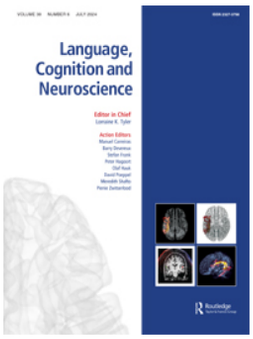

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Online evidence for pseudo-relative effects on Italian RC attachment resolution

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ABSTRACT
This study investigates the resolution of relative clause attachment ambiguities, focussing on the availability of Pseudo-Relative Small Clauses (PRs) in Italian. The PR-first hypothesis posits that, when controlling for other factors, PRs are preferred over relative clauses due to their structural simplicity, leading to an apparent preference for "high attachment" in PR-licensing languages. Through a self-paced reading experiment, this study examines how PR availability affects ambiguity resolution in Italian, and how it interacts with locality principles during online sentence processing. We find a significant slowdown in the LA condition with PR-licensing verbs, also tied to lower comprehension accuracy, and unclear evidence for an advantage of LA in non-PR contexts. Overall, our results add support to the PR-first hypothesis for Italian, while opening new questions about the interplay of structural ambiguity, locality, and language-specific properties.

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KEYWORDS
Relative clauses; pseudo relatives; attachment ambiguity; self-paced reading; Italian

1. Introduction

The cross-linguistic variability of attachment preferences for ambiguous relative clauses (RC; see 1) has been at the centre of debates about the complex array of principles/mechanisms guiding human sentence processing (Clifton Jr. & Frazier, 1996; Cuetos & Mitchell, 1988; Gibson et al., 1996; Grillo & Costa, 2014; Hemforth et al., 2000, a.o). Consider a sentence as in (1):

(1) She saw the son of the doctor that was at the party.

When a complex determiner phrase (DP) of the form *DP1 of DP2* is followed by an RC, ambiguity arises. Early studies on English revealed a general preference to disambiguate towards an interpretation that sees the RC (*that was at the party*) modify the closest DP (*the doctor*), in line with principles of locality that have been shown to be relevant for other sentence processing phenomena (De Vincenzi, 1991; Frazier, 1978; Gibson, 1991; Phillips, 1996, a.o.). Starting with a seminal study on Spanish by Cuetos and Mitchell (1988) however, we now know that languages tend to vary significantly in their preference for which DP (DP1: *the son*, or DP2: *the doctor*) the RC is attached to, leading to High Attachment (HA; the RC modifies the first DP) or Low Attachment (LA; the RC modifies the second DP) interpretations (Abdelghany & Fodor, 1999; Brysbaert, 1996; Carreiras & Clifton Jr., 1993; Cuetos & Mitchell, 1988; De Vincenzi & Job, 1993; Ehrlich, 1999; Fedorova et al., 2007; Fraga et al., 2005; Gutierrez-Ziardegi et al., 2004; Hemforth et al., 2000; Lovric, 2003; Mitchell et al., 2000; Papadopoulou & Clahsen, 2003; Shen, 2006, a.o.). Additionally, a variety of properties – referentiality of the DPs, lexical and structural frequency, semantic or pragmatic plausibility, length and structural position of the RC, implicit prosody, etc. – have been discussed as potential factors affecting variation in attachment preferences across and within languages (Acuna-Farina et al., 2009; Fernández, 2003, 2005; Ferreira, 2003; Fraga et al., 2005; Gilboy et al., 1995; Hemforth et al., 2015; MacDonald et al., 1994). Past work has also reported potential differences based on experimental task (i.e. online and offline; De Vincenzi & Job, 1993, a.o.), and individual variation across speakers as well (Swets et al., 2008). Thus, while RC attachment is clearly affected by a variety of factors, this variation still leaves unanswered questions about the interaction of ambiguity resolution strategies, language-specific properties, and general parsing mechanisms. This paper builds on these lines of inquiry and connects to recent work linking (some of) this cross-linguistic variation to the availability of syntactic structures known as *Pseudo-Relative Clauses* (Aguilar et al., 2021, 2022; Grillo & Costa, 2014; Grillo, Costa et al., 2015). In particular, we evaluate the relevance of Pseudo-Relatives to the disambiguation strategies adopted during online sentence processing in Italian.

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

1.1. The pseudo-relative-first hypothesis

Surveying past literature on RC attachment preferences in so-called HA languages (e.g. Italian, Spanish, a.o.), Grillo and Costa (2014) observed that in some of these languages there is an additional structural ambiguity available at the complementiser, beyond the classic LA *vs.* HA choice. That is, some languages allow for a structure – Pseudo-Relative Clauses (PRs) – denoting direct perception of events. While PRs and RCs are identical with respect to their surface strings, they are different at the semantic, syntactic, and prosodic levels (Grillo, 2012; Grillo & Costa, 2014, a.o.). From a syntactic perspective, RCs are usually analysed as DP-adjuncts: the matrix verb takes a DP as its complement, and that DP is directly modified by the RC – which is thus interpreted as providing restrictions on the perception of that entity/individual (2a). PRs instead have been analysed as finite constructions projected as complements of perceptual verbs (like English eventive Small Clauses; Cinque, 1992). That is, in a PR construction the matrix verb takes the whole PR as its complement and the modified complex DP (DP1 of DP2) is the subject of that clause (see Figure 1). At the semantic level, this is interpreted as reporting the perception of an event (2b).

(2) Gianni vide il figlio che correva.

a. Gianni vide [$_{DP}$il [$_{NP}$figlio [$_{RC}$che correva]]].
Gianni saw [the [son [that ran]]].

b. Gianni vide [$_{SC}$[$_{DP}$il figlio] [che correva]].
Gianni saw [[the son] [running]].

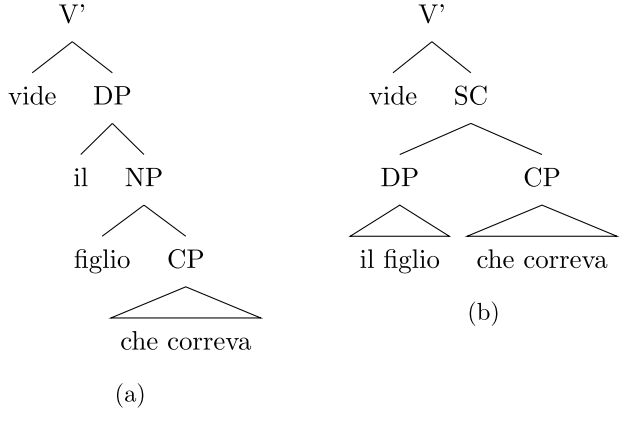

Figure 1. Sketch of the structural differences between a Relative Clause (a) and a Pseudo-Relative (b) analysis of the fragment "… vide il figlio che correva" (*saw the son that ran/running*), following Cinque (1992).

Thus, the lower DP is not grammatically available to the PR, and the only compatible reading under a PR parse is similar to an RC interpretation tied to the first DP. In essence, PR constructions do not allow for attachment ambiguity. According to Grillo and colleagues, when other linguistic factors are carefully controlled for, this ambiguity (PRs *vs.* RCs) is resolved in favour of PRs leading to what *looks like* an overall HA preference in PR-licensing languages (the *PR-first* Hypothesis). In other words, the PR-first hypothesis implies that, when faced with a sentence ambiguous between a PR and an RC interpretation, and in the absence of other disambiguating cues, the parser favours committing to a PR structure (Aguilar et al., 2021, 2022; Grillo & Costa, 2014; Grillo, Costa et al., 2015).

Importantly, while string identical, the structural and interpretative differences between PRs and RCs are reflected in their distribution, so that a variety of properties can be manipulated to modify the availability of one over the other in sentential contexts. As mentioned above, PRs are arguments of the verb, and they are *eventive*: they denote the direct perception of ongoing situations (Cinque, 1992). Thus, PRs are allowed under perceptual verbs (which can introduce both entities and events) but, like English small clauses, they are disallowed under stative predicates – which can only select entities/DPs, and thus cannot license PRs or eventive SCs. Also tied to the fact that PRs describe direct perception of events are tense restrictions on their distribution. Since the tense of the embedded clause is anaphoric in PRs, the perceptual action introduced in the matrix clause and the embedded clause event must happen simultaneously. Thus, the tense specification of the matrix and the embedded verbs must match. A detailed discussion of the variety of restrictions on the distribution of PRs is outside of the scope of this paper, but the reader is referred to Grillo (2012) and Grillo and Costa (2014) (for an overview of semantic and syntactic properties of PR-licensing environments) and Moulton and Grillo (2014), Grillo and Moulton (2016), and Grillo and Turco (2016) (for an in-depth discussion of PR availability and prosodic differences between PRs and RCs).

