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# Seeing events vs. entities: The processing advantage of Pseudo Relatives over Relative Clauses

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## Abstract

We present the results of three offline questionnaires (one attachment preference study and two acceptability judgments) and two eye-tracking studies in French and English, investigating the resolution of the ambiguity between pseudo relative and relative clause interpretations. This structural and interpretive ambiguity has recently been shown to play a central role in the explanation of apparent cross-linguistic asymmetries in relative clause attachment (Grillo & Costa, 2014; Grillo et al., 2015). This literature has argued that pseudo relatives are preferred to relative clauses because of their structural and interpretive simplicity. This paper adds to this growing body of literature in two ways. First we show that, in contrast to previous findings, French speakers prefer to attach relative clauses to the most local antecedent once pseudo relative availability is controlled for. We then provide direct support for the pseudo relative preference: grammatically forced disambiguation to a relative clause interpretation leads to degraded acceptability and greater processing cost in a pseudo relative environment than maintaining compatibility with a pseudo relative.

*Keywords:* Universality of Parsing Principles, Ambiguity Resolution, Economy of Computation, Locality, Attachment Preferences, (Pseudo)Relative Clauses

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1 **1. Introduction**

2 One strong hypothesis in psycholinguistics is that language processing is governed by mech-  
3 anisms grounded in universal principles of optimal computation, such as those evidenced in  
4 primacy and recency effects. Principles of this sort, which dominate models of language pro-  
5 cessing and are often observed across cognitive domains, can hardly be construed as acquired,  
6 which explains their universal nature.<sup>1</sup>

7 From this perspective, crosslinguistic variation in parsing preferences is only apparent and  
8 ultimately reducible to grammatical variation, i.e. to the interaction of the grammatical properties  
9 of a given language with these basic principles of economy of computation.

10 There is, however, one domain of research in sentence processing where universality was  
11 famously called into question: relative clause (RC) attachment (Cuetos & Mitchell, 1988, and  
12 much related literature). Cuetos and Mitchell (1988) first observed that speakers of Spanish and  
13 English displayed a strikingly different parsing preference in the resolution of syntactic ambigu-  
14 ties involving two potential attachment sites of a RC: while English speakers relied on principles  
15 of minimal effort, attaching the RC to the closest potential host (the most local NP, *the actress*  
16 in (1-a)); Spanish speakers appeared to violate this principle, showing an overall preference for  
17 attachment to the non-local host (*the maid* in (1-b)). The locality principle governing attachment  
18 seemed therefore to apply differently across languages.

- 19 (1) a. Someone shot the maid<sub>1</sub> of the actress<sub>2</sub> that<sub>2</sub> was<sub>2</sub> standing on the balcony  
20 b. Alguien disparó contra la criada<sub>1</sub> de la actriz<sub>2</sub> que<sub>1</sub> estaba<sub>1</sub> en el balcón

21 This asymmetry was particularly striking because of its exceptionality and specificity. Spanish  
22 and English speakers, in fact, show the same preferences when disambiguating sentences which  
23 involve principles governing structure building and filler-gap dependencies. They also show the  
24 same tendency to prefer local attachment when constituents other than RCs are tested (e.g. when  
25 attaching temporal modifiers in: *John said that Mary left yesterday*). These findings generated a

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<sup>1</sup>A related, though independent, argument from learnability is discussed in detail in Fodor (1998a,b) in support of the universalist perspective: children need to parse the language they hear in order to acquire the grammar of their native language. This will be very hard, if not impossible, if principles of parsing have to be acquired themselves. And principles of parsing can hardly be acquired as long as there is no grammar to base this process on.

26 vast amount of literature aimed at explaining away this asymmetry.<sup>2</sup>

27 One such theoretical framework is the *Tuning Hypothesis*. Mitchell & Cuetos (1991) pro-  
28 posed that preferences for high or low attachment of RCs across languages stem from expo-  
29 sure to different statistical regularities that could vary depending on individuals or languages  
30 (Mitchell et al., 1995). Empirically, the literature provides conflicting results on this. See Cuetos  
31 et al. (1996) for supporting data from corpus analyses of English and Spanish and Mitchell &  
32 Brysbaert (1998) for problematic results from Dutch (see also Desmet et al. 2002a; Desmet &  
33 Gibson 2003; Gibson & Schütze 1999 for further discussion). One issue with corpus studies on  
34 RC attachment, which might in part explain the conflicting results, is that they did not take into  
35 account a number of fine-grained properties of both the RC and the complex DP that have been  
36 independently shown to strongly affect attachment. These include the type of relation between  
37 the two Nouns (Gilboy et al., 1995; Frazier & Clifton, 1996), the type of preposition connecting  
38 the two DPs (De Vincenzi & Job, 1993, 1995), the number of NPs (Gibson et al., 1996) and  
39 length of the DPs and the RC (on which see Hemforth et al., 2015, and references cited therein).<sup>3</sup>  
40 From a theoretical perspective, an important question of *directionality of the effect* is raised by  
41 corpus studies, that is, whether a form is less frequent because it is inherently more complex or  
42 less favoured by the parser, limiting its explanatory power.

43 Even though the role of RC-attachment frequency distributions in language specific pref-  
44 erences should not be disregarded, it now appears clear that it can hardly be the only factor  
45 explaining all the variation in attachment, particularly across languages. The in-depth investiga-  
46 tion of RC attachment across structures and languages thus uncovered a variety of other factors  
47 that contribute to the disambiguation of RC attachment and the processing of adjuncts more  
48 generally. It is now apparent that semantic, pragmatic and prosodic factors all contribute to the  
49 disambiguation of sentences involving multiple potential hosts for an RC, and that these factors  
50 apply in substantially the same way across languages (for recent reviews see Grillo & Costa  
51 2014; Hemforth et al. 2015).

52 An important recent development in this debate came with the discovery that the previous  
53 literature on RC-attachment contained a grammatical confound in the cross-linguistic compar-

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<sup>2</sup>Borrowing the words of an anonymous reviewer: “A great deal of psycholinguistic ink has been spilled trying to identify the basis for th(is) purported difference”.

<sup>3</sup>Previous corpus studies looking at RC-attachment also did not consider the confounding role of the selective availability of Pseudo Relatives, on which see below, which makes an evaluation of their results highly problematic.

54 isons (Grillo, 2012). A subset of the languages under study, including Spanish but not English,  
 55 allow for constructions known as *Pseudo Relatives* (PR). Faithful to their name, these imposters  
 56 are string identical to RCs (2). The two constructions, however, display very different structural,  
 57 interpretive and prosodic properties. Crucially, there is no attachment ambiguity under the PR  
 58 parse (2-b, c), as the first NP of a complex NP is the only accessible subject for the embedded  
 59 predicate. In other words, with PRs High Attachment is obligatory.<sup>4</sup> PRs are found not only in  
 60 Spanish but also in a number of so-called High Attachment languages (including French, Dutch,  
 61 Greek and Serbo-Croatian, among others). PRs, however are not available in Low Attachment  
 62 languages including English, Basque, Romanian and Chinese.<sup>5</sup> Not recognizing this grammati-  
 63 cal distinction necessarily puts the explanatory burden for variation in attachment preferences on  
 64 the parser, causing the aforementioned crisis.

- 65 (2) a. Jean a vu [DP l' [NP homme [CP qui courait.]]]  
 J. has seen the man that run.  
 66 'John saw the man that ran.'
- 67 b. Jean a vu [PR [DP l'homme] [CP qui courait.]]  
 J. has seen the man that ran.  
 68 'J. saw the man running.'
- 69 c. John saw [PR the man running].

70 Discovery of this confound led to formulation of the *PR-first Hypothesis*, which suggests  
 71 that PRs are both interpretively and structurally simpler than RCs and thus should be preferred  
 72 by the parser (see below for details). Recent results on RC attachment indirectly support this hy-  
 73 pothesis by showing a strong effect of PR availability on RC attachment: when the PR confound  
 74 is eliminated and only unambiguous RCs are presented, there is a strong tendency to attach lo-  
 75 cally across languages and structures. Non-local / High Attachment is observed across languages  
 76 when a PR reading is available.

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<sup>4</sup>For ease of exposure, throughout this paper, we will call the obligatory interpretation of the NP1 as the subject of the PR in "NP1 of NP2" constructions in PR environments "High Attachment" although this strictly only applies to relative clauses.

<sup>5</sup>For reference on RC attachment in these languages see e.g.: Mitchell et al. (1990); Frenck-Mestre & Pynte (2000); Zagar et al. (1997); Colonna et al. (2000); Colonna & Pynte (2001a) (French), Brysbaert & Mitchell (1996); Mitchell & Brysbaert (1998); Mitchell et al. (2000); Desmet et al. (2002b) (Dutch), Papadopoulou & Clahsen (2003) (Greek), Lovrić (2003) (Serbo-Croatian, Gutierrez-Ziardegi et al. (2004) (Basque), Ehrlich et al. (1999) (Romanian), Shen (2006) (Chinese).

77 In the present paper we extend these findings in multiple directions. After a brief introduction  
 78 on the contrast between PRs and RCs and a short summary of previous experiments on the effects  
 79 of PR availability on the resolution of RC attachment ambiguities (remainder of Section 1) we  
 80 show in an offline completion study that native speakers of French display a clear preference for  
 81 Low Attachment when unambiguous RCs are tested and other relevant factors (such as prosody  
 82 or referentiality) are controlled (Section 2). As predicted, High Attachment is observed with the  
 83 same complex NP + RC combinations in environments that license PRs. We then directly test  
 84 the PR-first Hypothesis in two sets of experiments that acquire acceptability judgments (Section  
 85 3) and eye-tracking while reading data (Section 4). Each of these experiments was carried out in  
 86 French, a PR-language, and in English, a non-PR language. Overall, the results further support  
 87 the claim that parsing principles are universal: previously reported cross-linguistic differences in  
 88 parsing preferences are strongly grounded in independent grammatical distinctions and are thus  
 89 epiphenomenal.

### 90 1.1. *Pseudo Relatives*

91 Relative clauses in the complement position of perceptual verbs in languages like French  
 92 (3), but not English, are ambiguous between an RC reading (3-a), and a pseudo relative reading  
 93 (3-b).<sup>6</sup> Despite being string identical, PRs and RCs are structurally and interpretively different.

94 As shown in (4) and (5), in RCs the CP is embedded within the DP it modifies, but in PRs it  
 95 stands in a sisterhood relation with the same DP. In (4), the RC *that ran* is embedded in the DP,  
 96 contrary to the PR *that ran* in (5) which is the sister of the DP and selected by the verb.

- 97 (3) a. Jean a vu [<sub>DP</sub> I' [<sub>NP</sub> homme [<sub>CP</sub> qui courait.]]]  
 98 J. has seen the man that run.  
 'John saw the man that ran.'
- 99 b. Jean a vu [<sub>PR</sub> [<sub>DP</sub> l'homme] [<sub>CP</sub> qui courait.]]  
 100 J. has seen the man that ran.  
 'J. saw the man running.'
- 101 c. I saw [<sub>PR</sub> the man running].

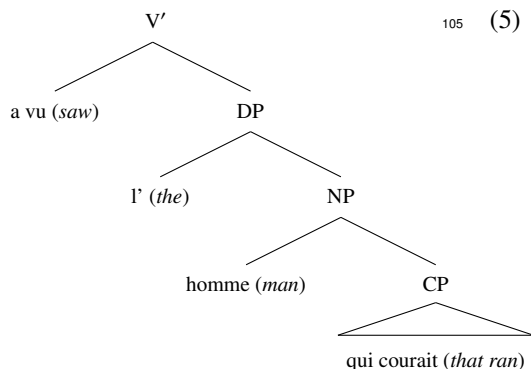
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<sup>6</sup>On PRs see e.g. Radford (1975); Kayne (1975); Graffi (1980); Burzio (1986); Cinque (1992); Rizzi (1992); Guasti (1988, 1992); Côté (1999); Rafel (1999); Casalicchio (2013); Moulton & Grillo (2015); Grillo & Moulton (2016) among others. For analysis of PRs as predicative relatives see Koenig & Lambrecht (1999) and Lambrecht (2000).

102

## RELATIVE CLAUSE

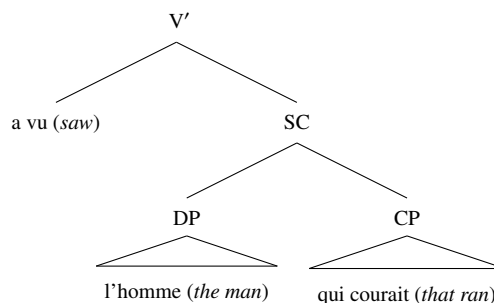
103 (4)



104

## PSEUDO RELATIVE

105 (5)



106 This structural difference is accompanied by a sharp difference in interpretation. RCs, being  
 107 modifiers of the DP they attach to, denote properties of the entities introduced by those DPs (6).  
 108 When a perceptual verb takes a DP modified by an RC, it provides a perceptual report of the  
 109 unique individual introduced by the DP, which possesses the property introduced by the RC (i.e.  
 110 the unique runner in the example in (6)). PRs, which roughly correspond to so-called eventive  
 111 small clauses in English (3)[c], are composed by a subject DP and a CP predicate. Like eventive  
 112 Small Clauses in English, PRs denote events or situations (7). Embedding of a PR under a  
 113 perceptual verb gives a perceptual report of an event (a *running* event in the present example).<sup>7</sup>

<sup>7</sup>For clarity of presentation, we show simplified semantics for PRs. For a more detailed discussion on the syntax-semantics of PRs see Moulton & Grillo (2015); Grillo & Moulton (2016) and references cited therein. For discussion of how these structural differences are encoded at the prosodic level, see Grillo & Turco (2016).



114 (6) RC: *John saw the man that runs*

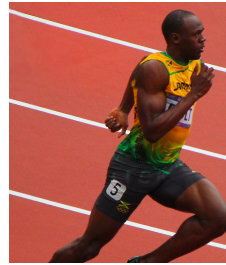


115

116  $\exists e$  [see(e) & EXPERIENCER(e)(John) & STIMU-  
117 LUS(the unique man that ran)(e)]

118 There is an event of *seeing* and the experiencer  
119 of that event is *John* and the stimulus of the event  
120 is *the unique man that ran*.<sup>8</sup>

121 (7) PR: *John saw the man running*



122

123  $\exists e\exists e'$  [see(e) & EXPERIENCER(e)(John) & STIMU-  
124 LUS(e')(e) & run(e') & AGENT(e')(the man)]

125 There is an event of *seeing* and the experiencer  
126 of that event is *John* and the stimulus of the event  
127 is *an event of running* and the agent of running  
128 is *the man*.<sup>9</sup>

129 The structural and interpretive differences between PRs and RCs are responsible for a num-  
130 ber of asymmetries in their distribution, which helpfully can be manipulated experimentally to  
131 independently investigate their processing. The remainder of this section briefly introduces two  
132 asymmetries used in the experiments that follow.

