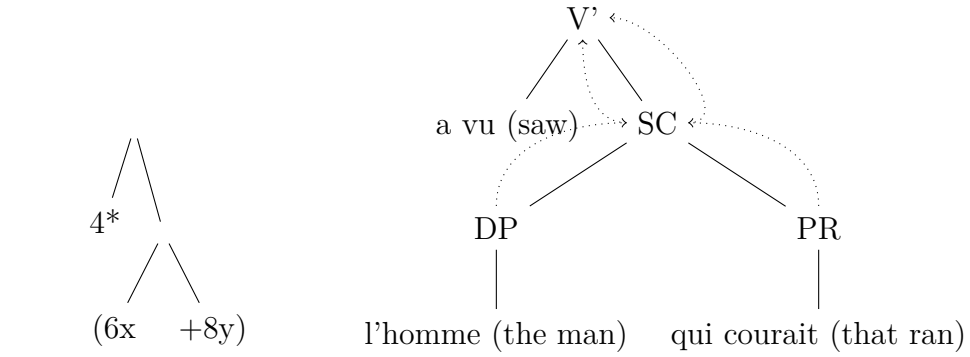
equations as simple as possible to ensure that even less mathematically skilled participants could be able to calculate equations without difficulties. The use of simpler equations led to more right answer and surely to a more robust priming effect.

Future Work

RC-attachment ambiguity could be tested in coordination contexts, especially with the Same-Size-Sister (SSS). This principle predicts that if two NPs are in coordination followed by an RC, the longer the first NP is, the more likely the RC only attaches to the second NP. Testing if the mathematical priming affects preferences for the SSS would give more information whether how powerful this priming is. If we observe an interaction between high/low-attachment-prompt and short/long NP1, this would suggest that mathematical priming does have an effect on ambiguity but the parser still takes into account its own preferences for parsing; If we observe an interaction only between high and low-attachment-prompt, this would suggest that mathematical priming strongly influence the parser to the point of ignoring standard preferences.

The evidence of structural priming presented in this paper suggests that this cross-domain effect could interact beyond RC-attachment ambiguity and work with other type of syntactic ambiguity. Branigan, Pickering, and McLean (2005) previously showed that Prepositional phrases are subject to priming effect but language to language, they may also be subject to mathematics to language.

Because mathematical priming could interact beyond RC-attachment, it might be possible to force the production or interpretation of a PR. The particularity of a PR is that a DP and a CP are in sisterhood relationship and both are selected by the same verb.



Pseudo Relative Prompt *Pseudo Relative*

Using a factorisation with two unknowns, we can mimic the structure of a pseudo relative: "6x", The DP, and "8y", the PR, are in a sisterhood relationship and they can't interact with each other due to their different unit, they have to go further up to be calculated by "4*", the verb.

Investigating how our language system is influenced by an other domain can provide us more information on how language is parsed, what may lie as common representations for cross-domain effects, what are the connections between different domains, and ultimately how the brain does all that. These questions shape without a doubt a promising framework for further research.

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Appendix

Experiment 1, 2 & 3

condition	item	verb & sentence
IC	1	Carl a critiqué l'agent des chanteurs qui
non-biased	1	Carl a accompagné l'agent des chanteurs qui
stative	1	Carl a été ami avec l'agent des chanteurs qui
perception	1	Carl a rencontré l'agent des chanteurs qui

IC	2	Grégoire a félicité les avocats de l'acteur qui
non-biased	2	Grégoire a interpellé les avocats de l'acteur qui
stative	2	Grégoire a été employé par les avocats de l'acteur qui
perception	2	Grégoire a épié les avocats de l'acteur qui
IC	3	Pierre a adoré les amis de l'athlète qui
non-biased	3	Pierre a snobé les amis de l'athlète qui
stative	3	Pierre a couru avec les amis de l'athlète qui
perception	3	Pierre a enregistré les amis de l'athlète qui
IC	4	Franck a réconforté les invités de la mariée qui
non-biased	4	Franck a flatté les invités de la mariée qui
stative	4	Franck a logé chez les invités de la mariée qui
perception	4	Franck a photographié les invités de la mariée qui
IC	5	Brice a sermonné le professeur des étudiants qui
non-biased	5	Brice a consulté le professeur des étudiants qui
stative	5	Brice a été marié avec le professeur des étudiants qui
perception	5	Brice a écouté le professeur des étudiants qui
IC	6	Béatrice a applaudi les enfants du musicien qui
non-biased	6	Béatrice a retenu les enfants du musicien qui
stative	6	Béatrice va à l'université avec les enfants du musicien qui
perception	6	Béatrice a imaginé les enfants du musicien qui
IC	7	Christian a réprimandé le père des étudiants qui
non-biased	7	Christian a prévenu le père des étudiants qui
stative	7	Christian a fait la fête avec le père des étudiants qui
perception	7	Christian a vu le père des étudiants qui
IC	8	Melissa a puni les filles du voisin qui
non-biased	8	Melissa a cherché les filles du voisin qui
stative	8	Melissa a été hebergé par les filles du voisin qui