Relevant to this paper is the fact that Grillo and Costa (2014) exploit a restriction on PR-availability tied to the properties of the matrix verb in order to test their hypothesis experimentally. Specifically, they tested Italian participants in an offline questionnaire on attachment preferences for 74 minimal pairs of sentences. The sentences contained either a PR-compatible verb (perceptual verbs), allowing for the selection of both PRs and RCs, or a stative verb only permitting RCs. Based on what summarised above, Italian allows for the three-way ambiguity of PR *vs.* HA RC

vs. LA RC when the matrix verb is perceptual but, when the verb is not perceptual, the ambiguity of PR *vs.* RC disappears. According to the PR-first Hypothesis then, when PRs are available (with perceptual verbs), Italian participants should prefer that structure and exhibit a "HA-like" interpretation.[1] When a PR-parse is not available and RC structures are the only available options (with stative verbs) the parser should then prefer an LA interpretation over the HA interpretation – following principles privileging locality of structure building (e.g. Late Closure or Recency; Frazier, 1978; Gibson, 1991). In line with these predictions Grillo and Costa (2014)'s results showed a strong preference for HA in the ambiguous PR/RC condition (78.6% HA) and a strong LA preference with unambiguous RCs (24.2% HA). These results have since then been extended to a number of languages, with different manipulations of PR-availability (Aguilar et al., 2021; Aguilar & Grillo, 2021; Alonso-Pascua, 2020; Branco-Moreno, 2014; Grillo, Costa et al., 2015; Grillo, Hemforth et al., 2015; Grillo & Spathas, 2014; Pozniak et al., 2019; Tomaz et al., 2014, a.o.). Additionally, recent studies have been controlling for PR-availability in order to evaluate the effect of other factors (morphosyntactic and semantic features, RC length, RC position, etc.) on ambiguity resolution strategies (Aguilar et al., 2022; Foppolo & Abbondanza, 2021).

1.2. PR-first and online preferences

Importantly, the PR-first hypothesis makes specific predictions not just about the interaction of PR-availability and locality of structure building effects, but about the timing of such effects during incremental processing. In particular, Grillo and Costa (2014) predict that the parser should prioritise i) a PR parse (for PR-related economy principles), ii) an LA RC parse (for locality principles) and then iii) a HA RC parse, in this order (as in Figure 2).[2] Thus, if we consider *temporarily* ambiguous sentences that are fully disambiguated towards one interpretation by the end of the parse (3), different levels of effort should arise depending on whether the disambiguating continuation (e.g. *was* in 3) is compatible with a HA or LA interpretation in PR-licensing or RC-only contexts.

(3) a. She saw the **son** of the doctors that **was** at the party.
b. She saw the son of the **doctors** that **were** at the party.

That is, we expect disambiguating towards an LA interpretation in PR-licensing contexts (e.g. with perceptual verbs) to be costly, since the parser should have first committed to a PR structure. If locality

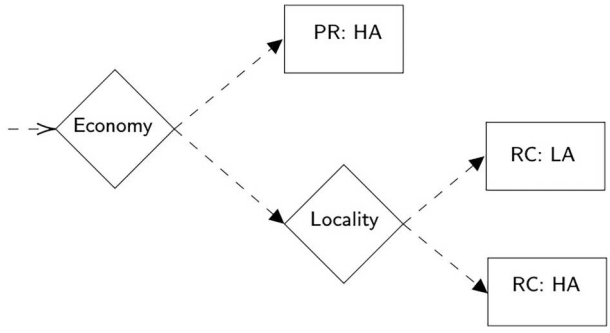

Figure 2. Sketch of the choices the parser is faced with when parsing ambiguous RC/PR structures, according to the PR-first Hypothesis.

principles are in action and bias the parser to prefer an LA RC structure over a HA RC one, in RC-only contexts we also expect more effort when disambiguating towards a HA interpretation. In this sense, while a variety of studies have reported evidence for PR-effects offline, only a few have explored the predictions of the PR-first hypothesis on word-by-word disambiguation strategies. Among these, Pozniak et al. (2019) focussed on the resolution of the PR vs. RC structural ambiguity, by modulating tense restrictions on PR availability. They modulated matrix-embedded clause tense-matching (PR licensing) with matrix-embedded clause tense-mismatching (PR incompatible) in an acceptability (offline) study and an eye-tracking study on French (a PR language) and English (a non-PR language). In both studies, their sentences varied across two dimensions: verb type (perceptual/stative) and tense (match/mismatch). Consistently with the PR-first hypothesis, French sentences with tense match were found to be more acceptable than those with a tense mismatch with perceptual verbs, but not with stative verbs. Focusing on the online results, they found a PR-advantage (shorter regression-path duration for the tense-matching condition) in PR-compatible contexts at the embedded verb in French. No tense effects modulated by verb type were found for English during offline or online tasks, consistently with the PR availability assumption and also in line with what was found for English RCs by Grillo, Costa et al. (2015).

Crucially, Pozniak et al. (2019) did not investigate the interaction between PR vs. RC ambiguity and HA vs. LA ambiguity. In their study, sentence continuations (including the embedded verb) were all identical across conditions apart from the tense manipulation. As mentioned above, the PR-first hypothesis gives us the tools to explore the joint interaction of PR-availability and locality principles. In this sense, Aguilar

et al. (2021) explored whether principles of locality and PR availability apply to the real-time comprehension of PR/RC ambiguous structures by conducting an eye-tracking experiment in Spanish.

Their materials consisted of temporarily ambiguous Spanish sentences with a complex DP ([DP1 of DP2]) followed by a finite that-clause, placed in the object position of either perceptual or non-perceptual verbs. Additionally, the two DPs differed in their grammatical gender: DP1 was masculine in half of the sentences and feminine in the other half, while DP2 had the reverse pattern. Gender agreement was then used to disambiguate all sentences: ambiguity was resolved towards HA or LA on an adjectival secondary predicate following the verb, agreeing in gender with only one of the two possible antecedents. Differently from Pozniak et al. (2019), matrix and embedded clause matched in tense across all conditions so that PR-availability was exclusively manipulated via verb type.

Aguilar et al. (2021) found evidence for a PR-effect in total reading time duration, with HA resolution being preferred over LA resolutions in PR-compatible contexts. However, in contrast with Pozniak et al. (2019), they found no PR-effect in more fine-grained measures of effort at the disambiguating region (i.e. Regression Path Duration), which they attribute to potential differences in study design and goals – in particular, the fact that Pozniak et al. (2019) used tense manipulation to evaluate the timing to PR/RC resolution, with no controls for LA/HA preferences. Additionally, Aguilar et al. (2021)'s results show an early preference for LA interpretations in RC-only contexts, thus adding evidence in support of parsing principles of locality guiding ambiguity resolutions when other structural factors (here, PR availability) are controlled for. Finally, they conducted an offline questionnaire by modifying the materials from their online study to be globally ambiguous. Here, they found an overall preference for HA, and argue that the online LA preference is overridden offline by other factors (e.g. length of the RC; Hemforth et al., 2015) in contrast with other studies that found offline preferences in Spanish to also be affected by PR-availability (Aguilar & Grillo, 2021; Alonso-Pascua, 2020; Branco-Moreno, 2014).

Overall then, Pozniak et al. (2019) and Aguilar et al. (2021)'s results suggest that real-time online processing can indeed be influenced by the presence of PRs, in line with the PR-first hypothesis. However, they leave many questions open about the cross-linguistic variability of this modulation, its interaction with the timing (and existence) of locality principles, and the potential different mechanisms captured by online and offline techniques. Asymmetries between offline and online tasks are well-known in the psycholinguistic literature on RC attachment, with some studies reporting consistent behaviour across tasks (Carreiras & Clifton Jr., 1993, a.o.), while others mirroring Aguilar et al. (2021)'s differential results (Maia et al., 2007; Pynte et al., 2003, a.o.). For instance, De Vincenzi and Job (1993) observe a similar mismatch in Italian: although an HA preference is dominantly observed in the results of offline tasks, online results based on self-paced reading tasks show an initial LA preference followed by a later reanalysis for HA. Importantly though, De Vincenzi and Job (1993) did not control for PR-availability, and so it is not fully possible to explore the interaction of such mismatches with the additional ambiguity observed by Grillo and Costa (2014). More broadly, the PR-first hypothesis is meant to capture a generalisation about potential sources of ambiguity tied to PR structures, but since PR properties differ across languages it is not necessarily making claims about the fact that such availability should have identical effects on processing strategies across all PR-licensing languages (Grillo et al., 2014). Therefore, extensive cross-linguistic investigation is necessary in order to fully understand the impact of such effects, and probe potential differences in mechanisms highlighted by different tasks.