133 *Restriction on Matrix Verb.* An important characteristic of PRs is that, just like English eventive  
134 small clauses and contrary to run-of-the-mill RCs, they are only available in selected environ-  
135 ments. PRs and small clauses are allowed under perceptual verbs but are clearly not available  
136 with stative predicates.<sup>10</sup>

137 (8) a. Marie a vu Bolt qui courait.  
138 M. has seen B. that run.IMPF.  
'Marie saw Bolt running.'

<sup>8</sup>*My Hero*, Zwerink (2011), Public Domain.

<sup>9</sup>*Run*, Mackintosh (2012), Public Domain.

<sup>10</sup>PRs and SCs are also licensed under other types of predicates, e.g. *meet*, *catch*, *film* a.o. Here and elsewhere we use proper names to disambiguate for the PR reading. Proper names can also head appositive RCs, however it is easy to show that these are also distinct from PRs (e.g., see Radford 1975 and much related work. For example, PRs do not involve the typical *comma intonation* of appositive RCs). The contrast with pronominals in (9) further clarifies that we are not dealing with appositive RCs, which are not licensed with pronouns.

- 139           b. \*Marie a épousé Bolt qui courait.  
               M.    has married B.   that run.IMPF  
 140           ‘\*Marie married Bolt that was running.’

141           The difference in meaning between a PR and RC is responsible for this asymmetry. While  
 142   perceptual verbs can introduce both events or entities (e.g. *Mary can see (the person) Bolt* or *see*  
 143   *(the event of) Bolt running*), other verbs exclusively introduce entities (e.g. *Marie can marry (the*  
 144   *person) Bolt*, but not *marry (the event of) Bolt running*).

145           This contrast is even more striking when pronominal objects are used. A perfectly acceptable  
 146   result arises under perceptual verbs (9-a) (that is, when a PR reading is licensed), and complete  
 147   ungrammaticality under stative verbs (when only the RC reading would be available). This asym-  
 148   metry is due to the fact that RCs, whether restrictive or appositive, can never modify pronominals.  
 149   Since PRs are not available under stative predicates, the PR-analysis which rescues (9-a), cannot  
 150   be used for (9-b).

- 151   (9)    a. Marie l’a       vu qui courait.  
               M.    him’has seen that run.IMPF.  
 152           ‘Mary saw him running.’  
 153           b. \*Marie l’a       épousé qui courait.  
               M.    him’has Married that run.IMPF  
 154           ‘\*Mary married him that was running.’

155   *Restrictions on Tense.* Another characteristic distinguishing PRs from RCs is that the tense of  
 156   the embedded clause is anaphoric in PRs. This means that the perceptual event introduced in  
 157   the matrix clause and the perceived event introduced by the PR must happen simultaneously.  
 158   Simplistically speaking, tense specification of the embedded clause has to match the tense spec-  
 159   ification of the matrix clause in PRs (10-a). A past under present leads to an ungrammatical  
 160   structure (10-b). This requirement obviously does not apply to RCs (10-c). This property of PRs  
 161   is not surprising. As mentioned above, PRs under perceptual verbs involve direct perception of  
 162   an event. If the event of perception happened in the past, then what was perceived (ie, another  
 163   event) must have also taken place in the past. Similarly, if I am watching John running now, he  
 164   must be running now. <sup>11</sup>

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<sup>11</sup>There are apparent restrictions to this rule, involving present under future and present under present perfect, which are discussed in [Grillo & Moulton \(2016\)](#). These are irrelevant for the present experiment which used past under present,

- 165 (10) a. Jean l'a vu qui courait. PR-only  
 J. him'has seen that run.IMPF  
 166 'John saw him running.'
- 167 b. \*Jean le voit qui courait.  
 J. him sees.PRES that ran.IMPF  
 168 'John sees him that was running.'
- 169 c. Jean voit l'homme qui courait. RC-only  
 J. sees.PRES the'man that ran.PAST  
 170 'John sees the man that was running.'

171 *1.2. Previous studies and the PR-first Hypothesis*

172 Grillo (2012) proposed that RC attachment preference should co-vary with PR availability  
 173 and thereby explain (in part) the cross-linguistic asymmetry in attachment preferences. Every-  
 174 thing else being equal, in Non-PR languages like English (as well as Basque, Romanian and  
 175 Chinese) speakers display a preference for local attachment of the RC (attachment to *the man*  
 176 in (11-a)), while in PR languages like French (as well as Italian, Spanish and Greek) speakers  
 177 prefer non-local, or High Attachment (attachment to *the son* in (11-b)).

- 178 (11) a. I saw the son of the man that was running.  
 179 b. J'ai vu le fils de l'homme qui courait.  
 I.have seen the son of the man that ran.  
 180 'I saw the son of the man running.'

181 Under the PR reading, the attachment ambiguity disappears because of standard structural re-  
 182 strictions (c-command), the only accessible subject for the embedded predicate is the non-local  
 183 NP (*the son*).<sup>12</sup>

- 184 (12) J'ai vu [<sub>PR</sub> [<sub>DP</sub> le fils<sub>i</sub> [<sub>PP</sub> de [<sub>DP</sub> l'homme<sub>j</sub>]]] [<sub>CP</sub> qui<sub>i,\*j</sub> courait.]]  
 I.have seen the son of the man that ran.  
 185 'I saw the son of the man running.'

186 To account for this pattern, Grillo (2012) and Grillo & Costa (2014) proposed the *PR-first Hy-*  
 187 *pothesis*: PRs are easier to parse than RCs for structural, semantic and pragmatic reasons. For

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which in no way can be construed as a PR.

<sup>12</sup>Structurally, this is the same scenario we find when the complex DP in a subject position, as in e.g.: *[[the son [of [the man]]] ran]*. In this configuration, the second NP (*man*) is too deeply embedded within the subject DP to be an accessible subject.

188 instance, PRs have impoverished syntax and semantics with respect to RCs. As discussed above,  
189 Tense is anaphoric/dependent in PRs but referential in RCs. Moreover, PRs stand in a sisterhood  
190 relation with the head NP, while RCs are embedded within the same NP, making the RC an ar-  
191 guably more complex configuration. Another reason for the smaller difficulty with PRs is that  
192 they convey information relevant for the main assertion of the clause (Frazier, 1990); in fact they  
193 can be projected as *arguments* of the main clause (I saw an event). By contrast, RCs are always  
194 *adjuncts* (I saw an entity, which has a certain property, introduced by the RC itself). Finally, PRs  
195 involve less presuppositions than RCs. PRs do not require selection from a pre-established set of  
196 entities in the discourse (Crain & Steedman, 1985; Altmann & Steedman, 1988).<sup>13</sup>

197 Further to the correlation observed in the previous literature, a number of novel experiments  
198 directly manipulated PR availability across languages and demonstrated a strong effect of PR  
199 availability on attachment preference.

200 Grillo & Costa (2014) report a significant effect of verb type on RC attachment in Italian, with  
201 High Attachment observed under perceptual verbs such as *see* (78.6% High Attachment prefer-  
202 ence) and Low Attachment under stative verbs like *live with* (24.2% High Attachment prefer-  
203 ence). Comparable results were obtained from other PR-languages: Greek (Grillo & Spathas,  
204 2014), Portuguese (Grillo et al. 2012a,b, 2013; Fernandes 2012; Tomaz et al. 2014) and Span-  
205 ish (Grillo et al., 2012b; Aguilar & Grillo, 2016). These are all languages that were previously  
206 classified as High Attachment languages. However, these studies showed that this classification  
207 is epiphenomenal: as predicted by the *PR-first Hypothesis*, Low Attachment preference was ob-  
208 served consistently in each of these languages in unambiguous RC environments, whereas High  
209 Attachment preference was only observed in PR-compatible environments.

210 Importantly, Grillo et al. (2015) show that predicate semantics/plausibility alone does not

---

<sup>13</sup>It is important to clarify that the name *PR-first* does not imply that this hypothesis is tied to a serial model of language processing. The hypothesis is perfectly compatible with (ranked) parallel models of sentence processing and *first* can be interpreted as most highly ranked. *PR-first* should also not be taken to be an independent parsing principle, it simply captures the application of independently motivated parsing principles (e.g. Relativized Relevance (Frazier, 1990) or Principle of Parsimony (Crain & Steedman, 1985)) to the PR-RC ambiguity. Preference for PR over RCs, finally, is certainly not the sole factor determining RC attachment; previous work has shown that this is strongly modulated by a number of other factors both within and across languages, including pragmatics (Gilboy et al., 1995; Frazier & Clifton, 1996), prosody (Fodor, 2002; Hemforth et al., 2015) as well as independent grammatical properties of the languages under scrutiny (e.g., RCs introduced by a complementizer vs. obligatory relative pronouns, like in German, Russian and Bulgarian; see Hemforth et al. 2000 and Grillo & Costa 2014).

211 account for these results, as the same verb type manipulation (perceptual vs stative) in English (a  
212 non-PR language) did not effect preferences (ie, lead to overall High Attachment).

213 In sum, RC attachment preferences in complex NPs are modulated by the availability of an  
214 eventive small clause (be it a PR, a prepositional infinitive construction or the garden variety  
215 accusative+progressive small clause in English), adding evidence to the idea that cross-linguistic  
216 differences in RC attachment are rooted in grammatical differences. These results are also con-  
217 sistent with the idea that there exists a preference for the PR reading over the RC reading, as  
218 claimed by the *PR-first Hypothesis*.

219 A straightforward prediction of the *PR-first Hypothesis* that has not been tested yet is that  
220 tense mismatch in the environment of PR-compatible verbs should lead to reanalysis of the initial  
221 PR preference, with observable processing costs. By contrast, tense (mis)match should play no  
222 role in the interpretation of the embedded clauses in globally unambiguous RCs, for instance,  
223 RCs in the environment of stative verbs. We therefore predict a qualitatively different effect of  
224 tense manipulation in globally unambiguous RC environments.

225 Before we describe the experiments that directly tested this *PR-first* prediction (Section 3  
226 and Section 4), we briefly show that PR availability modulates RC attachment preferences in  
227 French (Section 2). This would serve as a pre-test of the effects of PR availability and add to the  
228 literature on RC attachment in French.

## 229 **2. Experiment 1: RC-attachment in French**

230 In the first experiment we wanted to make sure that verb type manipulation (that is, PR avail-  
231 ability) modulates RC attachment in French in the same way as it does in other PR-compatible  
232 languages. As discussed for Italian, under perceptual verbs (cf. example (13-a)) the embedded  
233 clause might be attached as sister of the non-local NP (*the son*), leading to a PR-reading with no  
234 attachment ambiguity. The alternative RC-reading can either be attached to the local NP (*the po-  
235 liceman*) or the non-local one (*the son*). Under stative verbs, however, only the latter ambiguity  
236 is present. The embedded clause can only be construed as a RC, attached either high or low. We  
237 tested the availability of these PR- and RC-readings in an offline completion study in French.

238 *Participants*

239 Sixty-nine native speakers of French (mean age 41.4 years) volunteered to participate in the  
240 experiment. They were recruited on the RISC platform (<https://www.risc.cnrs.fr>). In this as well  
241 as all following experiments, participants provided informed consent before starting the first  
242 trials.

243 *Material*

244 The critical trials consisted of 24 ambiguous target sentences containing complex NPs of the  
245 form NP1 of NP2 followed by a finite CP. These complex NPs were placed in object position of  
246 either perceptual verbs (13-a) or stative verbs (13-b). Sixty unrelated fillers were added. All items  
247 were presented to participants in a standard Latin square design: verb types were counterbalanced  
248 across the items. The order of items was randomized individually for each participant.

- 249 (13) a. Marie écoute le fils du policier qui parle. PERCEPTUAL  
250 Marie hears the son of the policeman that is speaking.  
251 b. Marie est employée par le fils du policier qui parle. STATIVE  
252 Mary is employed by the son of the policeman that is speaking.

253 *Procedure*

254 Participants read the sentences on a computer screen through the IBEX platform (Drummond  
255 2013). After reading each sentence, participants were asked to complete a sentence describing  
256 the event in the embedded clause by filling in the blank space in the subject position with either  
257 the local or non-local NP. This is illustrated in (14).

- 258 (14) Léa est fiancée au voisin du coordonnier qui danse.  
259 Le ..... danse.  
260 ‘Lea is engaged to the neighbour of the shoemaker that is dancing.’  
261 The ..... is dancing.’

262 *Analysis*

263 The attachment preference data were analyzed with a Bayesian linear mixed-effects model  
264 that assumes a Bernoulli distribution of the dependent variable, with a logit link function. The

265 model was fitted using the *brms* package (Bürkner, 2018) in R (R Core Team, 2018). The bi-  
266 nary dependent variable of attachment preference was coded as 1 (High Attachment) or 0 (Low  
267 Attachment). The levels of the factor VERB TYPE were coded as 1 (perceptual) and -1 (stative).  
268 The Bayesian model generates a posterior distribution for each of the model parameters. The  
269 parameters of interest are typically the slopes of the group-level (or fixed) effects. In this model,  
270 it is the slope parameter for the fixed effect of VERB TYPE.

271 Due to the 1/-1 coding of the factor, zero represents the point of "no difference" between  
272 the two verb types. Therefore, we will calculate the probability that the parameter of interest is  
273 greater or smaller than zero. A high probability that the VERB TYPE parameter is greater than zero  
274 would suggest there is evidence that High Attachment is preferred with perceptual verbs (coded  
275 as 1). By contrast, high probability that the parameter is smaller than zero would mean that High  
276 Attachment is preferred with stative verbs (coded as -1).

277 For the interpretation of the data, we will look at the estimated mean ( $\hat{\beta}$ ) and range of the  
278 posterior distribution for the parameter of interest. The distribution's 85% credible intervals will  
279 mark the range of which which we can be certain with probability 0.85 that it includes the true  
280 value of the parameter of interest, given the data and the model at hand. Similarly, the 95%  
281 credible intervals will mark the range of which we can be certain with a probability of 0.95 that it  
282 includes the true value of the parameter (Hoekstra et al., 2014; Morey et al., 2016). It should be  
283 emphasized that, in this kind of analysis, we refrain from calling an effect "significant" or "not  
284 significant". These terms, used in Frequentist analyses, reflect the binary nature of statistical  
285 inference in such models (an effect can be either significant or not). By contrast, inference in the  
286 Bayesian analysis used here is not categorical. Evidence for a particular effect may be more or  
287 less strong, as expressed by whether zero is excluded from the posterior distribution altogether,  
288 whether it lies outside the 95% credible intervals, outside the 85% credible intervals, and so on.  
289 In the appendix we provide a more detailed motivation for preferring the Bayesian analysis over  
290 a Frequentist one.