perception	8	Melissa a aperçu les filles du voisin qui
IC	9	Sandra a hai les jardiniers du millionnaire qui
non-biased	9	Sandra a heurté les jardiniers du millionnaire qui
stative	9	Sandra est voisin des jardiniers du millionnaire qui
perception	9	Sandra s'est représenté les jardiniers du millionaire qui
IC	10	Rayan a calmé le capitaine des marins qui
non-biased	10	Rayan a suivi le capitaine des marins qui
stative	10	Rayan a vécu avec le capitaine des marins qui
perception	10	Rayan a regardé le capitaine des marins qui
IC	11	Joel a engagé les stylistes de la célébrité qui
non-biased	11	Joel a menacé les stylistes de la célébrité qui
stative	11	Joel travaille avec les stylistes de la célébrité qui
perception	11	Joel a filmé les stylistes de la célébrité qui
IC	12	Adrien a titularisé les assistants du PDG qui
non-biased	12	Adrien a évité les assistants du PDG qui
stative	12	Adrien s'entraîne avec avec les assistants du PDG qui
perception	12	Adrien a observé les assistants du PDG qui
IC	13	Alban a détesté les comptables du ministre qui
non-biased	13	Alban a approché les comptables du ministre qui
stative	13	Alban est lié aux comptables du ministre qui
perception	13	Alban a espionné les comptables du ministre qui
IC	14	Tina a guidé les médecins du mannequin qui
non-biased	14	Tina a idéalisé les médecins du mannequin qui
stative	14	Tina étudie avec les médecins du mannequin qui
perception	14	Tina a surveillé les médecins du mannequin qui
IC	15	Louis a envié le manager des acteurs qui
non-biased	15	Louis a brusqué le manager des acteurs qui

stative	15	Louis est employé par le manager des acteurs qui
perception	15	Louis a surpris le manager des acteurs qui
IC	16	Christophe a hué les sbires du dictateur qui
stative	16	Christophe a pardonné les sbires du dictateur qui
non-biased	16	Christophe a collaboré avec les sbires du dictateur qui
perception	16	Christophe a entendu les sbires du dictateur qui
IC	17	Stéphane a craint les fans du chanteur qui
non-biased	17	Stéphane a harcelé les fans du chanteur qui
stative	17	Stéphane passe du temps avec les fans du chanteur qui
perception	17	Stéphane a dessiné les fans du chanteur qui
IC	18	George a récompensé le représentant des employés qui
non-biased	18	George a humilié le représentant des employés qui
stative	18	George a divorcé du représentant des employés qui
perception	18	George a distingué le représentant des employés qui
IC	19	Alice a remercié le chirurgien des soldats qui
non-biased	19	Alice a fréquenté le chirurgien des soldats qui
stative	19	Alice a été fiancé au chirurgien des soldats qui
perception	19	Alice a peint le chirurgien des soldats qui
IC	20	Paul a embauché le coach des cheerleaders qui
non-biased	20	Paul a distrait le coach des cheerleaders qui
stative	20	Paul est sorti avec le coach des cheerleaders qui
perception	20	Paul a repéré le coach des cheerleaders qui

Experiment 3

verb	equation prompt	item	Equation
stative verb	low attachment	1	9*(6+8)
perception verb	low attachment	1	5*(2+2)
stative verb	low attachment	2	3*(1+4)
perception verb	low attachment	2	3*(4+9)
stative verb	low attachment	3	4*(2+4)
perception verb	low attachment	3	8*(1+7)
stative verb	low attachment	4	1*(3+1)
perception verb	low attachment	4	2*(8+7)
stative verb	low attachment	5	2*(9+3)
perception verb	low attachment	5	9*(6+1)
stative verb	low attachment	6	4*(7+2)
perception verb	low attachment	6	9*(9+4)
stative verb	low attachment	7	2*(3+5)
perception verb	low attachment	7	7*(3+5)
stative verb	low attachment	8	3*(3+4)
perception verb	low attachment	8	9*(5+3)
stative verb	low attachment	9	1*(1+5)
perception verb	low attachment	9	7*(5+9)
stative verb	low attachment	10	9*(3+2)
perception verb	low attachment	10	8*(5+3)
stative verb	high attachment	11	(5+6)*1
perception verb	high attachment	11	(8+9)*8
stative verb	high attachment	12	(6+9)*1
perception verb	high attachment	12	(5+2)*5
stative verb	high attachment	13	(9+8)*2

perception verb	high attachment	13	(6+1)*1
stative verb	high attachment	14	(7+8)*7
perception verb	high attachment	14	(1+2)*3
stative verb	high attachment	15	(4+3)*9
perception verb	high attachment	15	(7+7)*4
stative verb	high attachment	16	(1+6)*8
perception verb	high attachment	16	(4+4)*5
stative verb	high attachment	17	(9+1)*6
perception verb	high attachment	17	(7+5)*3
stative verb	high attachment	18	(8+3)*6
perception verb	high attachment	18	(1+4)*5
stative verb	high attachment	19	(2+4)*8
perception verb	high attachment	19	(5+5)*5
stative verb	high attachment	20	(7+6)*9
perception verb	high attachment	20	(8+4)*2