Bringing our focus back to Italian, Foppolo and Abbondanza (2021) recently investigated how different disambiguating cues (i.e. gender, number, and animacy) affect RC attachment preferences in Italian across a variety of offline (acceptability judgments) and online (self-paces reading and Maze) tasks. They found that, when PR-availability is controlled for, attachment preferences vary based on different semantic and morphosyntactic cues/properties, depending on the nature of the task. Importantly though, target items in their study were limited to sentences using stative verbs (i.e. verbs that disallow PRs) and thus their results cannot speak to the interaction of locality principles of disambiguation and RC/PR disambiguation strategies.

In this paper then, we set out to extend Grillo and Costa (2014)'s original results for Italian and explore online effects of PR-availability during the processing of temporarily ambiguous sentences with a self-paced reading paradigm. Our study aims to contribute cross-linguistic insights to the understanding of (a) the timing of how PR availability influences parsing preferences in contexts that allow for both PRs and RCs and (b) how RC attachment preferences manifest online when a PR parse is made unavailable.

2. Materials and methods

2.1. Participants

One hundred and two Italian participants (average age: 32.11) were recruited using the online subject pool Prolific, and were compensated with $15/hr upon completion of the task. Task completion was evaluated through the use of a completion code presented to participants at the end of the experiment. For the purpose of this study, the Prolific interface was set up to automatically restrict participation to users whose first language was Italian, and residing in Italy at the time of the experiment.

2.2. Design and materials

We conducted a self-paced reading experiment with two factors crossed: matrix verb type – PR taking verbs (perceptual verbs) *vs.* RC only verbs (non-perceptual verbs) – and attachment type (HA *vs.* LA). Target stimuli were declarative sentences including a complex DP of the form [DP1 of DP2] followed by a finite relative clause. All sentences were adapted from the original globally ambiguous sentences in Grillo and Costa (2014) but modified to be temporarily ambiguous until the embedded verb (Table 1). Temporal ambiguity was resolved on the embedded verb by number feature matching with an antecedent noun (the singular/plural modified DP). Number disambiguation was chosen in order to have one single point of disambiguation with minimal changes across conditions, while keeping matrix and embedded verbs matched and avoiding strong cues for RCs vs PRs before the disambiguating word (cf. Aguilar et al., 2021; Pozniak et al., 2019). We used number morphosyntax –instead of gender agreement as in Aguilar et al. (2021) – so to modify the sentences in Grillo and Costa (2014) as little as possible. Non-trivial changes would have been required to add a secondary adjectival predicate (to showcase gender agreement) while also preserving tense-matching and naturalness to modern Italian speakers. Furthermore, DP1 and DP2 were kept animate and of the same gender (within each individual item) in order to avoid animacy/gender attraction effects. To avoid potential gender bias effects (Reali et al., 2015; Tripp & Munson, 2022; Vigliocco & Franck, 1999) the number of masculine/feminine [DP1 of DP2] complexes was counterbalanced across items and conditions (i.e. half the items contained masculine DP pairs, and the other half feminine DP pairs).

Previous literature has reported that both gender and number manipulation can lead to attraction effects in

Table 1. Italian stimuli by condition, and regions for the analysis.

	Verb (PR availability)	Attachment				Target	Spillover 1	Spillover 2
a.	Perceptual (PR/RC)	LA	*Gianni vide il figlio dei*	*medici*	*che*	*correvano*	*la*	*maratona*
			Gianni saw the son-SG of the	doctors-PL	who	were running-PL	the	marathon
b.	Perceptual (PR/RC)	HA	*Gianni vide il figlio dei*	*medici*	*che*	*correva*	*la*	*maratona*
			Gianni saw the son-SG of the	doctors-PL	who	was running-SG	the	marathon
c.	Non-Perceptual (RC only)	LA	*Gianni amò il figlio dei*	*medici*	*che*	*correvano*	*la*	*maratona*
			Gianni loved the son-SG of the	doctors-PL	who	were running-PL	the	marathon
d.	Non-Perceptual (RC only)	HA	*Gianni amò il figlio dei*	*medici*	*che*	*correva*	*la*	*maratona*
			Gianni loved the son-SG of the	doctors-PL	who	was running-SG	the	marathon

comprehension (Acuna-Farina et al., 2009; Cunnings et al., 2017; Gonzalez Alonso et al., 2021; Slioussar & Malko, 2016, a.o.). In particular, when number was used as a source of disambiguation some studies report that a preference for HA was not always found in Spanish (Carreiras et al., 2001; Fernández, 2003; Fernández & Sainz, 2004; Ferreira, 2003). In Italian acceptability judgments and self-paced reading results, Foppolo and Abbondanza (2021) report no interaction between the properties of the antecedent DPs (gender, number, animacy) and attachment (HA/LA), although effects of both number and gender were found for the Maze task. Nonetheless, in the design of our materials, we fully counterbalanced number across all conditions, which allows us to potentially explore the effects of agreement on our main questions.

Target items were built in quartets (Table 1), comprising of two sentences with perceptual verbs, and two sentences with stative verbs. For each verb type in the quartet, one sentence was then disambiguated towards HA, and the other towards LA. As mentioned, disambiguation was operationalised via number agreement between one of the two antecedent DPs and the embedded verb. The number of singular and plural nouns in the DP1 or DP2 position was counter-balanced per verb-type condition across materials. That is, the number of items containing the configuration $DP1_{sing}$ and $DP2_{plur}$ was the same as the number of items containing the $DP1_{plur}$ and $DP2_{sing}$ configuration, and the same was true for the number morphology on the disambiguation verb (i.e. the number of LA/HA disambiguations using singular agreement was the same as the number of LA/HA disambiguations using plural agreement).

Based on these quartets, we created 24 lexically distinct sets of experimental items over the four target conditions, distributed among four lists in a Latin Square design. Forty-eight fillers were intertwined with target items. Both Pozniak et al. (2019) and Aguilar et al. (2021) reported ordering effects in their online experiments – as effects of PR availability were present only in the first half of their items – which they ascribe to within-task priming of the RC structure due to its availability across all conditions. To address this, we included 24 unambiguous PRs (as in 4), which have been shown to compensate for the potential imbalance in the target data (Fernandes et al., 2018):

(4) Gianni vede Matteo che corre la maratona.
"*Gianni sees Matteo who runs the marathon.*"

The remaining fillers were attention checks created with sentences containing number or colour words (e.g. 5).

Table 2. Predictions of RT effort at the disambiguating word (>: slower/harder than).

Condition	Verb type	Prediction
PR/RC	Perceptual	LA > HA
RC only	Non-perceptual	HA > LA

(5) Sara ha tre libri e Matteo ha quattro penne.
"*Sara has three books and Matteo has four pens.*"

In sum, each participant saw 72 sentences in total (24 target sentences and 48 filler sentences). All materials are available on OSF.

2.3. Procedure

The self-paced reading experiment was conducted on the web-based survey platforms Ibex Farm ($N = 73$) and PCIbex Farm ($N = 39$) (Zehr & Schwarz, 2018). In order to familiarise participants with a word-by-word self-paced non-cumulative moving window reading task, a practice session was included prior to the trial. Participants were asked to read the sentences at their natural speed, and the presentation order was randomised across participants. Each sentence appeared on a single line. After each sentence, participants were presented with a comprehension question probing accurate interpretations of the sentences. The overall experiment took an average of 20 minutes. The protocol was approved by the IRB.

2.4. Predictions

Predictions are summarised in Table 2. In PR constructions, the first DP serves as the subject of the embedded clause, aligned with the HA interpretation. Consequently, LA sentences should be more challenging to disambiguate towards than HA sentences with perceptual verbs, since the parser would have to discard the PR structure it had partially committed to. Thus, according to the PR-first hypothesis, when we force an LA interpretation in PR-compatible contexts, we expect to incur some additional effort at the disambiguating word. In RC-only contexts, if locality principles hold, we anticipate the reverse pattern: increased effort should be observed in high-attachment sentences following non-perceptual verbs – under the assumption that the parser prefers local attachment in the absence of other factors (Frazier, 1990; Gibson, 1998; Gibson et al., 1996).