291 In the model for this experiment, the fixed effects part included an intercept and the main  
292 effect of VERB TYPE. The random effects part included adjustments for subjects and items of  
293 an intercept, the slope for this main effect and the correlations between intercepts and slopes  
294 (Baayen et al., 2008; Barr et al., 2013). We placed weakly informative priors on the model  
295 parameters (Nicenboim & Vasisith, 2016). The model ran with 4 MCMC chains and 3000

296 iterations each, of which the first 1500 iterations, the so-called warm-up phase, were discarded.  
297 Model convergence was verified by checking visually that the chains converged, by making sure  
298 that the  $\hat{R}$  statistics for each parameter coefficient was equal to 1 and by checking that the number  
299 of effective samples per iteration was reasonably high for the parameters of interest (Gelman  
300 et al., 2013).

### 301 *Results*

302 As can be seen in Figure 1 The results show an overall High Attachment preference (61%) in  
303 PR-compatible environments (under perceptual verbs) and a strong preference for Low Attach-  
304 ment (72%) with unambiguous RCs (under stative verbs).<sup>14</sup> The statistical model confirms that  
305 the difference between High Attachment preference in the two verb types is reliable ( $\hat{\beta} = 1.11$ ,  
306 95% CrI = [0.75, 1.51],  $P(\hat{\beta}) > 0 = 1$ ). The posterior distribution of the main effect of VERB TYPE  
307 has a range of positive numbers only (cf. Figure 2). We thus can be certain with probability 1  
308 that the true parameter value for this effect is greater than zero. In other words, given the data,  
309 we find strong evidence for a High Attachment preference in sentences with perceptual verbs.

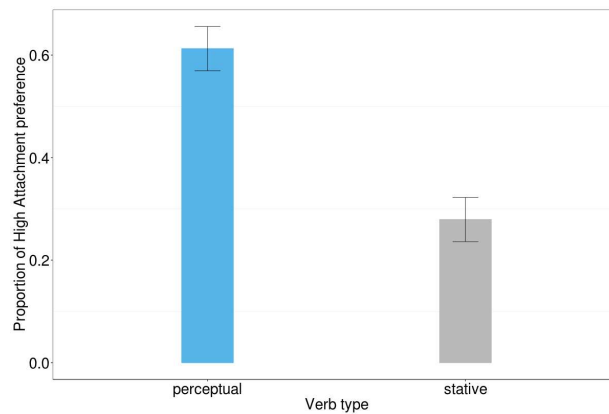


Figure 1: Mean High Attachment preference under the two verb types (with 95% confidence intervals).

310

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<sup>14</sup>On a few trials, participants left the space blank or filled in an irrelevant word (37 out of 1656 trials, 2.2% of the data). These trials were excluded from the analysis.



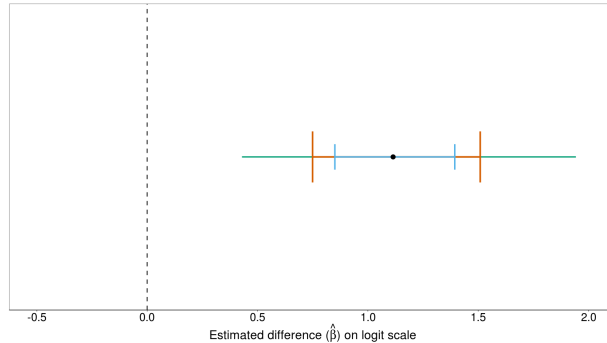


Figure 2: Posterior distribution for the effect of High Attachment preference in perceptual vs. stative verbs. The posterior's mean is represented by the black dot. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

311

312 *Intermediate discussion*

313 As in previously reported results for other PR-compatible languages, we find that PR avail-  
 314 ability strongly modulates RC attachment also in French. A strong preference for local attach-  
 315 ment is observed with unambiguous RCs (under stative predicates), supporting the idea that  
 316 locality principles play a central role across languages. Conversely, a High Attachment prefer-  
 317 ence emerges when PRs are available (with perceptual verbs). Since only the non-local NP is an  
 318 accessible subject in the PR reading, we can explain the strong preference for High Attachment  
 319 in PR-compatible environments as a preference for the PR reading over the RC reading. Exper-  
 320 iment 1 thus provides further support for the idea that PR-compatible structures are universally  
 321 preferred by the parser over RCs.

322 The set of results discussed so far provides merely indirect support for a parsing preference  
 323 of PRs over RCs. Our goal here is to provide a test capable to directly falsify the *PR-first Hy-*  
 324 *pothesis*. If PRs are indeed preferred to RCs, a RC disambiguation of otherwise PR-compatible  
 325 structures should come with an observable cost.

326 Several factors can be manipulated to force a RC reading in otherwise PR-compatible envi-  
 327 ronments. One case in point is tense. As mentioned, tense is anaphoric in PRs, but not in RCs.  
 328 In other words, the tense specification of the embedded clause must match the tense specification  
 329 in the matrix clause in PRs but not in RCs.

330 This allows us to construct minimal pairs which are locally ambiguous between a PR and RC  
331 reading up to the point of the tense specification of the embedded predicate which disambiguates  
332 the structure: tense match (15-a) is compatible with a PR reading; tense mismatch (15-b) will  
333 force a RC reading.

- 334 (15) a. Jean **a vu** la fille qui **poussait** la femme. PR/RC  
J. **has seen.PAST** the girl that **pushed.PAST** the woman.  
335 'J. saw the girl that pushed the woman / pushing the woman.'
- 336 b. Jean **voit** la fille qui **poussait** la femme. RC-only  
J. **sees.PRES** the girl that **pushed.PAST** the woman.  
337 'J. sees the girl that pushed the woman / \*pushing the woman.'

338 Tense manipulation constitutes an ideal type of disambiguation in that it allows us to keep the  
339 entire structure of 'DP + embedded clause' identical across conditions, as in example (15). The  
340 only difference across conditions is the tense specification on the matrix clause: PAST in the PR-  
341 compatible condition vs. PRESENT in the globally unambiguous RC-condition.

342 In the following sections we present the results of four experiments that were designed to test  
343 the effects of tense (mis)match in French (a PR-language) and in English (a non-PR language),  
344 while manipulating the environment of PR-compatible sentences (perceptual verbs) and RC-only  
345 sentences (stative verbs). The first two experiments used acceptability judgments as a proxy for  
346 processing complexity (Section 3). The second set of studies used eye-tracking while reading  
347 with the same stimuli, in order to further investigate the time course of the potential processing  
348 difficulty (Section 4).

### 349 3. Experiment 2: Acceptability of tense (mis)match in French and English

350 The interaction of PR-availability (verb type) and tense (mis)match was tested in an accept-  
351 ability rating experiment in French, a PR-language, and English, a non-PR language, as a control.

#### 352 *Participants*

353 Fifty-eight native French speakers (mean age 29) and 103 native English speakers (mean age  
354 31) participated in the experiments.

355 French participants were volunteers recruited on the RISC platform; English speakers were  
356 recruited via Amazon Mechanical Turk. English speakers received a monetary compensation for

357 their participation.

358

### 359 *Material*

360 Both experiments, in French and in English, realized a 2x2 design. As shown in Table 1, we  
361 manipulated two variables: VERB TYPE (perceptual / stative) and TENSE (match / mismatch). The  
362 rest of the sentence, i.e. the region of interest (NP + embedded clause), including the critical  
363 region (embedded verb), were kept identical across conditions. All relative clauses in the critical  
364 items were subject relative clauses, both in French and in English.<sup>15</sup> We created 24 items, with  
365 6 items per condition, arranged in 4 lists in a standard Latin square design. Twenty-six fillers  
366 in French and twenty-nine fillers in English were added to each list and three practice trials pre-  
367 ceded the experiment for each list.<sup>16</sup> The items and the fillers were fully randomized, so that  
368 each participant saw a different order of the sentences. The experimental items and the fillers in  
369 French and English were close translations.

370

---

<sup>15</sup>The French relative clauses used here cannot be confused with object relative clauses with a post-verbal subject. The complementizer *qui* unambiguously marks the sentence as a subject relative clause, object RCs are introduced by the alternative complementizer *que*.

<sup>16</sup>The fillers consisted of ambiguous sentences in English and in French with either a collective or a distributive reading. Sentences like "The children built a sandcastle. The sandcastle(s) were beautiful" tested whether participants thought all the children built only one castle together, or whether they thought each child built one castle of their own). All the fillers were grammatical sentences, and were rated in the range between 6.5 and 9.3 on the 1-10 scale (Dobrovie-Sorin et al. 2016).

Verb Type	Tense	Example item
Perceptual	Match	<i>Jean a vu la fille qui <b>poussait</b> la femme.</i> John <b>saw</b> the girl that <b>pushed</b> the lady.
	Mismatch	<i>Jean voit la fille qui <b>poussait</b> la femme.</i> John <b>sees</b> the girl that <b>pushed</b> the lady.
Stative	Match	<i>Jean était marié à la fille qui <b>poussait</b> la femme.</i> John <b>was married to</b> the girl that <b>pushed</b> the lady.
	Mismatch	<i>Jean est marié à la fille qui <b>poussait</b> la femme.</i> John <b>is married to</b> the girl that <b>pushed</b> the lady.

Table 1: Example of an item in the four conditions

### Procedure

The procedure was the same in English and French. Participants had to judge the acceptability of each sentence on a scale from 1 (completely unacceptable) to 10 (completely acceptable). The sentences appeared one at a time on the computer screen with the acceptability scale below it. Both experiments were run on the Ibx Platform (Drummond 2013 Ibx Farm, <http://spellout.net/ibexfarm/>). Participants did the experiment at a place of their choice. They were however asked to do it in a quiet environment and to not take breaks.

### Predictions

Based on the *PR-first Hypothesis* we should expect to see a three-way interaction of TENSE, VERB TYPE and LANGUAGE. More specifically, the *PR-first Hypothesis* predicts higher acceptability for French sentences with tense match (which are PR-compatible) than with tense mismatch under perceptual verbs. No such effect is predicted in sentences with stative verbs. Also, no interaction is expected in English, as a PR interpretation is excluded in this languages and all items describe unambiguous RCs.

### Analysis

The acceptability judgment data were analyzed with a Bayesian cumulative mixed-effects model with a logit link function (Agresti 2012; Christensen & Brockhoff 2013) using the *brms* package

390 in R. The levels of the factor TENSE were coded as 1 (match) and -1 (mismatch); the levels of  
391 the factor VERB TYPE were coded as 1 (perceptual) and as -1 (stative); the levels of the factor  
392 LANGUAGE were coded as 1 (French) and -1 (English). The interpretation of the results will follow  
393 the same principles as in Experiment 1.

394 The fixed effects part included an intercept and the main effects of TENSE, VERB TYPE and LAN-  
395 GUAGE, as well as all their possible interactions. The random effects part included adjustments  
396 for subjects and items of an intercept, of slopes for the effects and interaction of TENSE and VERB  
397 TYPE, and the correlations between intercepts and slopes. We ran the model with 4 chains and  
398 6000 iterations each. The first 3000 warm-up iterations in each chain were discarded. Model con-  
399 vergence was verified by checking the chains' convergence, the  $\hat{R}$  statistics for each parameter  
400 coefficient and the number of effective samples per iteration.

#### 401 *Results*

402 Sentences with tense match were rated as more acceptable than sentences with a tense mismatch  
403 under perceptual verbs in French (Figure 3). The effect did not show up under stative verbs,  
404 for which there was a similar acceptability level in both tense mismatch and tense match trials.  
405 Moreover, the different effect of tense on the two verb types did not show up in English.

406 Further the analysis showed that the posterior distribution for the crucial three-way interaction of  
407 TENSE by VERB TYPE by LANGUAGE excludes zero and has a range of only positive values ( $\hat{\beta} = 0.17$ ,  
408 95% CrI = [0.10, 0.24],  $P(\hat{\beta}) > 0 = 1$ ), presenting strong evidence in support of an interaction  
409 (Figure 4). To break down this interaction and see in which language we find evidence for  
410 the interaction of TENSE and VERB TYPE, we ran two additional models, one for each language  
411 separately. Each model estimated fixed effects intercept and slopes for the main effects of TENSE,  
412 VERB TYPE and their interaction, and random intercepts for subjects and items.<sup>17</sup>

413 For French (left panel of Figure 5) we found evidence for the effect of VERB TYPE ( $\hat{\beta} = 0.20$ , 95%  
414 CrI = [0.09, 0.31],  $P(\hat{\beta}) > 0 = 0.99$ ), suggesting that sentences with perceptual verbs were rated  
415 as more acceptable than sentences containing stative verbs. There was similarly reliable evidence  
416 for the effect of TENSE ( $\hat{\beta} = 0.19$ , 95% CrI = [0.09, 0.29],  $P(\hat{\beta}) > 0 = 0.99$ ), meaning that sentences

---

<sup>17</sup>Note that in a Bayesian analysis it is not necessary to apply a correction for multiple testing, such as a Bonferroni-correction for p-values in a Frequentist analysis. This is because there are no Type I or Type II errors in a Bayesian analysis, where inference does not depend on assumptions made concerning the replicability of the experiment and its results (Nicenboim et al. 2018).

417 with tense match were rated higher than sentences with tense mismatch. Most importantly, there  
 418 was strong evidence for the interaction of VERB TYPE by TENSE ( $\hat{\beta} = 0.27$ , 95% CrI = [0.17, 0.38],  
 419  $P(\hat{\beta}) > 0 = 1$ ). This interaction means there was no difference in rating between tense match and  
 420 mismatch under stative verbs, but under perceptual verbs tense mismatch sentences were rated  
 421 lower than tense match sentences.  
 422 Crucially, these results were different in English (right panel of Figure 5). In this language, there  
 423 was strong evidence for the effect of VERB TYPE ( $\hat{\beta} = 0.11$ , 95% CrI = [0.04, 0.19],  $P(\hat{\beta}) > 0 =$   
 424 0.99). There was no evidence for the main effect of TENSE ( $\hat{\beta} = 0.04$ , 95% CrI = [-0.04, 0.11],  
 425  $P(\hat{\beta}) > 0 = 0.84$ ) and, as predicted, no evidence for the interaction of VERB TYPE and TENSE ( $\hat{\beta} =$   
 426 0.03, 95% CrI = [-0.04, 0.11],  $P(\hat{\beta}) > 0 = 0.78$ ).

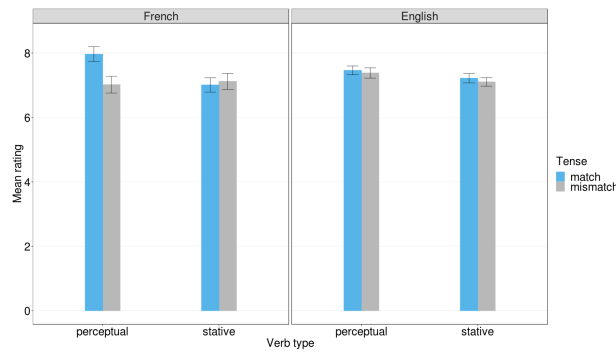


Figure 3: Mean acceptability rate (with 95% confidence intervals) as a function of tense and verb type, in French (left panel) and English (right panel).