3. Results

Analyses were conducted on the response accuracy for the comprehension task, and reading times (RTs)

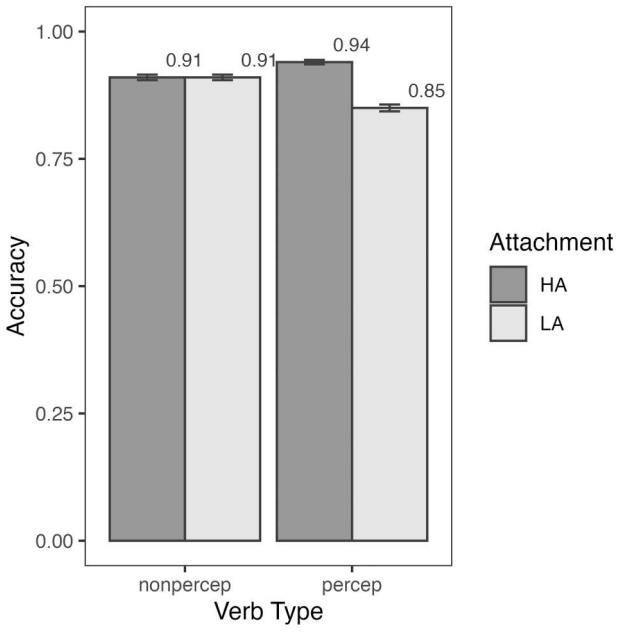

Figure 3. Accuracy of the comprehension task.

within the regions of interest. Data from participants whose comprehension task accuracy was below 80% for target sentences were discarded. Nineteen participants failed to meet this criterion (17%). Additionally, in the RT analyses, all items with incorrect answers (9.7%) were excluded.

3.1. Comprehension results

For the statistical analyses conducted as part of this study, we utilised the R statistical software, version 4.1.2 (R Core Team, 2021) and the lme4 package, version 1.1.31 (Bates et al., 2015), for linear mixed-effects modelling.

Among the 93 participants included in the analysis, the average comprehension accuracy was 90.58%. A summary of the comprehension results based on Verb and Attachment Type is in Figure 3 and Table 3. Visually, we observe that comprehension rates in the Perceptual Verb-LA condition were lower than the other conditions. Comprehension accuracy rates were analysed using a generalised LME model with a binomial distribution, using Verb Type, Attachment Type, and Number features of the second DP (DP2) as fixed factors. The final converged model was *answer* ~ *verb*∗*attachment*∗*dp2_num*+

Table 3. Accuracy of the comprehension task (raw counts in parentheses).

	HA	LA
Non-perceptual verb (RC only)	91% (2752)	91% (2746)
Perceptual verb (PR/RC)	94 % (2765)	85 % (2770)

Table 4. Summary of logistic mixed effect analysis of the comprehension task.

Term	Estimate	Std. Error	*z* value	Pr(> |*z*|)
(Intercept)	2.8266	0.5304	5.330	9.84e−08***
Perceptual(P) verb	1.6330	0.2426	6.731	1.68e−11***
LA	−0.1690	0.1704	−0.992	0.321325
DP2_sg	0.9012	0.6938	1.299	0.193938
P verb:LA	−1.0136	0.2927	−3.463	0.000534***
P verb:DP2_sg	−2.0441	0.2996	−6.823	8.89e−12***
LA:DP2_sg	0.5447	0.2336	2.331	0.019732*
P verb:LA:DP2_sg	−0.0550	0.3708	−0.148	0.882087

(1|*participant*) + (1|*set*). For the binomial logistic model, *p*-values were taken from the Z value. All factors were treatment-coded. Statistical results are described in Table 4.

We found a significant effect of Verb Type and a strong interaction effect between Verb Type and Attachment Type. We also found a significant interaction effect between the number properties of the second DP and Verb Type, and a marginal interaction between DP2 number and Attachment Type. Note that the number properties of DP2 are symmetrical with respect to the properties of DP1 (that is, when DP1 is singular DP2 is plural, and vice versa, across all items and conditions). We visualise comprehension rates split by number in addition to the other factors in Figure 4 (see also Table 5).

Finally, planned (paired) contrasts are reported using the Tukey test (using the emmeans function) in the emmeans R package (Lenth et al., 2018). For simplicity, while all potential pairwise comparisons were performed, we report in Table 6 only the significant

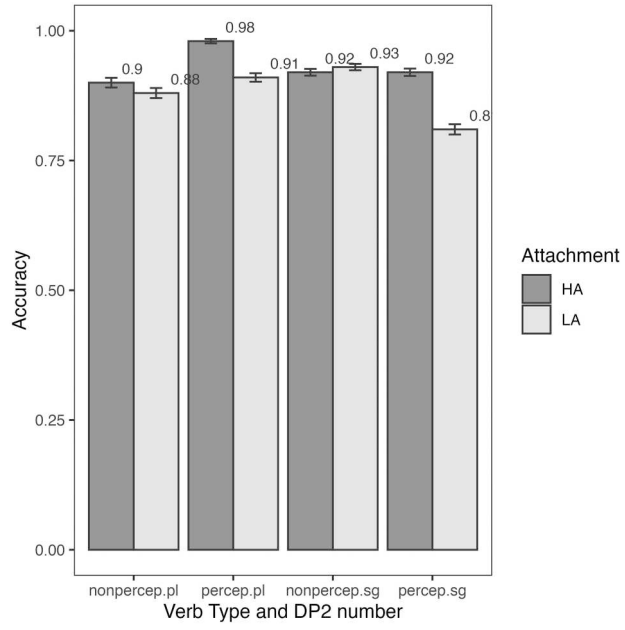

Figure 4. Accuracy of the comprehension task by attachment type, verb type, and DP2 number.

Table 5. Accuracy of the comprehension task by Attachment Type, Verb Type, and DP2 number (raw counts in parentheses).

Verb	DP2	HA		LA	
Non-perceptual verb (RC only)	plural (pl)	92%	(1710)	93%	(1645)
	singular (sg)	90%	(1042)	88%	(1101)
Perceptual verb (PR/RC)	plural (pl)	92%	(1505)	81%	(1575)
	singular (sg)	98%	(1260)	91%	(1195)

contrasts. Notably, the difference between HA and LA found for perceptual (but not non-perceptual) verbs (as in Figure 3) was significant independently of number (c: Estimate = 1.1826, SE = 0.232, $z = 5.099$, $p<.0001$; g: Estimate = 0.6929, SE = 0.154, $z = 4.490$, $p = 0.0002$). Additionally, we observe a HA advantage for perceptual verbs over non-perceptual verbs, but only in the plural case (a: Estimate $= -1.6330$, SE = 0.243, $z = -6.731$, $p<.0001$).

3.2. Self-paced reading results

For the analysis of self-paced reading data, sentences were segmented into three regions for analysis. The critical region was the disambiguating verb (**target**). Each of the two words following the target served as a separate spillover region (**spillover1** and **spillover2**) to capture any delayed effects, and potential sentence wrap-up effects. The region number was not present on the screen during the task. For the reading time data analysis with R(version 4.1.2), we used Linear Mixed Effect Regression (LMER) analysis (Baayen et al., 2008; Frank & Jaeger, 2010; Jaeger, 2008), using the lme4 R package (Bates et al., 2015, version 1.1-31).

Before the RT analyses, data-trimming processes were applied in the following steps. First, items (9.4%) that were inaccurately answered were additionally excluded. RTs shorter than 100 ms and longer than 5000 ms were eliminated as outliers, affecting 0.16% of the data. Then, we calculated residual reading times to compensate for variation in word length across similar conditions and to account for individual differences in reading times (deviations from regressions; Ferreira & Clifton Jr., 1986; Keating & Jegerski, 2015; Trueswell et al., 1994, a.o.). We first transformed the RT data to a logarithmic scale for normalisation, and we calculated word length for each observation as the number of characters in each word. A linear mixed-effects model was then fitted with the logarithmically transformed RTs as the dependent variable, and word length as a fixed effect. We included random intercepts for participants to account for between-subject variability. Finally, we calculated the residual RTs from this model by using the residual function in R. These residuals represent the RTs after removing the predicted effects of word length, thus providing a measure of reading time adjusted for this factor. This process ensures that the resulting data are normalised and that the analysis considers individual reading speeds and the inherent differences in word lengths in a sentence across conditions. Following Keating and Jegerski (2015), we also removed data points beyond three standard deviations from the mean of the relevant condition (less than 2.27% of the test data). The analyses presented below are based on the residual RTs for the remaining trials (see Figure 5 for both raw and residual RTs at the critical regions).

Table 6. Summary of pairwise comparison of the comprehension task.