427

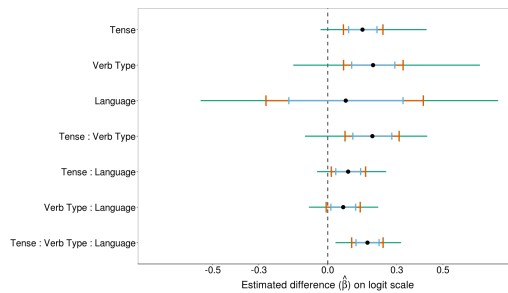


Figure 4: Acceptability rating – posterior distributions of the fixed-effects parameters in the model that includes both languages together. The black dot marks the posterior's mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

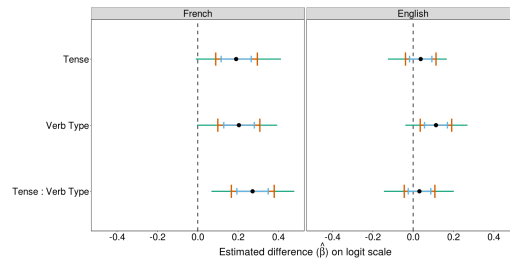


Figure 5: Acceptability rating – posterior distributions of the fixed-effects parameters in the models fitted separately for French (left panel) and English (right panel). The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

#### 430 *Intermediate Discussion*

431 As predicted by the *PR-first Hypothesis*, tense mismatch negatively affected acceptability when it  
 432 forced a RC reading in an otherwise PR-compatible environment, that is, under perceptual verbs  
 433 and only in French. The tense manipulation, however, did not affect acceptability in globally  
 434 unambiguous RC-only environments. Importantly, this interaction was only observed in French.  
 435 No effects of tense and no interaction between TENSE and VERB TYPE were found in English,  
 436 where only the RC-parse was available across the two types of verbs. The results thus fully  
 437 support the *PR-first* predictions. The parser does appear to favour a PR over a RC interpretation,  
 438 when the former is available. Along with previous results from RC attachment studies, these  
 439 results point to a preference for secondary predication over restrictive interpretation or, to put it  
 440 differently, a preference for *events* over *entities* in the complement of perceptual verbs.

441 An anonymous reviewer of a previous version of this paper correctly pointed out that the rating  
 442 of the matching condition under perceptual verbs is higher than all the other conditions and  
 443 raises the question of whether this might depend on the fact that in this condition the parser does  
 444 not have to make a choice among alternative parses, while this choice is imposed in the tense  
 445 mismatch condition, i.e. when an RC reading is imposed on the locally ambiguous structure.  
 446 Notice, however, that an interpretation of the results in terms of competition does not explain the  
 447 low ratings of the unambiguous RC conditions. Given that matrix stative predicates only license  
 448 an RC parse of the embedded clause, the positive effect of lack of competition should be also

449 observed here, contrary to what we see. Low rates in all the RC conditions seem to align with  
450 an inherent higher complexity of the RC. The reviewer's observation, nevertheless, raises a very  
451 important point, as it is important to decide whether a single factor (i.e. complexity of RCs)  
452 underlies the low ratings of RCs across verb type, or whether the effect is qualitatively different  
453 in the two environments. To address this question we need to complement the current offline  
454 results with online data.

#### 455 **4. Experiment 3: Tracking eye-movements while reading tense (mis)match across lan-** 456 **guages**

457 We now proceed to the following question: how does the apparent preference for PRs over RCs  
458 unfold online? To address this question, we ran two eye-tracking studies, one in French and one  
459 in English, using the same stimuli from the acceptability judgment experiments.

##### 460 *Participants*

461 We had two separate groups of participants, a French-speaking one and an English-speaking one.  
462 In the first group, 62 French native speakers living in Paris participated in the French experiment  
463 (mean age 28). For the experiment in English, 50 English native speakers participated in the  
464 experiment, with 26 living in London, 20 in Glasgow and 4 temporarily in Paris (mean age  
465 26). All participants gave their informed consent and received either monetary compensation or  
466 course credits to participate in the experiment, and all were naive as to the purpose of the study.  
467 All participants had normal or corrected-to-normal vision.

##### 468 *Materials*

469 The linguistic material in each language was the same as in the corresponding acceptability  
470 judgment experiment. Differently from the rating experiments, though, comprehension questions  
471 were added to verify that participants were paying attention and concentrated on reading the  
472 sentences. The experiment in French and the one in English each included 16 simple questions  
473 for each list (around 35% of all the trials). For example, for a sentence like *John saw the girl*  
474 *that pushed the lady*, the question was *Did the girl push a lady?* These questions were identical  
475 across conditions.



476 *Procedure*

477 Eye fixations were recorded with Eyelink II in the French experiment. As for English, eye  
478 fixations were recorded with Eyelink 1000 for the experiments in London, and Eyelink II for  
479 the experiments in Glasgow and Paris. The system recorded each participant's dominant eye  
480 movements while they were reading sentences using the Miles test (Miles, 1930). Sentences  
481 appeared in 20-point font on the screen on a single line for the target items. Participants had to  
482 read the sentence at a natural pace and press the space bar on the keyboard when they were done.  
483 To answer the comprehension questions, they had to press yes/no-buttons on the keyboard. Each  
484 session started with the same three practice items and lasted less than 30 minutes.

485 *Exclusion of participants*

486 In the French experiment, 10 participants had an accuracy rate of less than 85% on the compre-  
487 hension questions. Since the questions were very easy, we assumed these participants were not  
488 sufficiently concentrated on understanding the sentences. We therefore decided to exclude them  
489 from the analysis. The rest of the French participants had an accuracy rate of above 95%. In the  
490 English experiment, 13 participants with an accuracy rate of less than 85% were also excluded  
491 from the analysis; the rest had an accuracy rate of above 90%. Following these exclusions, we  
492 analyzed the data of 52 French-speaking participants and 37 English-speaking participants.

493 *Analysis*

494 The items were divided into four regions (see Table 2). The critical region included the  
495 embedded verb. According to our hypothesis, and following the results from the acceptability  
496 judgment study, tense mismatch should generate longer reading times at this disambiguating  
497 region only in PR-compatible environments (with perceptual verbs) in French, but not in  
498 English. Besides the embedded verb region we also analyzed the pre-critical region with the  
499 second noun and the complementizer, to make sure that the relevant effects do not emerge prior  
500 to the disambiguation point. Also the post-critical end-of-sentence region was analyzed, to  
501 check for possible spill-over effects. The complementizer did not constitute a separate analysis  
502 region because there were hardly any fixations on it alone. We merged it into the second region  
503 and not into the third one because, unlike the embedded verb, the complementizer does not carry  
504 any disambiguating information.

505

Conditions	Regions			
	First Noun + Verb	Second Noun + Complementizer	Verb	End of Sentence
Perception-match	<i>Jean a vu</i>	<i>la fille qui</i>	<i>poussait</i>	<i>la femme.</i>
	John saw	the girl that	pushed	the lady.
Perception-mismatch	<i>Jean voit</i>	<i>la fille qui</i>	<i>poussait</i>	<i>la femme.</i>
	John sees	the girl that	pushed	the lady.
Stative-match	<i>Jean était marié à</i>	<i>la fille qui</i>	<i>poussait</i>	<i>la femme.</i>
	John was married to	the girl that	pushed	the lady.
Stative-mismatch	<i>Jean est marié à</i>	<i>la fille qui</i>	<i>poussait</i>	<i>la femme.</i>
	John is married to	the girl that	pushed	the lady.

507 Table 2: Eye-tracking experiment: example of an item divided into the four analysis regions

508 In the analysis we were interested mainly in two dependent variables: regression path duration,  
509 which reflects the time readers fixate the region of interest for the first time until they move on  
510 to fixate the following region (Konieczny et al. 1997; Liversedge et al. 1998), and the proportion  
511 of regressions out of the region (Clifton et al. 2007). We analyzed other eye-tracking measures  
512 as well, specifically first pass reading times and total reading times, but we did not necessarily  
513 expect to find effects in all of them. The reason for this assumption is that all the sentences in  
514 this experiment are not only perfectly grammatical, but also short and involve a relatively simple  
515 semantic revision when reanalysis is required, as compared to that required by other well-known  
516 cases of reanalysis (as in e.g. classical garden path sentences or long-distance dependencies).  
517 In classical garden path sentences (e.g. *the defendant examined by the lawyer turned out to*  
518 *be unreliable*), revision of the initial thematic role assignment (from agent to patient for *the*  
519 *defendant*) is forced at the disambiguation point. Similarly, filled-gap sentences (e.g. *the cat that*  
520 *the dog worried about...*) force revision of the initial thematic assignment to the head of the RC  
521 (from experiencer to theme for *the cat*). Our manipulation does not require such a significant  
522 revision to thematic role assignment: the head NP of the RC/subject of the PR is in both readings  
523 the subject (and agent) of the embedded predicate.<sup>18</sup> Similarly, the present manipulation does not

<sup>18</sup>Notice that a change of argument structure is needed for the matrix predicate, as the matrix verb takes the modified

524 involve any major syntactic modification of the critical region (in terms of e.g. categorial status  
525 or argument structure). Garden path sentences typically involve either voice change (e.g. for the  
526 verb *examined* in the previous example) or changes to argument structure, e.g. from transitive  
527 to intransitive interpretation (for the verb *mended* in e.g. *while the woman mended the sock fell*  
528 *off her lap*). The same is true of filled-gap sentences, which involve revision from argument  
529 to adjunct interpretation. In the present manipulation, the verb stays in the active voice and no  
530 changes to argument structure are required.

531 Finally, the present manipulation does not engender any complexity effects related to locality/  
532 similarity based interference, as those observed in the processing of long-distance dependencies  
533 (Gibson, 1998; Gordon et al., 2001; Dyke & Lewis, 2003) as the subject NP and the embedded  
534 verb are in a local relation in both the RC and PR parse.

535

536 Summarizing, there is no reason to expect particularly strong effects locally at the ROI, as  
537 no revision of expected syntactic category or semantic revision is needed and because the  
538 disambiguation does not involve similarity based interference. Our manipulation (which targets  
539 tense inflection) is also not locally problematic, but might encourage regressions to ensure the  
540 main clause tense was properly parsed. Hence, we would not expect to find as strong effects in  
541 all of the typical measures that show an effect in other studies as the variables underlying the  
542 effect across these different studies vary significantly.

543

544 Regression path durations, first pass reading times and total reading times were log-transformed  
545 and analyzed with Bayesian Gaussian models (linear mixed-effects models that assume a normal  
546 distribution of the dependent variable). The proportion of regressions-out was analyzed with a  
547 Bayesian mixed-effects model that assumes a Bernoulli distribution of the dependent variable,  
548 using a logit link function. All models were fitted in the *brms* package in R.

549 In all the models, the levels of the factor TENSE were coded as 1 (match) and -1 (mismatch), the  
550 levels of the factor VERB TYPE were coded as 1 (perceptual) and as -1 (stative), and the levels of  
551 the factor LANGUAGE were coded as 1 (French) and -1 (English). Data interpretation will follow

---

DP as argument under the RC analysis, but the whole PR (perception of an event/situation) under the PR analysis. Notice however, that this is a relatively minor revision, as perception of an event also involves perception of the subject of that event (see also Rizzi (1992) for a claim that PRs in fact require direct perception of their subject and that the thematic role of stimulus is shared by the whole PR and the subject DP in this case).

552 the same principle as in the previous experiments.

### 553 *Item order effects*

554 In a first attempt to analyze the data, we fit four models, one for each of the four dependent  
555 measures (regression path duration, proportion of regressions-out, first pass duration and total  
556 reading times), on the data from the embedded verb region. Each model included, besides the  
557 experimental factors, two additional continuous covariates. The length of the region, as expressed  
558 by the number of characters it is composed of, was included in order to control for the varying  
559 length of the region across different trials. Moreover, we included interactions between the ex-  
560 perimental factors and the order of presentation of the items in the experiment. This was done  
561 in order to control for any potential learning effects during the experiment and their influence on  
562 the experimental manipulations (see below for discussion).

563 The fixed effects part of the models included the main effects and all possible interactions of the  
564 three experimental factors: TENSE, VERB TYPE and LANGUAGE. The covariate WORD LENGTH WAS  
565 centered and only its main effect was estimated (without interactions). Finally, all interactions  
566 between the three experimental factors and the centered covariate ITEM ORDER were estimated,  
567 but not its main effect. The random effects part included adjustments for subjects and items  
568 of an intercept, of slopes for the main effects and interaction of TENSE and VERB TYPE, and the  
569 correlations between intercepts and slopes.

570 All model parameters were assigned weakly informative priors. The models were run with 4  
571 chains and 3000 iterations each, whereby the first 1500 iterations were discarded. Model con-  
572 vergence was verified by visually checking the convergence of the chains and by making sure  
573 that the  $\hat{R}$  statistics for all parameter coefficients was equal to 1 and that the number of effective  
574 samples per iteration was reasonably high.

575 The results showed strong evidence for several model terms involving an interaction of ITEM OR-  
576 DER with one or more of the experimental factors. For instance, in the proportion of regressions-  
577 out model, the probability of the four-way interaction TENSE by VERB TYPE by LANGUAGE by ITEM  
578 ORDER being greater than zero was 0.96 (90% CrI = [0.001, 0.03]). This shows that the order of  
579 presentation of the items influenced processing throughout the experiment differently in the vari-  
580 ous conditions, and that these effects were dissimilar in the two languages. Figure 6 shows these  
581 effects in French for regression path duration and Figure 7 for the proportion of regressions-out  
582 (in English, since all the conditions are relative clauses, strong item order effects did not emerge;

583 this is the reason for the four-way interaction including LANGUAGE).

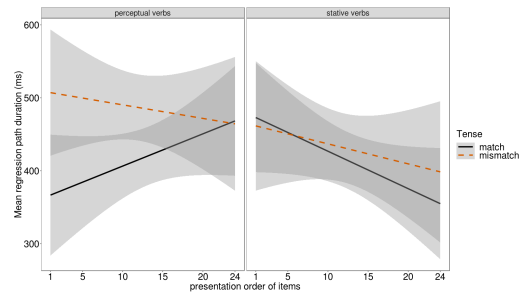


Figure 6: Regression path duration in the embedded verb region in the French data in relation with the order of presentation of the items (x-axis), as a function of Tense (solid line = tense match; dashed line = tense mismatch) and Verb Type (left panel = perceptual verbs; right panel = stative verbs).

584

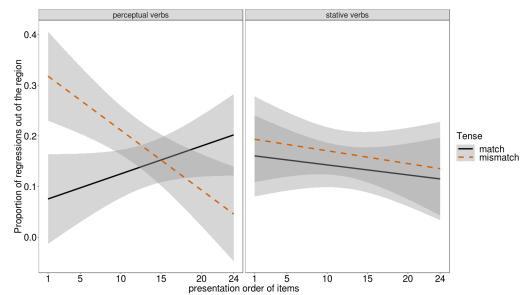


Figure 7: Proportion of regressions out of the embedded verb region in the French data in relation with the order of presentation of the items (x-axis), as a function of Tense (solid line = tense match; dashed line = tense mismatch) and Verb Type (left panel = perceptual verbs; right panel = stative verbs).

585

586 In both measures we observe that, as the experiment proceeded and more items were presented,  
587 regression path duration and proportion of regressions-out increase in tense-match and decreased  
588 in tense-mismatch sentences with perceptual verbs, whereas no such effect emerged under stative  
589 verbs. In other words, the difference between tense match and tense mismatch under perceptual  
590 verbs in French is reduced while reading more of the experimental items (cf. left panels in  
591 Figures 6 and 7).

592 While we did not expect this effect, following [Fernandes et al. \(2018\)](#), it does have a plausible  
593 explanation. Fernandes et al. argue that two aspects of the present study can lead to adaptation.  
594 First of all they point out that in our design a PR reading is possible in only one condition (tense  
595 match under perceptual verbs), whereas the remaining three conditions can only be parsed as  
596 RCs. Moreover, sentences in the PR-compatible condition also allow a RC parse. Fernandes et  
597 al. argue that this lack of balance can lead to structural priming effects, generating a stronger  
598 preference for the RC reading over the course of the experiment. Fernandes et al. also argue  
599 that the design also contains a highly reliable cue which could potentially lead to adaptation: the  
600 prediction of a PR is voided when perceptual verbs are in the present tense.

601 Learning effects of this sort are well-known, as language processing strongly relies on predictive  
602 mechanisms which have been shown to adapt to reliable cues ([Clayards et al., 2008](#); [Wells et al.,  
603 2009](#); [Kamide, 2012](#); [Fine et al., 2010, 2013](#); [Kurumada et al., 2014, a.o.](#)). Repeated exposure to  
604 unexpected syntactic structures leads to a reduction of their processing disadvantage over alterna-  
605 tive parses ([Fine et al. 2013](#); but see [Stack et al. 2018](#) for contrary evidence). Adaptation effects  
606 are thus known to occur and are not necessarily specific to our design and material. Of direct  
607 relevance for the present study, [Fernandes et al. \(2018\)](#), using an Italian version of the stimuli  
608 from the current experiment, demonstrated that participants indeed adapted to the complex, but  
609 highly reliable cue provided by the perceptual verb+present tense, which is always followed by a  
610 tense mismatched embedded clause. Moreover, they showed that reducing the reliability of this  
611 cue (by adding a small number of unambiguous PRs following perceptual verbs in the present  
612 tense) significantly lowered the effect of order of presentation.

613 Given the strong influence of these effects, in the remainder of this section we will present an  
614 analysis of the first half of the trials only, excluding the remaining trials in the data sets of both  
615 languages. Our interpretation and discussion will therefore be based on this portion of the data.  
616 An analysis of the second half of the experiment, as well as the analysis of the full data set with  
617 all items included together, are available under the following link: <https://osf.io/v26rx/>. This  
618 repository contains also the data sets and analysis R scripts for all the studies presented in this  
619 article.

## 620 *Results*

621 Table 3 shows the mean regression path duration and the mean proportion of regressions-out  
622 in each sentence region in the French and English experiments. In French, at the embedded

623 verb region, regression path duration was longer and the proportion of regressions-out higher  
 624 in sentences with tense mismatch than in sentences with tense match under perceptual verbs.  
 625 This reflects greater processing difficulty in the former condition. By contrast, when the verb  
 626 was stative there was no difference between tense match and mismatch. In English, the tense  
 627 manipulation did not influence processing at the verb region differently under perceptual and  
 628 stative verbs.

629 The Bayesian model on the regression path duration in the embedded verb region revealed evi-  
 630 dence for the crucial three-way interaction of TENSE by VERB TYPE by LANGUAGE, as indicated by  
 631 the fact that zero is excluded from the 85% credible intervals of this posterior ( $\hat{\beta} = -0.03$ , 85%  
 632 CrI = [-0.06, -0.002], 95% CrI = [-0.07, 0.009],  $P(\hat{\beta}) < 0 = 0.94$ ). The model on the proportion  
 633 of regressions-out showed even stronger evidence for the same interaction, as suggested by the  
 634 greater probability that zero is excluded from the posterior distribution ( $\hat{\beta} = -0.19$ , 85% CrI =  
 635 [-0.35, -0.05], 95% CrI = [-0.40, 0.009],  $P(\hat{\beta}) < 0 = 0.97$ ). Figure 8 shows the posteriors of  
 636 the fixed-effects in the model on regression path duration and Figure 9 shows the fixed-effects  
 637 posteriors in the model on the proportion of regressions-out. Table 4 summarizes the information  
 638 on the posteriors.<sup>19</sup>

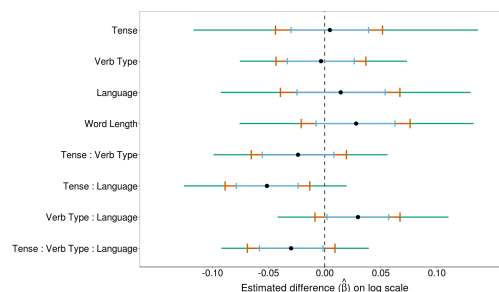


Figure 8: **Regression path duration** in the embedded verb region – posterior distributions of the fixed-effects parameters in the model that includes both languages together. The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

<sup>19</sup>In the appendix we provide a table summarizing the first-pass reading times and total reading times data, as well as a summary of the information on the fixed-effects posteriors for the models of these dependent measures. In addition, we provide the results of the analysis in the pre-critical region comprising the second noun and the complementizer, and in the end-of-sentence region in which we check for spill-over effects. The analyses reported in the appendix are not discussed, since they revealed no evidence for the relevant effects.

French data								
Verb type	Tense	Regression path duration				Proportion of regressions-out		
		First noun + verb	Second noun + complementizer	Embedded verb	End of sentence	Second noun + complementizer	Embedded verb	End of sentence
Perceptual	Match	670 (74.88)	493 (70.77)	396 (77.52)	1310 (167.13)	0.2 (0.07)	0.12 (0.06)	0.97 (0.04)
	Mismatch	657 (83.71)	519 (86.69)	495 (88.27)	1218 (166.42)	0.23 (0.08)	0.25 (0.07)	0.91 (0.05)
Stative	Match	845 (86.96)	526 (85.77)	420 (71.58)	1242 (191.1)	0.38 (0.11)	0.14 (0.06)	0.86 (0.08)
	Mismatch	723 (71.04)	483 (66.44)	431 (88.36)	1169 (149.56)	0.32 (0.09)	0.15 (0.07)	0.86 (0.07)

English data								
Verb type	Tense	Regression path duration				Proportion of regressions-out		
		First noun + verb	Second noun + complementizer	Embedded verb	End of sentence	Second noun + complementizer	Embedded verb	End of sentence
Perceptual	Match	600 (78.17)	702 (128.33)	445 (110.28)	1179 (185.71)	0.31 (0.1)	0.32 (0.12)	0.91 (0.07)
	Mismatch	656 (71.96)	728 (126.76)	383 (74.64)	1326 (166.37)	0.3 (0.12)	0.22 (0.09)	0.87 (0.1)
Stative	Match	832 (78.85)	562 (96.77)	474 (73.66)	1131 (162.07)	0.22 (0.08)	0.29 (0.11)	0.82 (0.12)
	Mismatch	859 (94.22)	624 (88.87)	442 (91.94)	1236 (162.07)	0.28 (0.11)	0.23 (0.1)	0.83 (0.09)

Table 3: Mean regression path duration in milliseconds and mean proportion of regressions-out (with 95% confidence intervals) in the French and English data, divided into the various regions of the sentence and broken by the four conditions.



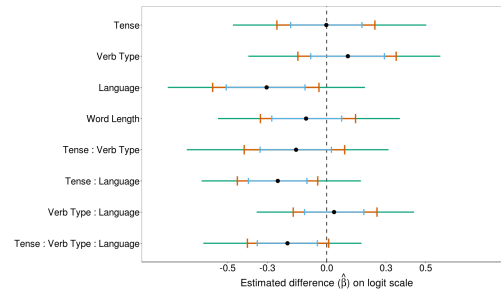


Figure 9: **Proportion of regressions out** of the embedded verb region – posterior distributions of the fixed-effects parameters in the model that includes both languages together. The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

640

641 Like in the acceptability judgment experiment, in the next step of the analysis we want to break  
 642 down the three-way interaction and see whether there is evidence for the TENSE by VERB TYPE  
 643 interaction in French but not in English, as predicted. For this purpose, we fit separate models,  
 644 one on the French data and one on the English data, for each of the dependent measures in the  
 645 embedded verb region. Each model included in the fixed-effects part parameters for the main  
 646 effect of TENSE and VERB TYPE as well as their interaction. In the random-effects part, the models  
 647 included intercepts for subjects and items.

648 As can be seen in Figure 10, the analysis of the regression path duration in French showed ev-  
 649 idence for the main effect of TENSE ( $\hat{\beta} = -0.05$ , 95% CrI = [-0.09, -0.003],  $P(\hat{\beta}) < 0 = 0.98$ ),  
 650 meaning that regression path duration was longer for sentences with tense mismatch than with  
 651 tense match. Importantly, there was also evidence for the interaction TENSE by VERB TYPE ( $\hat{\beta} =$   
 652  $-0.05$ , 85% CrI = [-0.08, -0.01], 95% CrI = [-0.09, 0.002],  $P(\hat{\beta}) < 0 = 0.97$ ). This interaction  
 653 reflects the greater processing cost of tense-mismatch sentences under perceptual verbs, as com-  
 654 pared to tense-match sentences, with no effect of tense under stative verbs. In English, although  
 655 there was evidence for the main effect of TENSE ( $\hat{\beta} = 0.06$ , 95% CrI = [0.002, 0.12],  $P(\hat{\beta}) < 0 =$   
 656 0.02), there was no evidence for the main effect of VERB TYPE and, crucially, not for the interac-  
 657 tion of the two factors ( $\hat{\beta} = 0.003$ , 85% CrI = [-0.04, 0.04], 95% CrI = [-0.05, 0.06],  $P(\hat{\beta}) < 0 =$   
 658 0.47).

Effect	Regression path duration			Proportion of regressions-out		
	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$
Tense	0.005	[-0.03, 0.04]	0.42	-0.002	[-0.18, 0.18]	0.50
Verb Type	-0.003	[-0.03, 0.03]	0.56	0.12	[-0.08, 0.29]	0.19
Language	0.01	[-0.02, 0.05]	0.29	-0.30	[-0.51, -0.11]	0.99
Word Length	0.03	[-0.008, 0.06]	0.13	-0.10	[-0.28, 0.08]	0.81
Tense : Verb Type	-0.02	[-0.06, 0.008]	0.87	-0.15	[-0.34, 0.02]	0.89
Tense : Language	-0.05	[-0.08, -0.02]	0.99	-0.25	[-0.39, -0.10]	0.99
Verb Type : Language	0.03	[0.002, 0.06]	0.06	0.04	[-0.11, 0.18]	0.37
Tense : Verb Type : Language	-0.03	[-0.06, 0.002]	0.94	-0.19	[-0.35, -0.05]	0.97

Table 4: Regression path duration and proportion of regressions-out in the embedded verb region – summary of the posteriors of the fixed-effects parameters in the models that include both languages together. For each effect we provide the estimated mean of the posterior, the 85% credible intervals and the probability that the posterior is smaller than zero. For the regression path duration, the estimated mean and the 85% credible intervals are on log scale; for the proportion of regressions-out they are on logit scale.

659 The posteriors of the models for the proportion of regressions-out are shown in Figure 11. These  
 660 models had similar results to those of the regression path models. In French the model revealed  
 661 evidence for the main effect of TENSE ( $\hat{\beta} = -0.26$ , 95% CrI = [-0.51, 0.009],  $P(\hat{\beta}) < 0 = 0.98$ ) and  
 662 for the interaction TENSE by VERB TYPE ( $\hat{\beta} = -0.26$ , 95% CrI = [-0.51, 0.007],  $P(\hat{\beta}) < 0 = 0.98$ ). In  
 663 English there was only evidence for the main effect of TENSE ( $\hat{\beta} = 0.23$ , 85% CrI = [0.04, 0.42],  
 664 95% CrI = [-0.02, 0.49],  $P(\hat{\beta}) < 0 = 0.96$ ), but not for the interaction ( $\hat{\beta} = 0.09$ , 85% CrI = [-0.10,  
 665 0.29], 85% CrI = [-0.17, 0.36],  $P(\hat{\beta}) < 0 = 0.26$ ) and neither for the main effect of VERB TYPE.  
 666 Table 5 summarizes the fixed-effects posteriors from the models of regression path duration and  
 667 proportion of regressions-out that were fitted separately on the French and the English data.

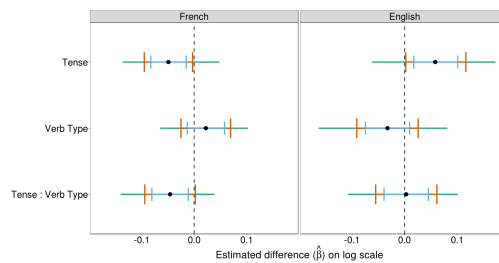


Figure 10: **Regression path duration** at the embedded verb region – posterior distributions of the fixed-effects parameters in the models fitted separately for French (left panel) and English (right panel). The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

668

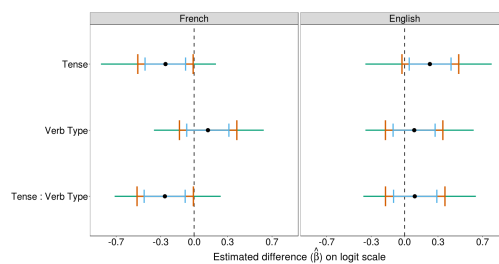


Figure 11: **Proportion of regressions out** of the embedded verb region – posterior distributions of the fixed-effects parameters in the models fitted separately for French (left panel) and English (right panel). The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

670 In sum, the outcome of the eye-tracking experiments in French and English add to (and support  
671 the interpretation of) the results of the previous offline experiments we presented in two ways.  
672 First, we replicated the finding of a tense-match advantage under perceptual verbs in French  
673 but not in English. This indicates that the preference for the PR interpretation is active at the  
674 earliest stages of processing. Second, it clarifies the results of the acceptability study, as it shows  
675 that the source of low rating of unambiguous RCs under stative verbs is different from that of the  
676 tense mismatch under perceptual verb. The latter, as shown by the eye-tracking results, is due to  
677 reanalysis, while the former is due to independent factors (e.g. inherent complexity of RCs also  
678 in the absence of ambiguity).