Comparison	Estimate	SE	*z*.ratio	*p*.value
a. nonpercep HA pl -- percep HA pl	−1.6330	0.243	−6.731	< .0001
b. nonpercep LA pl -- percep LA pl	−0.6194	0.164	−3.772	0.0040
c. nonpercep HA sg -- percep LA sg	1.1039	0.137	8.031	< .0001
d. nonpercep LA sg -- percep LA sg	1.4797	0.148	9.993	< .0001
e. percep HA pl -- percep LA pl	1.1826	0.232	5.099	< .0001
f. percep HA sg -- percep LA sg	0.6929	0.154	4.490	0.0002
g. percep HA pl -- nonpercep LA pl	1.8020	0.228	7.895	< .0001
h. percep HA sg -- nonpercep LA sg	−0.7868	0.177	−4.453	0.0002

After the normalisation process described above, we fit an LMER model for each region of interest. The regression models included Verb type (Perceptual/Non-Perceptual), Attachment (High/Low) and DP2 number (Singular/Plural) as fixed effects, and incorporated random intercepts for participants and items. When constructing models, we started with the maximal random effect structure and progressively simplified it until the model converged (Barr et al., 2013). All factors were treatment-coded. A summary of the converged models at each region is included in Table 8.[3] Results for each region are summarised in Table 7 for descriptive statistics and Table 8 for inferential statistics. We reported in the "slope" column of Table 8 whether the random slope parameter corresponding to a fixed-effect factor was included in the model for participants or items. The analyses yielded coefficients, standard errors, t-values and *p*-values for each fixed effect and interaction. The *p*-values were taken from the t-value. A given coefficient was judged to be significant at 0.05 if the absolute value of t exceeded 2 (Baayen et al., 2008). Finally, planned (paired) contrasts are reported using the Tukey test (using the emmeans function) in the emmeans R package (Lenth et al., 2018).

At the target region, we observed no significant effects of verb, attachment, or number. However, there was a marginally significant interaction between verb and attachment. Visual inspection of the log-transformed

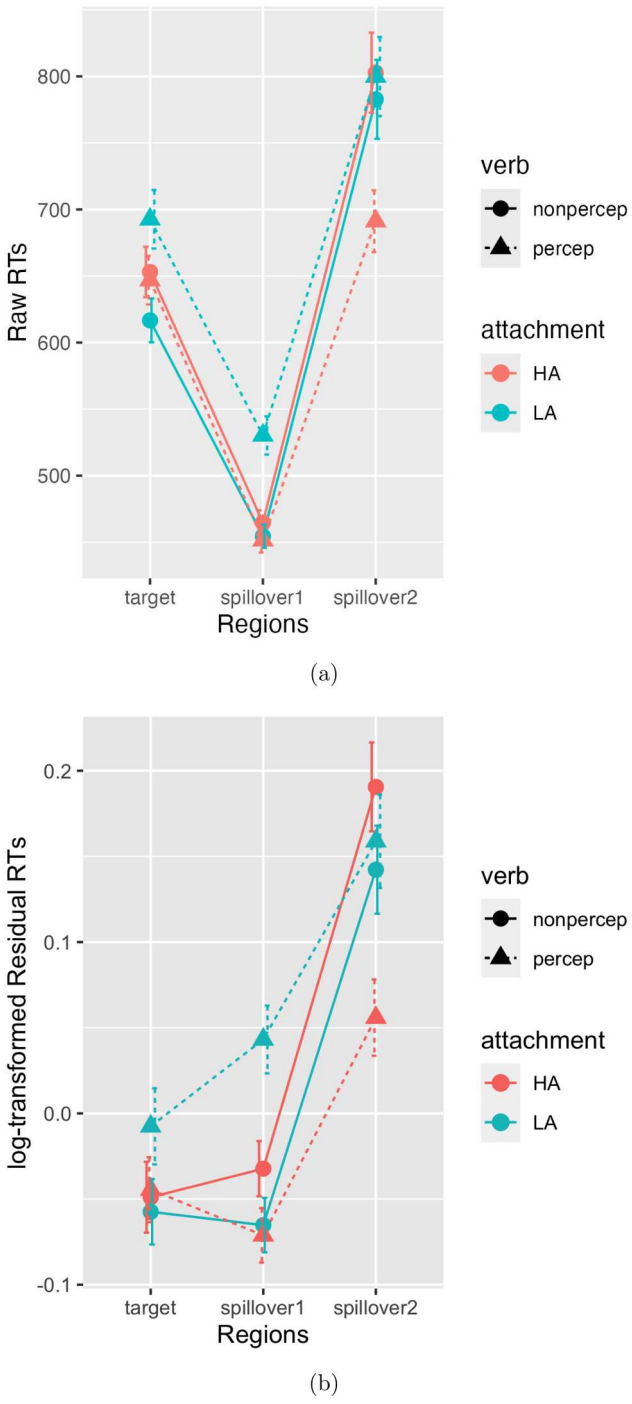

Figure 5. Region by Region (a) raw and (b) log-transformed residual RTs.

RTs reveals slower RTs for the Perceptual-LA condition compared to all other conditions. Qualitatively, this pattern aligns with the PR-first predictions, such that the sentences including perceptual verbs took longer to read when an LA interpretation was forced. This RT gap was sustained and got significantly more pronounced at the first spillover region (spillover1). In the first spillover region, we again found a significant interaction between verb type and attachment. Pairwise nested comparisons revealed a significant impact of attachment type in the perceptual verb condition ($\beta = -0.11581$, SE = 0.0267, t.ratio $= -4.341$, $p = 0.0004^{***}$), where reading times were slower for LA disambiguation (Table 9). In regards to locality effects with non-perceptual verbs, we found no significant differences between LA and HA in the non-perceptual condition – although we observe a tendency for slower RTs in the HA non-perceptual case. In the second spillover region (spillover2), we observed a main effect of verb type. Pairwise comparisons revealed a significant effect of verb type within HA conditions ($\beta = 0.1513$, SE = 0.0363, t.ratio = 4.172, $p = 0.0002^{***}$), with significantly slower reading times for non-perceptual verbs. However, no significant differences were found within the verb type condition. Note also that the spillover2 region is the last word of the sentence, and thus it is potentially affected by sentence final wrap-up effects. Finally, we found no online effects of DP number, nor any interaction between DP number and other factors.

3.3. Additional analyses

Concerning locality effects with non-perceptual verbs, inspection of both the raw and residual RTs reveals a clear tendency for slower RTs (at the target and spillover1 regions, respectively) in the HA disambiguation for the non-perceptual condition. Additionally, an anonymous reviewer points out a potential additional confound in Grillo and Costa (2014)'s (and thus, our) non-perceptual items. While the psycholinguistic literature on PRs (this study included) has focussed on the availability of PRs as complements of perceptual verbs, Italian also allows for pseudo-relatives in a variety of other environments (Cinque, 1992, a.o.). In particular, besides perceptual verbs, PRs could be licensed in contexts with verbs like *amare/odiare* (*love/hate*), or as adjuncts in *absolute with* constructions due to the ambiguity of *con/with* with some (but, importantly, not all) matrix predicates (see 6).

(6) Pietro si allenó con i maestri del ragazzo che cantavano.
Pietro REFL trained with the teachers of the boy who sang.3PL.
RC. "*Pietro trained together with the teachers of the boy who sang.*"

Adjunct PR. "*Pietro trained while the teachers of the boy sang.*"

Table 7. Mean residual RTs by region (standard errors in parentheses).

Verb type	Attachment	Target	Spillover1	Spillover2
percep	HA	−0.044523243 (0.01899289)	−0.071196803 (0.01589493)	0.055909274 (0.02225204)
percep	LA	−0.007544854 (0.02221024)	0.043116173 (0.01973607)	0.158875939 (0.02725911)
nonpercep	HA	−0.048941997 (0.02069453)	−0.032265647 (0.01611154)	0.190592803 (0.02589088)
nonpercep	LA	−0.057446259 (0.01908348)	−0.065230667 (0.01588678)	0.142234848 (0.02569974)

An inspection of our non-perceptual items reveals that approximately half of them (9–11 sets, depending on how flexible one is with allowing absolute constructions) could potentially support a kind of adjunct-PR analysis. We thus annotated the non-perceptual items either as allowing for adjunct PRs (11 sets) or as "pure" RC-only items. We then conducted unplanned, exploratory analyses of our reading time data, focussing only on the non-perceptual items split over these two Structure levels (Adjunct PR vs. RC). Mirroring the approach described in the previous section, we fit an LMER model for each region of interest on log-transformed residualized RTs. The regression models included Structure (Adjunct PR/RC), Attachment (HA/LA) and DP2 number (Singular/Plural) as fixed effects. Just like in our previous analysis, we began building models with a comprehensive random effect structure and gradually simplified them until the models converged (Barr et al., 2013). All factors were treatment-coded. Results for each region are summarised in Table 10 for descriptive statistics and Table 11 for inferential statistics.[4] Inspection of the RTs (Figure 6) shows a pattern fully consistent with the PR-first hypothesis: significantly slower RTs for LA conditions with adjunct PR items as soon as the target region. More importantly, this time we also observe a locality effect for RC-only structures, with significantly slower RTs for the HA condition already at the disambiguating verb. Additionally, and differently from what we observed for the perceptual conditions, at the spillover1 region the HA advantage for PRs disappears, as we see a general trend for slower RTs in HA vs. LA conditions independently of structure type – although with no significant effect of either Structure nor Attachment.