## 679 5. General discussion

680 In this paper, we set out to investigate the processing of the PR/RC ambiguity, with the double  
681 goal of clarifying the timing of this disambiguation and testing the *PR-first Hypothesis*, that is,  
682 the claim that the parser displays a structural preference for PRs over RCs.  
683 Previous results, based on RC attachment preferences, indirectly supported this hypothesis. Res-  
684 olution of this ambiguity in the absence of attachment ambiguities, however, had not been tested  
685 directly so far.

686 We presented three sets of experiments: one sentence completion task assessing effects of PR  
687 availability on RC attachment in French, two acceptability judgment tasks and two eye-tracking  
688 while reading studies in French and English. Each experiment adds to the results of the previous  
689 ones, providing an increasingly clearer picture on the processing of PRs and RCs.

690 The first experiment on effects of PR availability on RC attachment in French adds to previous  
691 work in this domain and further supports the *PR-first Hypothesis*. Once PR availability is con-  
692 trolled for, by using matrix verbs that only select for entities as complements, a Low Attachment  
693 preference is observed also in French. This is despite the fact that previously this language has  
694 consistently been shown to display a High Attachment preference for RCs. When PRs are made  
695 available, using perceptual matrix verbs, which can also select events, the usual High Attachment  
696 preference is observed, as previously shown for Italian, Portuguese and Spanish, but not for non-  
697 PR languages like English (Grillo et al., 2015). This first study, aside from adding an important

Effect	Regression path duration			Proportion of regressions-out		
	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$
<b>French</b>						
Tense	-0.05	[-0.08, -0.02]	0.98	-0.26	[-0.44, -0.08]	0.98
Verb Type	0.02	[-0.01, 0.06]	0.18	0.12	[-0.07, 0.31]	0.18
Tense : Verb Type	-0.05	[-0.08, -0.01]	0.97	-0.26	[-0.45, -0.08]	0.98
<b>English</b>						
Tense	0.06	[0.02, 0.10]	0.02	0.23	[0.04, 0.42]	0.04
Verb Type	-0.03	[-0.07, 0.01]	0.86	0.09	[-0.10, 0.27]	0.25
Tense : Verb Type	0.003	[-0.04, 0.04]	0.47	0.09	[-0.10, 0.29]	0.26

Table 5: Regression path duration and proportion of regressions-out in the embedded verb region – summary of the posteriors of the fixed-effects parameters in the models fitted separately for French (top) and English (bottom). For each effect we provide the estimated mean of the posterior, the 85% credible intervals and the probability that the posterior is smaller than zero. For the regression path duration, the estimated mean and the 85% credible intervals are on log scale; for the proportion of regressions-out they are on logit scale.

698 piece to the RC attachment literature, provides a baseline for the following studies that test the  
699 interplay between the verb type and tense manipulations. Having established that PR availability  
700 plays a role in the processing of embedded finite clauses in French, we moved on to ask whether  
701 this effect is also observable in the absence of attachment ambiguities and, if so, how does it  
702 unfold in time.

703 To this aim, we designed an acceptability judgment task which capitalizes on a well-known  
704 asymmetry between PRs and RCs: the constraint on the PR tense to be anaphoric to, or match  
705 that of the matrix clause. We compared acceptability ratings of (perfectly grammatical) embed-  
706 ded clauses which either matched or mismatched the matrix clause in tense specification. The  
707 (mis)matching clauses were embedded within either perceptual or stative verbs. We reasoned that  
708 a PR preference might generate a higher acceptability for PR-compatible (tense matching) em-  
709 bedding, over PR-incompatible (tense mismatching) embedded clauses. As RCs do not require  
710 tense matching, we did not expect any effects. We further predicted the effect to be language  
711 dependent. A disadvantage for tense mismatch under perceptual verbs should only be observed  
712 in PR-languages (e.g. French), but not in non-PR languages (e.g. English). The reason is that it  
713 depends on PR availability and it is not tied, for instance, to an interaction between the semantics  
714 of the matrix predicate and tense (mis)match.

715 The results fully support our predictions, showing an interaction between verb type and tense in  
716 the desired direction and only for French. A mismatch in tense between the matrix and embed-  
717 ded predicates leads to significantly lower acceptability rate under perceptual verbs. Since all  
718 the target sentences used in this experiment were perfectly grammatical, we attribute the lower  
719 acceptability to the processing cost of reanalysis, triggered by the tense mismatch, from the orig-  
720 inally preferred PR to the more complex RC.

721 Finally, we conducted two eye-tracking studies, in French and English, using the same design  
722 and materials from the acceptability studies. This final set of experiments further strengthens the  
723 interpretation of the acceptability judgments studies and contributes a valuable insight into the  
724 timing of the PR/RC ambiguity resolution. We were able to replicate the tense match advantage  
725 observed uniquely in French under perceptual verbs in eye-fixations at the disambiguating em-  
726 bedded verb region. Shorter regression path duration and a smaller proportion of regressions-out  
727 were found for tense match than for tense mismatch sentences at the embedded verb exclusively  
728 under perceptual verbs and only in French but not in English.

729 It is worth noting that the evidence for the various main effects and interactions in the eye-  
730 tracking data is based on posterior distributions that exclude zero with probability slightly smaller  
731 than 1.0. Importantly, this can be expected since we let participants read sentences that are all  
732 grammatical and with a structure that is relatively easy to parse. As discussed above, reanalysis  
733 in the present case does not involve factors known to significantly raise complexity in processing  
734 in garden-path sentences or complex structures involving word order change (like object relative  
735 clauses). Specifically, no major modification of argument structure, like inversion of thematic  
736 role assignment or similarity based interference, is involved here. Hence, we cannot expect to  
737 observe an effect-size comparable to the one found in typical studies on garden-path effects and  
738 other processing difficulties.

739 These results are consistent with the proposed preference for PRs over RCs and indicate that  
740 this is a syntactic preference present at the earliest stages of parsing and not determined by later  
741 interpretive components. Alternative interpretations of the results, e.g. in terms of frequency dis-  
742 tribution of PR vs. RCs are difficult to test. This is because establishing the relative frequency of  
743 these string identical structures (i.e. deciding whether a given occurrence of *see + DP + that* in  
744 a corpus should be counted a PR or a RC) is problematic as it would require making non-trivial  
745 decisions about disambiguation, which in general cannot be done automatically and, more often  
746 than not, cannot be done conclusively. Assuming this could be done successfully, there remains  
747 the problem of *directionality of the effect*. That is, are PRs preferred because they are more fre-  
748 quent or are they more frequent because they are more preferred on independent grounds? While  
749 frequency effects on processing complexity are well-known, we find that grounding frequency  
750 distribution in independently motivated principles of economy of computation provides a more  
751 principled explanation for the regularity of the effects described here. The preference for PRs  
752 over RCs, in fact, aligns with a more general preference for more parsimonious structures.

753 Taken together, our results provide strong direct support for the *PR-first Hypothesis*. A preference  
754 for PRs emerges both in acceptability judgments and eye-fixations with perfectly grammatical  
755 sentences. Forcing a RC reading of otherwise PR-compatible sentences leads to lower accept-  
756 ability rating and greater processing cost as expressed by longer regression path duration and a  
757 bigger proportion of regressions-out. PR availability also leads to stronger preference for High  
758 Attachment of RCs in French and, crucially, its unavailability leads to Low Attachment, support-  
759 ing a universal preference to attach incoming material to the most local host as one of the central

760 factors in RC attachment ambiguities.

761 These results further show that cross-linguistic asymmetries in parsing preferences of RC attach-  
762 ment are epiphenomenal and greatly modulated by PR availability ([Grillo, 2012](#)), among other  
763 grammatical factors ([Gilboy et al., 1995](#); [Frazier & Clifton, 1996](#); [Hemforth et al., 2000, 2015](#)).



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## 974 **Appendix A. Items from Experiment 1: French completion task**

975 Mean % of High Attachment is indicated for each item.

- |     |   |       |
|-----|---|-------|
| 976 | 1. a. Jean voit le fils du médecin qui bricole.                       | 53.84 |
| 977 | J. sees the son of the doctor that tinkers.                           |       |
| 978 | b. Pierre partage la maison avec le fils du médecin qui bricole.      | 68.75 |
| 979 | P. shares the house with the son of the doctor that tinkers.          |       |
| 980 | 2. a. Kelly entend la grand-mère de la fille qui fait le ménage.      | 38.88 |
| 981 | K. hears the grandmother of the girl that does the housework.         |       |
| 982 | b. Kelly travaille avec la grand-mère de la fille qui fait le ménage. | 0     |
| 983 | K. works with the grandmother of the girl that does the housework.    |       |
| 984 | 3. a. Jean entend le professeur du garçon qui chante.                 | 50    |
| 985 | J. hears the professor of the boy that sings.                         |       |

986	b. Jean court avec le professeur du garçon qui chante.	0
987	J. runs with the professor of the boy that runs.	
988	4. a. L'écrivain regarde la tante de la fille qui jongle.	15
989	The writer looks at the aunt of the girl that juggles.	
990	b. L'écrivain est marié à la tante de la fille qui jongle.	5.26
991	The writer is married to the aunt of the girl that juggles.	
992	5. a. Marie écoute le fils du policier qui murmure.	92.3
993	M. listens to the son of the policeman that whispers.	
994	b. Marie est employée par le fils du policier qui murmure.	53.33
995	M. is employed by the son of the policeman that whispers.	
996	6. a. Marie observe l'ami du député qui cuisine.	70.58
997	M. observes the friend of the congressman that cooks.	
998	b. Marie est fiancé à l'ami du député qui cuisine.	20
999	M. is engaged with the friend of the congressman that cooks.	
1000	7. a. Jeanne surprend la domestique de l'actrice qui vole.	75
1001	J. surprises the maid of the actress that steals.	
1002	b. Jeanne s'entraîne avec la domestique de l'actrice qui vole.	23.07
1003	J. trains with the maid of the actress that steals.	
1004	8. a. L'avocat surprend le chauffeur du voisin qui nage.	42.10
1005	The lawyer surprises the chauffeur of the neighbour that swims.	
1006	b. L'avocat s'entraîne avec le chauffeur du voisin qui nage.	31.57
1007	The lawyer trains with the chauffeur of the neighbour that swims.	
1008	9. a. David observe la fille de la domestique qui s'entraîne.	92.30
1009	D. observes the daughter of the maid that trains.	
1010	b. Marc est divorcé de la fille de la domestique qui s'entraîne.	25
1011	M. is divorced from the daughter of the maid that trains.	
1012	10. a. Alain observe la nièce de l'infirmière qui patine.	84.21
1013	A. observes the niece of the nurse that skates.	
1014	b. Alain est lié à la nièce de l'infirmière qui patine.	44.44
1015	A. is linked to the niece of the nurse that skates.	
1016	11. a. Jeanne photographie le collègue du boucher qui court.	75
1017	J. photographs the colleague of the butcher who runs.	

1018	b. Jeanne danse avec le collègue du boucher qui court.	38.46
1019	J. dances with the colleague of the butcher that runs.	
1020	12. a. Cathy regarde l'ami du juge qui peint.	80
1021	C. looks at the friend of the judge that paints.	
1022	b. Cathy est fiancée à l'ami du juge qui peint.	15.78
1023	C. is engaged with the friend of the judge that paints.	
1024	13. a. Lily imagine l'amie de la fleuriste qui travaille.	42.85
1025	L. imagines the friend of the florist that works.	
1026	b. Lily fait la fête avec l'amie de la fleuriste qui travaille.	68.75
1027	L. parties with the friend of the florist that works.	
1028	14. a. Rachel rêve de l'ami du frère qui boit.	21.05
1029	R. dreams of the friend of the brother that drinks.	
1030	b. Rachel est marié à l'ami du frère qui boit.	15
1031	R. is married to the friend of the brother that drinks.	
1032	15. a. David dessine le petit-fils de l'homme qui fume.	66.66
1033	D. draws the granddaughter of the man that smokes.	
1034	b. David est employé par le petit-fils de l'homme qui fume.	30.76
1035	D. is employed by the granddaughter of the man that smokes.	
1036	16. a. Philippe filme l'agent de l'acteur qui ronfle.	60
1037	P. films the agent of the actor that snores.	
1038	b. Philippe passe du temps avec l'agent de l'acteur qui ronfle.	15.78
1039	P. spends time with the agent of the actor that snores.	
1040	17. a. Le pompier enregistre le cousin de l'avocat qui siffle.	64.28
1041	The firefighter records the cousin of the lawyer that whistles.	
1042	b. Le pompier est employé par le cousin de l'avocat qui siffle.	31.25
1043	The firefighter is employed by the cousin of the lawyer that whistles.	
1044	18. a. Léa aperçoit l'ami du cordonnier qui danse.	73.68
1045	L. perceives the friend of the shoemaker that dances.	
1046	b. Léa est fiancée à l'ami du cordonnier qui danse.	35
1047	L. is engaged to the friend of the shoemaker that dances.	
1048	19. a. Sally photographie la belle-fille de l'infirmière qui étudie.	56.25
1049	S. photographs the daughter-in-law of the nurse that studies.	



1050	b.Sally collabore avec la belle-fille de l’infirmière qui étudie.	57.14
1051	S. collaborates with the daughter-in-law of the nurse that studies.	
1052	20. a. Le chanteur regarde le frère du PDG qui saigne.	90
1053	The singer looks at the brother of the CEO that bleeds.	
1054	b. Le chanteur étudie avec le frère du PDG qui saigne.	27.77
1055	The singer studies with the brother of the CEO that bleeds.	
1056	21. a. Le policier filme l’amie de la sœur qui tricote.	69.23
1057	The policeman films the friend of the sister that knits.	
1058	b.Le policier est marié à l’amie de la sœur qui tricote.	50
1059	The policeman is married to the friend of the sister that knits.	
1060	22. a. L’architecte imagine la sœur de la collègue qui danse.	36.84
1061	The architect imagines the sister of the colleague that dances.	
1062	b. L’architecte est divorcé de la sœur de la collègue qui danse.	5
1063	The architect is divorced from the sister of the colleague that dances.	
1064	23. a. David voit le professeur de l’ami qui pilote.	46.66
1065	D. sees the professor of the friend that flies.	
1066	b. David fait la fête avec le professeur de l’ami qui pilote.	14.28
1067	D. parties with the professor of the friend that flies.	
1068	24. a. Le voisin écoute le fils du concierge qui chante.	89.47
1069	The neighbour listens to the son of the porter that sings.	
1070	b. Le voisin va à l’université avec le fils du concierge qui chante.	31.57
1071	The neighbour goes to the university with the son of the porter that sings.	

1072 **Appendix B. Items for French *acceptability* and *eye-tracking* studies**

1073 Mean acceptability rate (scale 1–10) is indicated for each item.

1074 Legend:

- 1075 a. Perception–Match
- 1076 b. Perception–Mismatch
- 1077 c. Stative–Match
- 1078 d. Stative–Mismatch

1079	1. a. Pierre a vu le garçon qui arrosait la fille avec le tuyau.	7.5
1080	b. Pierre voit le garçon qui arrosait la fille avec le tuyau.	7.5
1081	c. Pierre a été ami avec le garçon qui arrosait la fille avec le tuyau.	6.2
1082	d. Pierre est ami avec le garçon qui arrosait la fille avec le tuyau.	7.9

1083	2. a. Léa a entendu le clown qui imitait le magicien.	7.6
1084	b. Léa entend le clown qui imitait le magicien.	7.4
1085	c. Léa a été fiancée au clown qui imitait le magicien.	8.0
1086	d. Léa est fiancée au clown qui imitait le magicien.	8.0
1087	3. a. Le policier a surpris le juge qui discutait avec le ministre.	8.5
1088	b. Le policier surprend le juge qui discutait avec le ministre.	7.3
1089	c. Le policier a couru avec le juge qui discutait avec le ministre.	6.9
1090	d. Le policier court avec le juge qui discutait avec le ministre.	6.6
1091	4. a. L'écrivain a regardé le journaliste qui menaçait le sénateur.	8.1
1092	b. L'écrivain regarde le journaliste qui menaçait le sénateur.	7.2
1093	c. L'écrivain s'est entraîné avec le journaliste qui menaçait le sénateur.	7.6
1094	d. L'écrivain s'entraîne avec le journaliste qui menaçait le sénateur.	7.2
1095	5. a. Marie a écouté le ministre qui critiquait le président.	8.5
1096	b. Marie écoute le ministre qui critiquait le président.	7.7
1097	c. Marie a été mariée au ministre qui critiquait le président.	7.9
1098	d. Marie est mariée au ministre qui critiquait le président.	8.0
1099	6. a. Sarah a aperçu le policier qui frappait le chauffeur.	9.4
1100	b. Sarah aperçoit le policier qui frappait le chauffeur.	6.3
1101	c. Sarah a divorcé du policier qui frappait le chauffeur.	6.9
1102	d. Sarah divorce du policier qui frappait le chauffeur.	6.6
1103	7. a. Jeanne a vu le professeur qui cherchait l'étudiant.	8.5
1104	b. Jeanne voit le professeur qui cherchait l'étudiant.	6.2
1105	c. Jeanne a été fiancée au professeur qui cherchait l'étudiant.	5.3
1106	d. Jeanne est fiancée au professeur qui cherchait l'étudiant.	7.1
1107	9. a. Léa a observé le bijoutier qui irritait le client.	7.5
1108	b. Léa observe le bijoutier qui irritait le client.	7.3
1109	c. Léa a collaboré avec le bijoutier qui irritait le client.	7.1
1110	d. Léa collabore avec le bijoutier qui irritait le client.	7.2
1111	10. a. Le détective a filmé le commerçant qui trompait le fournisseur.	8.2
1112	b. Le détective filme le commerçant qui trompait le fournisseur.	7.3
1113	c. Le détective a été employé par le commerçant qui trompait le fournisseur.	6.9
1114	d. Le détective est employé par le commerçant qui trompait le fournisseur.	5.4

1115	12. a. Léa a espionné le professeur qui accueillait le doyen.	8.1
1116	b. Léa espionne le professeur qui accueillait le doyen.	7.8
1117	c. Léa a vécu avec le professeur qui accueillait le doyen.	7.8
1118	d. Léa vit avec le professeur qui accueillait le doyen.	7.5
1119	13. a. Léo s'est représenté la serveuse qui agaçait la dame.	5.7
1120	b. Léo se représente la serveuse qui agaçait la dame.	6.2
1121	c. Léo se représente la serveuse qui agaçait la dame.	7.6
1122	d. Léo est marié à la serveuse qui agaçait la dame.	7.4
1123	14. a. Thomas a regardé la vendeuse qui aidait la cliente.	8.7
1124	b. Thomas regarde la vendeuse qui aidait la cliente.	6.9
1125	c. Thomas a été fiancé à la vendeuse qui aidait la cliente.	7.3
1126	d. Thomas est fiancé à la vendeuse qui aidait la cliente.	7.4
1127	15. a. David a rencontré la danseuse qui courait avec la chanteuse.	7.2
1128	b. David rencontre la danseuse qui courait avec la chanteuse.	6.8
1129	c. David a été ami avec la danseuse qui courait avec la chanteuse.	7.0
1130	d. David est ami avec la danseuse qui courait avec la chanteuse.	7.4
1131	18. a.(match-perception) Léa a enregistré la conductrice qui insultait la victime.	9.4
1132	b. Léa enregistre la conductrice qui insultait la victime.	6.7
1133	c. Léa a logé chez la conductrice qui insultait la victime.	6.9
1134	d. Léa loge chez la conductrice qui insultait la victime.	6.5
1135	19. a. Sally a entendu la soprano qui impressionnait la ballerine.	7.2
1136	b. Sally entend la soprano qui impressionnait la ballerine.	6.4
1137	c. Sally a été amie avec la soprano qui impressionnait la ballerine.	7.4
1138	d. Sally est amie avec la soprano qui impressionnait la ballerine.	7.4
1139	20. a. Le chanteur a écouté la présidente qui critiquait la journaliste.	8.1
1140	b. Le chanteur écoute la présidente qui critiquait la journaliste.	6.6
1141	c. Le chanteur a collaboré avec la présidente qui critiquait la journaliste.	6.7
1142	d. Le chanteur collabore avec la présidente qui critiquait la journaliste.	7.0
1143	21. a. Le caméraman a observé la chirurgienne qui aidait la sage-femme.	8.6
1144	b. Le caméraman observe la chirurgienne qui aidait la sage-femme.	7.3
1145	c. Le caméraman est sorti avec la chirurgienne qui aidait la sage-femme.	6.9
1146	d. Le caméraman sort avec la chirurgienne qui aidait la sage-femme.	7.7

1147	24. a. Le chorégraphe a épié la scénariste qui encourageait la pianiste.	7.4
1148	b. Le chorégraphe épie la scénariste qui encourageait la pianiste.	7.0
1149	c. Le chorégraphe a été hébergé par la scénariste qui encourageait la pianiste.	6.5
1150	d. Le chorégraphe est hébergé par la scénariste qui encourageait la pianiste.	7.2

1151 **Appendix C. Items English *acceptability* and *eye-tracking* studies**

1152 Mean acceptability rate (scale 1–10) is indicated for each item.

1153 Legend:

- 1154 a. Perception–Match
- 1155 b. Perception–Mismatch
- 1156 c. Stative–Match
- 1157 d. Stative–Mismatch

1158	1. a. Peter saw the boy that sprayed water over the girl.	7.6
1159	b. Peter sees the boy that sprayed water over the girl.	7.5
1160	c. Peter was friends with the boy that sprayed water over the girl.	8.2
1161	d. Peter is friends with the boy that sprayed water over the girl.	8.3
1162	2. a. (match-perception) Leah heard the clown that imitated the magician.	7.7
1163	b. Leah hears the clown that imitated the magician.	7.2
1164	c. Leah was engaged to the clown that imitated the magician.	7.7
1165	d. Leah is engaged to the clown that imitated the magician.	7.8
1166	3. a. The policeman was pointing at the judge that argued with the minister.	8.1
1167	b. The policeman is pointing at the judge that argued with the minister.	7.6
1168	c. The policeman was jogging with the judge that argued with the minister.	7.2
1169	d. The policeman is jogging with the judge that argued with the minister.	7.2
1170	4. a. The writer was watching the journalist that threatened the senator.	7.3
1171	b. The writer is watching the journalist that threatened the senator.	7.4
1172	c. The writer was training with the journalist that threatened the senator.	7.8
1173	d. The writer is training with the journalist that threatened the senator.	6.9
1174	5. a. Mary listened to the minister that criticized the president.	7.4
1175	b. Mary listens to the minister that criticized the president.	7.5
1176	c. Mary was married to to the minister that criticized the president.	7.9
1177	d. Mary is married to to the minister that criticized the president.	7.7

1178	6. a. Sarah caught sight of the policeman that hit the driver.	8.7
1179	b. Sarah catches sight of the policeman that hit the driver.	7.8
1180	c. Sarah was divorced from the policeman that hit the driver.	7.1
1181	d. Sarah is divorced from the policeman that hit the driver.	8.3
1182	7. a. Jean saw the professor that looked for the student.	7.6
1183	b. Jean sees the professor that looked for the student.	5.8
1184	c. Jean was engaged to the professor that looked for the student.	5.4
1185	d. Jean is engaged to the professor that looked for the student.	5.9
1186	8. a. Jack observed the postman that attacked the neighbour.	7.8
1187	b. Jack observes the postman that attacked the neighbour.	7.6
1188	c. Jack worked with the postman that attacked the neighbour.	7.9
1189	d. Jack works with the postman that attacked the neighbour.	7.7
1190	9. a. Leah was watching the jeweller that irritated the customer.	6.9
1191	b. Leah is watching the jeweller that irritated the customer.	7.4
1192	c. Leah was working for the jeweller that irritated the customer.	7.8
1193	d. Leah is working for the jeweller that irritated the customer.	7.6
1194	10. a. The detective filmed the shopkeeper that cheated the supplier.	7.8
1195	b. The detective films the shopkeeper that cheated the supplier.	7.1
1196	c. The detective was employed by the shopkeeper that cheated the supplier.	7.0
1197	d. The detective is employed by the shopkeeper that cheated the supplier.	6.8
1198	11. a. Peter was photographing the butler that attacked the gardener.	7.5
1199	b. Peter is photographing the butler that attacked the gardener.	8.3
1200	c. Peter was living with the butler that attacked the gardener.	7.0
1201	d. Peter is living with the butler that attacked the gardener.	7.8
1202	12. a. Leah spied on the professor that met the dean.	7.0
1203	b. Leah spies on the professor that met the dean.	6.9
1204	c. Leah lived with the professor that met the dean.	7.4
1205	d. Leah lives with the professor that met the dean.	6.2
1206	14. a. Tom was watching the shop assistant that helped the customer.	8.2
1207	b. Tom is watching the shop assistant that helped the customer.	7.5
1208	c. Tom was engaged to the shop assistant that helped the customer.	7.5
1209	d. Tom is engaged to the shop assistant that helped the customer	7.8

1210	15. a. David was meeting the dancer that jogged with the singer.	7.3
1211	b. David is meeting the dancer that jogged with the singer.	7.8
1212	c. David was friends with the dancer that jogged with the singer.	6.6
1213	d. David is friends with the dancer that jogged with the singer.	7.4
1214	18. a. Leah was recording the driver that insulted the victim.	8.4
1215	b. (mismatch-perception)Leah is recording the driver that insulted the victim.	7.4
1216	c. Leah lived with the driver that insulted the victim.	7.4
1217	d. Leah lives with the driver that insulted the victim.	7.7
1218	19. a. Sally heard the soprano that impressed the ballerina.	7.2
1219	b. Sally hears the soprano that impressed the ballerina.	7.6
1220	c. Sally was friends with the soprano that impressed the ballerina.	7.1
1221	d. Sally is friends with the soprano that impressed the ballerina.	7.6
1222	20. a. The singer heard the manager that criticized the journalist.	6.8
1223	b. The singer hears the manager that criticized the journalist	6.8
1224	c. (match-stative)The singer worked with the manager that criticized the journalist.	8.0
1225	d. The singer works with the manager that criticized the journalist.	7.3
1226	21. a. The cameraman was watching the surgeon that helped the midwife.	6.9
1227	b. The cameraman is watching the surgeon that helped the midwife.	7.4
1228	c. The cameraman went out with the surgeon that helped the midwife.	8.0
1229	d. The cameraman goes out with the surgeon that helped the midwife.	8.0
1230	22. a. The architect saw the girl that pushed the lady.	8.0
1231	b. The architect sees the girl that pushed the lady.	7.4
1232	c. The architect was friends with the girl that pushed the lady.	7.4
1233	d. The architect is friends with the girl that pushed the lady.	7.3
1234	23. a. David caught sight of the manager that bothered the clerk.	8.0
1235	b. David catches sight of the manager that bothered the clerk.	7.0
1236	c. David was trained by the manager that bothered the clerk.	6.4
1237	d. David is trained by the manager that bothered the clerk.	6.4
1238	24. a. The choreographer spied on the scriptwriter that encouraged the piano player.	6.3
1239	b. The choreographer spies on the scriptwriter that encouraged the piano player.	6.9
1240	c. The choreographer housed the scriptwriter that encouraged the piano player.	7.0
1241	d. The choreographer houses the scriptwriter that encouraged the piano player.	4.7

1242 **Appendix D. Justification of the choice of a Bayesian analysis**

1243 The Bayesian framework for data analysis allows the incorporation of previous information (prior) into the  
1244 experimental data that have been collected, yielding a new probability distribution (posterior) that indicates  
1245 how the prior information should be updated in the light of the observed data (Kruschke 2015; Kruschke &  
1246 Liddell 2017). The advantages of Bayesian analysis over the traditional frequentist methods are discussed in  
1247 detail in numerous publications (Wagenmakers 2007; Kruschke 2013, 2015; McElreath 2016; Nicenboim  
1248 & Vasishth 2016; Sorensen et al. 2016). Here we will only briefly mention some of the motivations for  
1249 opting for this method.

1250 The most important characteristic of Bayesian analysis is a straightforward interpretation of the results. The  
1251 posterior distribution of a main effect or an interaction provides information on how reliable the evidence  
1252 for the effect or the interaction is. This contrasts with *Frequentist* null hypothesis significance testing  
1253 methods which provide information on the null hypothesis (i.e., the possibility that there is no effect) and  
1254 not on the hypothesis actually being tested by the experimenter (Vasishth & Nicenboim 2016). Moreover,  
1255 uncertainty around effects is expressed in a Bayesian framework by means of credible intervals, for instance  
1256 95% credible intervals, defined as the portion within which we can be certain with probability 0.95 that the  
1257 true parameter lies. Again, the credible intervals thus provide direct information on the results. By contrast,  
1258 traditional confidence intervals merely provide information on sampling techniques (Wagenmakers 2007;  
1259 Hoekstra et al. 2014; Morey et al. 2016; Nicenboim & Vasishth 2016; Vasishth & Nicenboim 2016).

1260 Another benefit, specific to the use of (generalized) linear mixed-effects models, is flexibility of model  
1261 fitting. Linear mixed-effects models are known to be most reliable with large amounts of data (Matuschek  
1262 et al. 2017). Small data sets can be a problem, especially when fitting maximal models, namely models with  
1263 the maximal structure of random effects allowed by the design (Barr et al., 2013), because of convergence  
1264 problems. Bayesian model fitting, by contrast, does not fail because of model complexity.