4. Discussion

In a self-paced reading experiment, we tested how PR-availability and locality principles interact during the online processing of RC attachment ambiguities in Italian. Based on Grillo and Costa (2014)'s PR-first hypothesis, we anticipated a strong attachment asymmetry between sentences with perceptual (PR licensing) *vs.* non-perceptual (RC only) verbs at the disambiguating region of temporarily ambiguous sentences. In other words, PR availability should make LA disambiguation costly with perceptual verbs, while locality preferences should make HA disambiguation costly with non-perceptual verbs. Our findings partially support these predictions.

Table 8. Summary of linear mixed effects models fitted to log-transformed residual RTs at each regions of interest.

	Estimate	SE	t	pr(> |t|)	Slope
target					
(Intercept)	−0.01875189	0.03676581	−0.5100362	0.61002612	(p,i)
P verb	−0.02544439	0.04250620	−0.5986041	0.54943692	
LA	−0.06303811	0.04381958	−1.4385831	0.15026868	
DP2_sg	−0.04648104	0.04154521	−1.1188062	0.26322282	
P verb:LA	0.12048493	0.05981317	2.0143543	0.04397235*	
P verb:DP2_sg	0.04411455	0.05571533	0.7917848	0.42848617	
LA:DP2_sg	0.08515023	0.05588117	1.5237732	0.12756537	
P verb:LA:DP2_sg	−0.12560706	0.07881777	−1.5936389	0.11101693	
spillover1					
(Intercept)	−0.0310892293	0.03215869	−0.96674416	0.3336719443	(p,i)
P verb	−0.0540547922	0.03538982	−1.52741063	0.1266589351	
LA	−0.0271527643	0.04171676	−0.65088378	0.5151215141	
DP2_sg	−0.0048735972	0.03537590	−0.13776604	0.8904253233	
P verb:LA	0.1751363147	0.04973719	3.52123443	0.0004295427***	
P verb:DP2_sg	0.0343014778	0.04650844	0.73753236	0.4607986723	
LA:DP2_sg	−0.0006344772	0.05319150	−0.01192817	0.9904829235	
P verb:LA:DP2_sg	−0.0637212900	0.06544670	−0.97363648	0.3302370683	
spillover2					
(Intercept)	0.26520065	0.04774688	5.5543031	2.787215e−08***	(p,i)
P verb	−0.18101060	0.05504962	−3.2881352	1.008534e−03**	
LA	−0.09858362	0.05716660	−1.7244968	8.461819e−02	
DP2_sg	−0.10475114	0.05484680	−1.9098860	5.614790e−02	
P verb:LA	0.09329859	0.07669530	1.2164838	2.238007e−01	
P verb:DP2_sg	0.05948283	0.07156430	0.8311802	4.058718e−01	
LA:DP2_sg	0.08063541	0.07196686	1.1204521	2.625212e−01	
P verb:LA:DP2_sg	0.10714354	0.10033289	1.0678806	2.855744e−01	

Table 9. Summary of pairwise comparison of the SPR task.

Comparison	Estimate	SE	t.ratio	p.value
target				
nonpercep HA -- percep HA	0.00339	0.0282	0.120	0.9994
nonpercep HA -- nonpercep LA	0.02046	0.0282	0.726	0.8867
nonpercep HA -- percep LA	−0.03383	0.0284	−1.193	0.6317
percep HA -- nonpercep LA	0.01708	0.0274	0.624	0.9244
percep HA -- percep LA	−0.03722	0.0276	−1.346	0.5336
nonpercep LA -- percep LA	−0.05429	0.0278	−1.951	0.2075
spillover1				
nonpercep HA -- percep HA	0.03690	0.0242	1.524	0.4252
nonpercep HA -- nonpercep LA	0.02747	0.0273	1.007	0.7461
nonpercep HA -- percep LA	−0.07890	0.0272	−2.899	0.0279*
percep HA -- nonpercep LA	−0.00943	0.0268	−0.353	0.9848
percep HA -- percep LA	−0.11581	0.0267	−4.341	0.0004***
nonpercep LA -- percep LA	-0.10637	0.0232	-4.584	< .0001***
spillover2				
nonpercep HA -- percep HA	0.1513	0.0363	4.172	0.0002***
nonpercep HA -- nonpercep LA	0.0583	0.0363	1.605	0.3761
nonpercep HA -- percep LA	0.0627	0.0360	1.740	0.3034
percep HA -- nonpercep LA	−0.0930	0.0351	−2.649	0.0407*
percep HA -- percep LA	−0.0886	0.0347	−2.554	0.0525
nonpercep LA -- percep LA	0.0044	0.0353	0.125	0.9993

In regards to PR-effects, we observed a processing advantage for HA in PR-compatible contexts but, importantly, *not* in RC-only contexts. A processing advantage was immediately visible at the target region (the disambiguating verb) and became significantly stronger as the sentences unfolded into the first spillover region. This effect is consistent with a general preference for a PR parse over a RC parse (Grillo & Costa, 2014), and provides new evidence from Italian in support of the online impact of PR availability on disambiguation strategies. This result is generally in line with the eye-tracking data of Pozniak et al. (2019), which found an early PR-advantage in PR-compatible contexts for French and with the total reading time data reported by Aguilar et al. (2021) for Spanish. Although both these studies found PR-compatible effects as early as the target region, differently from us, Aguilar et al. (2021) did not find evidence of a PR-effect in the spillover region. However, the different techniques adopted in the two studies (self-paced reading vs. eye-tracking) invite caution in fully interpreting these timing differences. Indeed, the fact that we found an initial slowdown for LA in PR-context, which then becomes prominent in later words is compatible with the known delayed characteristics of self-paced reading measures (Witzel et al., 2012, a.o.). Additionally, Aguilar et al. (2021)'s considered a single spillover region containing the two/three words (a prepositional phrase) following the disambiguating word. It is thus possible that slower PR-availability effects were masked in their data by sentence-final wrap-up effects (Aaronson & Scarborough, 1977; Hirotani et al., 2006; Just & Carpenter, 1980; Warren et al., 2009), together with potential timing differences tied to the different morphosyntactic features used to disambiguate and to the nature of the constituent following the disambiguation (a DP argument of the disambiguated verb in our case, a prepositional phrase in theirs). Moreover, our online results are mirrored by the pattern of accuracy responses for the comprehension questions, where we observed significantly lower accuracy rates for LA disambiguated sentences in PR contexts only.

In regards to the role of locality principles, we found suggestive but complicated evidence, that we unpack in what follows. From our main analyses, while we did observe a trend for slower RTs in the HA condition of non-perceptual verb, we found no statistically significant evidence in favour of a locality bias (i.e. a preference for LA interpretations) in RC-only contexts, from RTs nor comprehension rates. A lack of a significant HA effect with RCs could suggest that, all other factors being equal, once we eliminate an additional layer of syntactic ambiguity (PR *vs*. RC) and exclusively consider genuine relative clauses, the parser does not strongly favour one interpretation of relative clause attachment (LA *vs*. HA) – in contrast with some previously reported offline (Aguilar & Grillo, 2021; Grillo & Costa, 2014) and online results (Aguilar et al., 2021; De Vincenzi, 1991) but in line with others (Carreiras & Clifton Jr., 1993; Foppolo & Abbondanza, 2021, a.o.). For Italian specifically, De Vincenzi (1991) reported an early cost to parse RCs disambiguated towards HA and a later preference for HA sentences. However, it is worth considering that De Vincenzi (1991) did not control for PR-availability, and thus their results cannot be fully interpreted in comparison to ours. In contrast, Foppolo and Abbondanza (2021) control for PR-availability (using RC-only sentences exclusively) and report no evidence of an LA preference in Italian self-paced reading. In Spanish, the eye-tracking study's results of Aguilar et al. (2021) revealed an initial inclination towards low attachment (LA) in RC-specific contexts. This preference quickly disappears and is in fact followed by a universal penalty for sentences with LA in the subsequent region. Crucially, this LA advantage at the target region appears in early measures of effort (Gaze and Regression path duration) but not in total reading time – which shows no differences between HA and LA conditions with RC-only verbs. Aguilar et al. (2021) explain the later disappearance of the locality effect in terms of the multi-factorial nature of RC attachment preferences, with slower/later measures being influenced not simply by structure building effects but by factors like prosody/length of the RC. While clearly in need of further investigation, this tentative explanation would be consistent with the fact that their total

Table 10. Mean residual RTs by region (standard errors in parentheses) for non-perceptual items coded for adjunct-PR availability.