1265 **Appendix E. Analysis results with other eye-tracking measures**

French data									
Verb type	Tense	First pass reading times				Total reading times			
		First noun + verb	Second noun + complementizer	Embedded verb	End of sentence	First noun + verb	Second noun + complementizer	Embedded verb	End of sentence
Perceptual	Match	665 (65.93)	365 (39.81)	312 (32.02)	358 (64.78)	1191 (121.94)	819 (96.59)	650 (79.79)	466 (95.04)
	Mismatch	657 (68)	375 (45.94)	341 (40.45)	380 (45.87)	1108 (89.97)	830 (104.05)	639 (66.29)	531 (71.41)
Stative	Match	838 (75.77)	304 (32.64)	304 (29.15)	382 (70.02)	1514 (136.81)	730 (71.84)	621 (68.64)	498 (89.64)
	Mismatch	723 (49)	319 (30.71)	330 (39.14)	360 (44.43)	1311 (92.41)	750 (122.17)	603 (65.7)	444 (80.25)

English data									
Verb type	Tense	First pass reading times				Total reading times			
		First noun + verb	Second noun + complementizer	Embedded verb	End of sentence	First noun + verb	Second noun + complementizer	Embedded verb	End of sentence
Perceptual	Match	600 (62.88)	373 (58.44)	282 (46.58)	481 (121.99)	1103 (148.9)	904 (128.61)	569 (80.88)	607 (130.65)
	Mismatch	656 (79.74)	399 (63.2)	306 (47.24)	407 (75.58)	1146 (134.89)	902 (120.51)	566 (89.13)	624 (87.41)
Stative	Match	812 (78.46)	390 (64.36)	349 (52.86)	414 (80.17)	1268 (123.6)	832 (121.72)	622 (92.73)	535 (92.5)
	Mismatch	850 (85.51)	422 (53.05)	316 (46.32)	405 (65.84)	1262 (125.99)	825 (117.16)	630 (84.46)	620 (88.31)

Table E.6: First pass reading times and total reading times in milliseconds (with 95% confidence intervals) in the French and English data, divided into the various regions of the sentence and broken by the four conditions.



Effect	First pass reading times			Total reading times		
	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$
Tense	-0.004	[-0.03, 0.02]	0.58	-0.01	[-0.04, 0.02]	0.71
Verb Type	-0.02	[-0.04, 0.006]	0.86	-0.01	[-0.04, 0.02]	0.69
Language	0.02	[-0.01, 0.05]	0.17	0.04	[0.002, 0.08]	0.07
Word Length	0.04	[0.02, 0.07]	0.01	0.07	[0.03, 0.11]	0.01
Tense : Verb Type	-0.01	[-0.04, 0.01]	0.77	0.004	[-0.02, 0.03]	0.41
Tense : Language	-0.01	[-0.03, 0.01]	0.74	-0.001	[-0.03, 0.02]	0.54
Verb Type : Language	0.03	[0.01, 0.06]	0.01	0.04	[0.01, 0.06]	0.02
Tense : Verb Type : Language	0.01	[-0.01, 0.03]	0.24	-0.02	[-0.04, 0.009]	0.82

Table E.7: **First pass reading times** and **total reading times** in the **embedded verb region** – summary of the posteriors of the fixed-effects model parameters. For each effect we provide the estimated mean of the posterior, the 85% credible intervals and the probability that the posterior is smaller than zero. For both dependent variables, the estimated mean and the 85% credible intervals are on log scale.

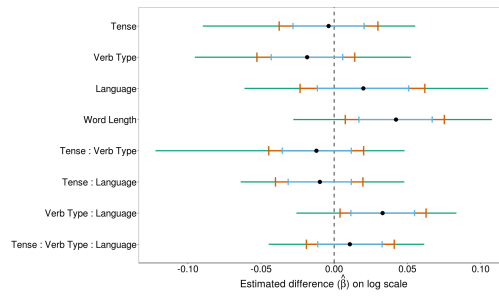


Figure E.12: **First pass reading times** in the **embedded verb region** – posterior distributions of the fixed-effects model parameters. The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

1266

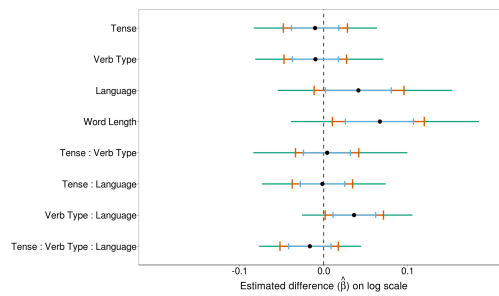


Figure E.13: **Total reading times** in the **embedded verb region** – posterior distributions of the fixed-effects model parameters. The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

1267

Effect	First pass reading times			Total reading times		
	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$
Tense	-0.02	[-0.05, 0.01]	0.83	-0.009	[-0.03, 0.02]	0.69
Verb Type	0.002	[-0.03, 0.04]	0.46	0.03	[-0.001, 0.05]	0.08
Language	0.006	[-0.03, 0.04]	0.41	-0.03	[-0.07, 0.009]	0.86
Word Length	0.14	[0.11, 0.18]	0	0.16	[0.13, 0.19]	0
Tense : Verb Type	0.03	[0.003, 0.06]	0.06	0.0007	[-0.03, 0.03]	0.48
Tense : Language	0.03	[-0.001, 0.05]	0.08	0.002	[-0.02, 0.03]	0.44
Verb Type : Language	0.04	[0.01, 0.07]	0.03	0.004	[-0.02, 0.03]	0.41
Tense : Verb Type : Language	-0.01	[-0.04, 0.01]	0.77	-0.009	[-0.03, 0.02]	0.71

Table E.8: **First pass reading times** and **total reading times** in the **pre-critical region** comprising the second noun and the complementizer – summary of the posteriors of the fixed-effects model parameters. For each effect we provide the estimated mean of the posterior, the 85% credible intervals and the probability that the posterior is smaller than zero. For both dependent variables, the estimated mean and the 85% credible intervals are on log scale.

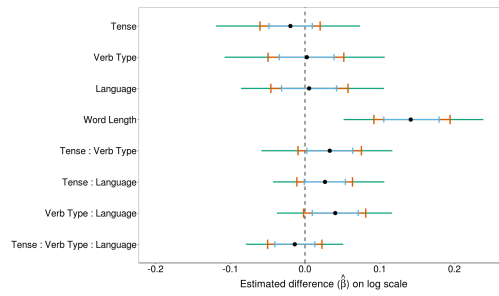


Figure E.14: **First pass reading times** in the **pre-critical region** (second noun + complementizer) – posterior distributions of the fixed-effects model parameters. The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

1268

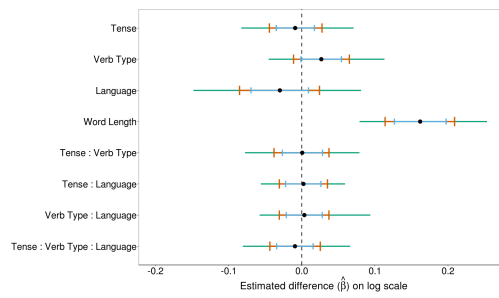


Figure E.15: **Total reading times** in the **pre-critical region** (second noun + complementizer) – posterior distributions of the fixed-effects model parameters. The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

1269

Effect	First pass reading times			Total reading times		
	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$
Tense	0.009	[-0.02, 0.04]	0.33	-0.03	[-0.05, 0.004]	0.89
Verb Type	0.02	[-0.02, 0.05]	0.23	0.02	[-0.009, 0.05]	0.16
Language	-0.05	[-0.1, -0.02]	0.98	-0.06	[-0.1, -0.02]	0.99
Word Length	0.18	[0.14, 0.21]	0	0.15	[0.11, 0.18]	0
Tense : Verb Type	0.01	[-0.02, 0.05]	0.29	0.02	[-0.01, 0.05]	0.18
Tense : Language	-0.01	[-0.04, 0.02]	0.72	0.04	[0.01, 0.06]	0.02
Verb Type : Language	-0.02	[-0.05, 0.007]	0.86	-0.02	[-0.05, 0.005]	0.88
Tense : Verb Type : Language	-0.003	[-0.03, 0.02]	0.56	-0.008	[-0.04, 0.02]	0.68

Table E.9: **First pass reading times** and **total reading times** in the **post-critical end-of-sentence region** – summary of the posteriors of the fixed-effects model parameters. For each effect we provide the estimated mean of the posterior, the 85% credible intervals and the probability that the posterior is smaller than zero. For both dependent variables, the estimated mean and the 85% credible intervals are on log scale.

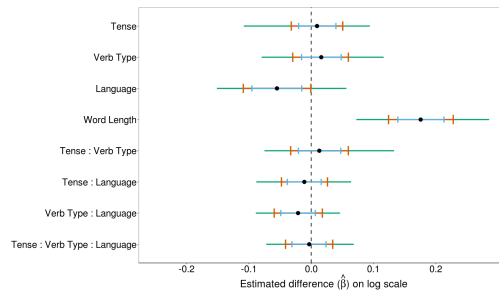


Figure E.16: **First pass reading times in the post-critical end-of-sentence region** – posterior distributions of the fixed-effects model parameters. The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

1270

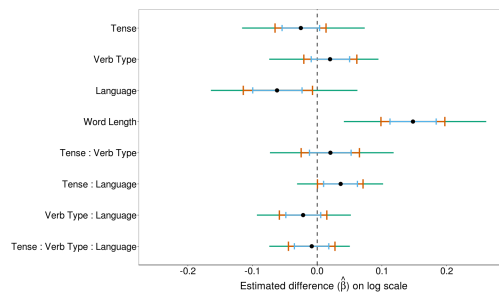


Figure E.17: **Total reading times in the post-critical end-of-sentence region** – posterior distributions of the fixed-effects model parameters. The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

1271

Effect	Regression path duration			Proportion of regressions-out		
	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$
Tense	-0.03	[-0.07, 0.01]	0.87	-0.03	[-0.21, 0.15]	0.61
Verb Type	0.01	[-0.02, 0.05]	0.25	-0.19	[-0.36, -0.03]	0.95
Language	-0.1	[-0.14, -0.06]	1	-0.03	[-0.17, 0.11]	0.60
Word Length	0.07	[0.03, 0.11]	0.009	-0.006	[-0.19, 0.17]	0.51
Tense : Verb Type	0.02	[-0.01, 0.05]	0.22	-0.02	[-0.18, 0.14]	0.58
Tense : Language	0.04	[0.01, 0.06]	0.03	0.06	[-0.07, 0.18]	0.27
Verb Type : Language	-0.03	[-0.05, 0.001]	0.91	-0.22	[-0.35, -0.09]	0.99
Tense : Verb Type : Language	-0.02	[-0.04, 0.01]	0.79	-0.04	[-0.16, 0.09]	0.66

Table E.10: **Regression path duration** and **proportion of regressions-out** in the **pre-critical region** comprising the second noun and the complementizer – summary of the posteriors of the fixed-effects model parameters. For each effect we provide the estimated mean of the posterior, the 85% credible intervals and the probability that the posterior is smaller than zero. For the regression path duration, the estimated mean and the 85% credible intervals are on log scale; for the proportion of regressions-out they are on logit scale.

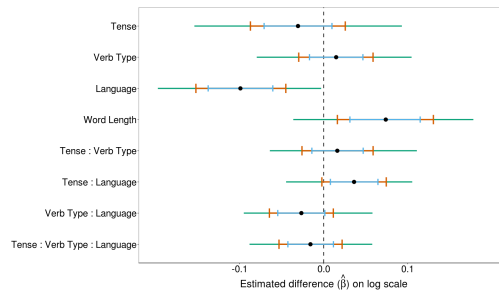


Figure E.18: **Regression path duration** in the **pre-critical region** (second noun + complementizer) – posterior distributions of the fixed-effects model parameters. The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

1272

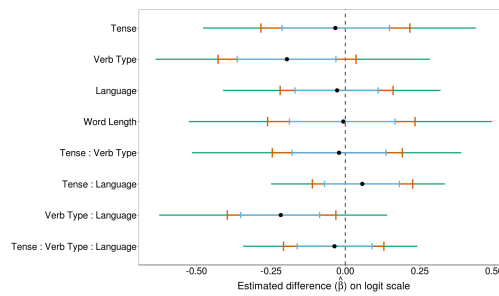


Figure E.19: **Proportion of regressions-out** of the **pre-critical region** (second noun + complementizer) – posterior distributions of the fixed-effects model parameters. The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

1273



Effect	Regression path duration			Proportion of regressions-out		
	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$	Estimated mean ( $\hat{\beta}$ )	85% credible intervals	$P(\hat{\beta}) < 0$
Tense	-0.005	[-0.04, 0.03]	0.59	0.25	[-0.02, 0.54]	0.09
Verb Type	0.02	[-0.006, 0.05]	0.12	0.40	[0.12, 0.69]	0.03
Language	-0.01	[-0.05, 0.03]	0.67	0.25	[0.002, 0.50]	0.07
Word Length	0.06	[0.03, 0.09]	0.005	-0.17	[-0.43, 0.08]	0.84
Tense : Verb Type	0.01	[-0.01, 0.04]	0.24	0.17	[-0.15, 0.49]	0.23
Tense : Language	0.04	[0.02, 0.07]	0.01	0.13	[-0.08, 0.35]	0.18
Verb Type : Language	-0.01	[-0.04, 0.02]	0.71	0.07	[-0.14, 0.3]	0.32
Tense : Verb Type : Language	0.01	[-0.01, 0.04]	0.22	-0.01	[-0.23, 0.20]	0.55

Table E.11: **Regression path duration** and **proportion of regressions-out** in the **post-critical end-of-sentence region** – summary of the posteriors of the fixed-effects model parameters. For each effect we provide the estimated mean of the posterior, the 85% credible intervals and the probability that the posterior is smaller than zero. For the regression path duration, the estimated mean and the 85% credible intervals are on log scale; for the proportion of regressions-out they are on logit scale.

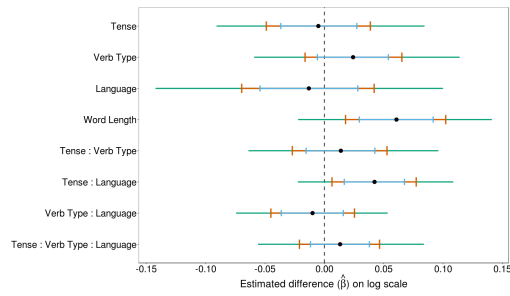


Figure E.20: **Regression path duration in the post-critical end-of-sentence region** – posterior distributions of the fixed-effects model parameters. The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

1274

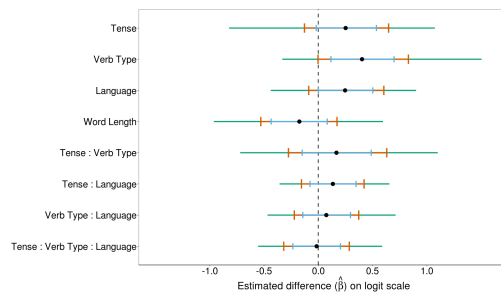


Figure E.21: **Proportion of regressions-out of the post-critical end-of-sentence region** – posterior distributions of the fixed-effects model parameters. The black dot marks the posterior’s mean. The outer bars show the 95% credible intervals; the inner bars show the 85% credible intervals. Zero is marked with a vertical dashed line.

1275