Structure	Attachment	Target	Spillover1	Spillover2
AdjunctPR	HA	−0.08967312 (0.02780554)	−0.04318420 (0.02057535)	0.16849037 (0.03273084)
AdjunctPR	LA	−0.02038989 (0.02971269)	−0.06071859 (0.02495608)	0.18637303 (0.04198363)
RC	HA	−0.01532463 (0.03137821)	−0.03086328 (0.02370060)	0.19995501 (0.03996266)
RC	LA	−0.09076045 (0.02510397)	−0.07782730 (0.01986220)	0.10444398 (0.03197616)

Table 11. Summary of linear mixed effects models fitted to log-transformed residual RTs at each region of interest, for non-perceptual items coded for adjunct-PR availability.

	Estimate	SE	t	pr(> |t|)	Slope
target					
(Intercept)	−0.070635858	0.04675093	−1.51089736	0.13081460	(p,i)
RC	0.129588187	0.06796273	1.90675369	0.05655249	
LA	0.050710319	0.07632992	0.66435704	0.50646182	
DP2_sg	−0.014422995	0.05738129	−0.25135364	0.80154070	
RC:LA	−0.219202446	0.10075419	−2.17561614	0.02958398*	
RC:DP2_sg	−0.106469231	0.08388578	−1.26921665	0.20436381	
LA:DP2_sg	0.004676884	0.09024305	0.05182542	0.95866780	
RC:LA:DP2_sg	0.161691350	0.12132315	1.33273287	0.18261948	
spillover1					
(Intercept)	−0.0463401985	0.03555709	−1.303261864	0.1924854	(p,i)
RC	0.0402503861	0.04942653	0.814347858	0.4154457	
LA	−0.0575633647	0.05609657	−1.026147712	0.3048220	
DP2_sg	−0.0164525732	0.04037629	−0.407481053	0.6836547	
RC:LA	−0.0001203940	0.07541111	−0.001596502	0.9987262	
RC:DP2_sg	−0.0001099665	0.06030969	−0.001823363	0.9985452	
LA:DP2_sg	0.0924824402	0.06552634	1.411378178	0.1581331	
RC:LA:DP2_sg	−0.1174934218	0.08927557	−1.316075852	0.1881486	
spillover2					
(Intercept)	0.21116277	0.05621807	3.7561368	0.0001725564***	(p)
RC	0.09366046	0.08712678	1.0749905	0.2823789993	
LA	−0.14780475	0.09551638	−1.5474283	0.1217599926	
DP2_sg	-0.05403724	0.06878798	-0.7855623	0.4321239732	
RC:LA	0.01916302	0.13144336	0.1457892	0.8840878020	
RC:DP2_sg	−0.09864386	0.10537232	−0.9361458	0.3491981156	
LA:DP2_sg	0.20633342	0.11250555	1.8339844	0.0666563096	
RC:LA:DP2_sg	−0.17625000	0.15551414	−1.1333375	0.2570725586	

reading time data align with the general pattern in our self-paced reading results when considering the well-known slower nature of self-paced reading measures. It is also worth remembering that Aguilar et al. (2021) used gender agreement to disambiguate between attachment types, while we used number. In this sense, Cairncross et al. (2024) recently conducted a self-paced reading study on Italian using gender disambiguation.[5] Consistently with our results, they found a HA advantage in PR-environments only, both in RTs and in the accuracy of the responses to a comprehension question. However, their reading time results also revealed an LA preference for non-perceptual items both at the disambiguating region (here, a secondary gender marked predicate) and in the following region. Like us, they found no evidence for an LA preference in comprehension.

These recent conflicting results on Spanish and Italian, together with the qualitatively slower RTs visible in our data in the HA disambiguation for the non-perceptual condition invite caution in interpreting the lack of a significant locality effect too strongly. Additionally, we noted a potential confound in the non-perceptual items used in this study. As mentioned before, Italian PRs are allowed (as adjuncts instead of complements) in numerous environments besides complements of perceptual verbs (Cinque, 1992, a.o.). We observed that about half of the non-perceptual items we used could *potentially* allow for this additional structure, and thus not really be "RC-only" sentences. Preliminary, exploratory analyses of non-perceptual items split between "potential PRs" and "RC-only" cases revealed a pattern of RTs fully consistent with both the PR-first hypothesis *and* with locality principles. Such analyses showed significantly slower RTs for HA sentences only in for the "RC-only" condition, with the opposite pattern (slow RTs for the LA items) in the "Adjunct PR" condition as soon as the target region. Note again that we lifted our stimuli directly from Grillo and Costa (2014), and so this is an issue present in the original Italian off-line study. However, recall that in this study we also included unambiguous PRs in the filler items, so to balance the number of pure RC interpretations. Because of the additional PR availability in some of the non-perceptual stimuli, it could then be

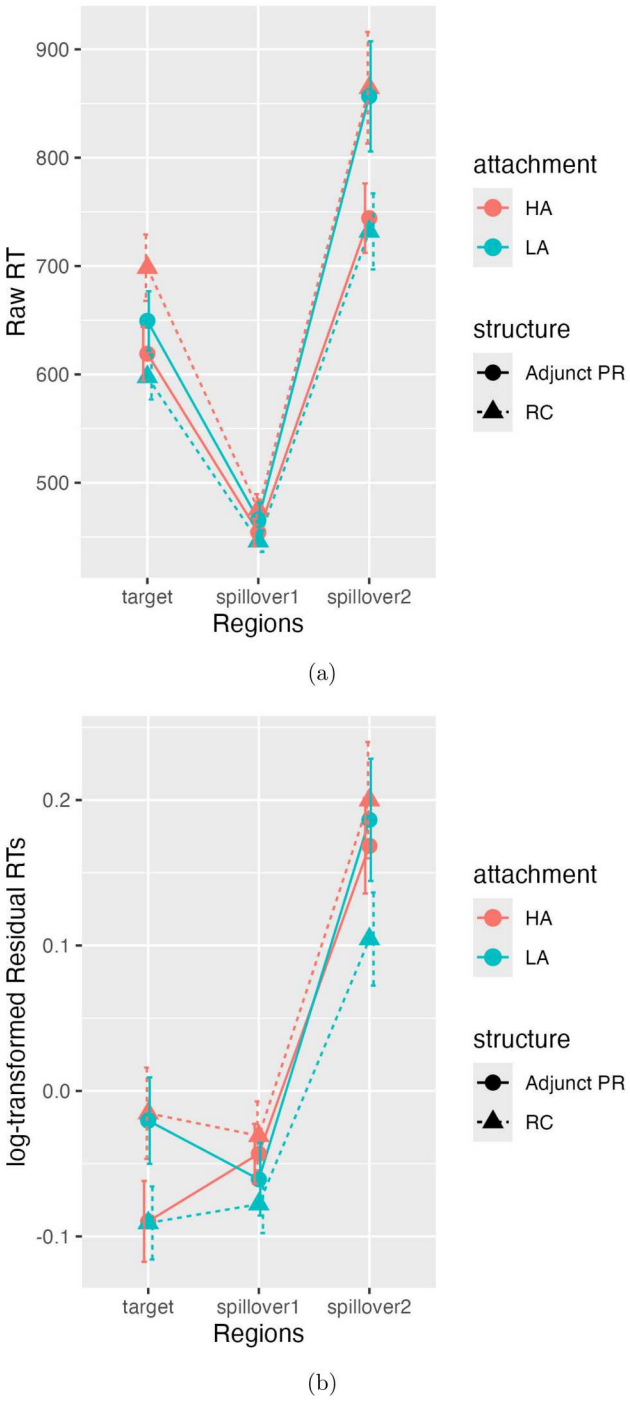

Figure 6. Region by Region (a) raw and (b) log-transformed residual RTs for non-perceptual items coded for adjunct-PR availability.

that instead of simply offsetting RC adaptation effects, we additionally primed a stronger PR effect across conditions, thus weakening the LA/locality advantage of "RC-only" constructions with non-perceptual verbs.[6] These analyses are certainly preliminary, and rely on a relatively small number of observations. Additionally, a throughout investigation of PRs under non-perceptual verbs would require norming the stimuli for the actual availability of adjunct PRs for modern Italian speakers in different contexts. This is a limitation of the current study worth exploring in future research and, together with a broader evaluation of past "RC-only" stimuli, it might also cast new light on the conflicting results arising from other studies of Italian PRs (Cairncross et al., 2024; Foppolo & Abbondanza, 2021). Going back to both accuracy scores and RTs, Grillo and Costa (2014) observe that LA preferences in online but not offline data could be related not to disambiguation but to *intervention* effects – for instance, as a case of attraction effects triggered by the intervening plural low noun (but cf. Maia et al., 2007; Miyamoto, 2005; Miyamoto et al., 1999). This prediction is predicated on the observation that agreement attraction has been found more reliably with plural nouns (*singular–plural asymmetry*; Bock & Cutting, 1992, a.o.), but note that evidence for this asymmetry is scarce for Italian, and more generally in languages with strong number morphosyntax (cf. Deutsch & Dank, 2011; Fernández & Sainz, 2004; Franck et al., 2002; Lorimor et al., 2008). If this were the case, we would predict an interaction between the properties (i.e. number) of the two DPs and Attachment, at least in the RC-only condition. However, in our online data, we found no effect of number either in isolation or as an interaction with other factors, in any of our regions of interest. Note that the grammatical gender of the DP is also a possible source of attraction, but as discussed in the earlier sections this was not possible in our stimuli, since we kept both DPs of the same gender within each item, and the embedded verb did not have morphosyntactic features marked for gender. While we did find a significant effect of the number in the comprehension data, it is crucial to note that our target contrast (LA disadvantage with perceptual verbs) surfaced independently of the number. We also did not observe a significant effect of number in the HA vs. LA patterns in non-perceptual conditions, although we do note a potential additional HA advantage in comprehension for the perceptual condition in cases where the lower noun was marked for plural – a fact that is not straightforwardly expected under the PR-first hypothesis (but compatible with it) nor trivially under the *singular–plural asymmetry* mentioned above. Additionally, the interaction of number and verb type suggests a connection between agreement checking and underlying structure, potentially related to reported syntactic effects on agreement attraction (Franck et al., 2010; Yadav et al., 2023). More generally then, while not directly affecting the interpretation of our central questions and slightly outside of the scope of the current study, the complex pattern arising from our accuracy data calls for further investigation of the relation PR availability, disambiguation cues, and attachment type.

As mentioned, previous studies paint a complicated scenario in terms of offline data, with a variety of conflicting results across languages, and with numerous discussions of asymmetries between online and offline tasks (Aguilar et al., 2022; Aguilar & Grillo, 2021; Alonso-Pascua, 2020; Branco-Moreno, 2014; Fernández & Sainz, 2004; Maia et al., 2007, a.o.). For instance, Aguilar et al. (2022); Aguilar and Grillo (2021); Grillo and Costa (2014, a.o.) reported a preference for LA interpretations in fully ambiguous sentences in RC-only contexts while Aguilar et al. (2021) report no LA advantage in an offline questionnaire (see also Cairncross et al., 2024). In this sense, both Grillo and Costa (2014) and Aguilar et al. (2021) argue that offline measures are affected more than online measures by the cumulative influences of the multi-factorial nature on ambiguity resolution, and that differences across studies probably reveal the complex array of factors (prosody, pragmatics, etc.) modulating these effects that have not been kept consistent across studies. In line with this, using a 7-point Likert scale acceptability task, Foppolo and Abbondanza (2021) show an effect of DP gender and animacy on attachment preferences in Italian. They report that in RC-only contexts using gender agreement to disambiguate, participants showed a general preference for LA over HA. Similar effects were found with an animacy manipulation, such that when DP1 was inanimate and DP2 was animate, low attachment received significantly higher ratings. Importantly, they report no offline differences for LA vs. HA conditions when number was used to disambiguate. In this sense, it is even remarkable that our offline data show PR effects in comprehension, with the previously reported HA advantage for Italian only showing up in PR-contexts, but not "pure" RC contexts. However, it is worth noticing that previous work has cast doubts on the direct relation between comprehension accuracy and ambiguity resolution, arguing for example that accuracy better reflects how information is retained during discourse processing (Maia et al., 2007), in contrast with the different biases of acceptability tasks (Hammerly et al., 2019; Laurinavichyute & von der Malsburg, 2024). With these issues in mind, together with Foppolo and Abbondanza (2021)'s evidence our results make it reasonable to hypothesise that the full resolution of RC attachment ambiguity (HA versus LA) in Italian occurs during the later stages of processing, and that earlier effects reported in some studies are more closely tied to the integration of different types of morpho-syntactic cues (cf. Cairncross et al., 2024). This is a complex open question that, together with the precise nature of the effects captured by different techniques, we leave for future investigation.

Future studies will generally be better informed by different manipulations of PR-availability (e.g. PR-type, Tense matching, etc.), since in this study we kept to verb type manipulation in order to minimise the differences from Grillo and Costa (2014)'s stimuli. Direct comparisons of the effects of disambiguation cues in PR-contexts across different tasks (along the lines of what Foppolo & Abbondanza, 2021, did in RC-only context) will also be valuable. Additionally, better consistency of PR-manipulation and experimental tasks cross-linguistically will facilitate a better understanding of the balance between language-specific properties (e.g. agreement morphosyntax) and processing mechanisms. In this sense, a more in-depth theoretical exploration of the properties of PRs across languages seems to be crucial, as exemplified by the issue with non-perceptual verbs highlighted here. Beyond Italian, Grillo and Costa (2014) suggests that the HA preference reported for Japanese and Korean could be explained by the PR-first hypothesis together with the variety of Romance languages surveyed in this paper. While it seems that both Japanese and Korean allow for PR-like small clauses, it is unclear that these are available in attachment ambiguity contexts (Kim, 2009; Shimoyama, 1999). In line with this, Lee (2021) found no effect of verb type in modulating RC attachment preferences with Korean participants.

5. Conclusion

Previous work has shown evidence for the effects of pseudo-relative clause availability on the resolution of RC attachment ambiguity, suggesting that a preference for PR structures leads to what had been previously characterised as a HA bias in PR-licensing languages (e.g. Italian, Spanish, French Aguilar & Grillo, 2021; Alonso-Pascua, 2020; Grillo, 2012; Grillo & Costa, 2014; Pozniak et al., 2019, a.o.), and suggesting that effects of locality should show up even for these languages in environments disallowing for PR structures (Aguilar et al., 2021). Building on this past work, this paper aimed to address two questions about the timing of ambiguity resolution in PR languages, through a self-paced reading study on Italian:

(1) Are there online effects of PR availability on ambiguity resolution strategies?
(2) Is there evidence for locality principles affecting RC disambiguation in Italian, when PR availability is controlled for?

Our results support the hypothesis that PR availability plays a crucial role in deciding attachment preferences in Italian, furthering our understanding of the online effects of verb type on structure building processes. In

regards to the second question, we found a suggestive but conflicting array of results for locality effects, contributing to an already complicated cross-linguistic scenario with respect to our understanding of structure building strategies during attachment resolution.

The timing and variety of our effects call for a more in-depth study of the principles guiding structural disambiguation, and for a more careful investigation of the exact specification of the "PR-first" hypothesis in terms of general parsing mechanisms. While many questions remain open, the results in this paper add to the growing array of evidence of the multi-factorial nature of ambiguity resolution, and showcase the value of strongly controlled stimuli in future cross-linguistic investigations of these factors.

Notes

1. Grillo and Costa (2014) suggest a variety of reasons for why a PR parse should be preferred over an RC parse. For instance, PRs project a relatively reduced functional structure compared to RCs and should thus be preferred for syntactic economy principles (but see De Santo & Lee, 2022), or pragmatic/discourse economy considerations due to PRs bringing fewer presuppositions than RCs (Referential theory; Altmann & Steedman, 1988; Crain, 1985). In fact, there is generally evidence in psycholinguistics for the processing advantage of arguments (in this case, PRs) over adjuncts (RCs), both in terms of their syntactic properties and in terms of their relevance to the main assertion of the clause (Frazier, 1990; Schütze & Gibson, 1999; Speer & Clifton, 1998).
2. While we are presenting these preferences as being deployed serially, this is done mostly for ease of exposition. The PR-first hypothesis is in fact perfectly compatible with parallel models of parsing (e.g. in terms of ranked preferences, Gibson & Pearlmutter, 2000), and the choice between serial vs. parallel parsing does not affect the type of predictions put forward here (Pozniak et al., 2019).
3. The converged models are $RTResidual \sim verb*attachment*dp2\_num + (1|participant) + (1|set)$ at the target region, $RTResidual \sim verb*attachment*dp2\_num + (1 + attachment|participant) + (1 + attachment|set)$ at the spillover1 region, $RTResidual \sim verb*attachment*dp2\_num + (1|participant) + (1|set)$ at the spillover2 region.
4. The converged models are $RTResidual \sim structure*attachment*dp2\_num + (1|participant) + (1|set)$ at the target region, $RTResidual \sim structure*attachment*dp2\_num + (1|participant) + (1|set)$ at the spillover1 region, $RTResidual \sim structure*attachment*dp2\_num + (1|participant)$ at the spillover2 region.
5. While differences (and similarities) in both design and results between this study and ours suggest exciting venues for future research, we became aware of this study only late in the review process, and thus it was not possible to include a full comparison with their results.
6. We thank an anonymous reviewer for pointing this out to us and suggesting this potential explanation.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

Stimuli, scripts, and data for the analyses are available on OSF at https://osf.io/s5z2f/.

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