Features matter: The role of Number and Gender features during the online processing of subject- and object- relative clauses in Italian

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In this study, we investigated whether different morphosyntactic features, i.e., number and gender, play a role during the adult online comprehension of subject relative clauses (SRC) and object relative clauses (ORC), in Italian. This study was inspired by developmental studies showing that children struggle with ORC compared to SRC; yet, ORC comprehension improves if the head and the subject of the RC mismatch in relevant morphosyntactic features (e.g., number but not gender in Italian, based on the featural Relativized Minimality principle, fRM). We found that Italian adults read ORC more slowly than SRC verbs; moreover, ORC verbs were read faster in the head-subject number mismatch condition, while there was no facilitation in the head-subject gender mismatch condition, in line with developmental studies and fRM. We conclude that online parsing is feature-sensitive, that features are not all equally "relevant", and that current models should be refined to account for these differences.

Keywords: sentence comprehension; relative clauses; number features; gender features; self-paced reading; relativized minimality

Introduction

One of the most fascinating properties of human language comprehension is the ability to organize strings of words into hierarchical representations with different structural complexity that lead to different meanings, in a limited amount of time. A specially insightful example is provided by relative clauses as in (1) and (2). Both relative clauses contain exactly the same words and both refer to the noun phrase *the waiter*, but they imply different relations between the words, that is different structural configurations and thus different meanings. In the sentence in (1) containing a subject relative clause (SRC), the entity working in the pub is also the entity greeting the boy. Roles are reversed in the sentence in (2) containing an object relative clause (ORC): Here the boy is greeting the entity working in the pub.

(1) … *the waiter that is greeting the boy works in this pub.* SRC

(2) … *the waiter that the boy is greeting works in this pub*. ORC

One important finding of previous experimental studies is that the comprehension of headed ORCs is more demanding than the comprehension of headed SRCs[i] during sentence reading. This so-called subject-object relative clause asymmetry in adult sentence comprehension has been extensively investigated in some languages, such as English (e.g., Gordon et al., 2001, 2004; Grodner & Gibson, 2005; Grodzinsky, 1989; Izumi, 2003; King & Just, 1991; Staub, 2010; Staub et al., 2017; Traxler et al., 2002 among others), while there is rather limited experimental work in other languages, such as Italian (Di Domenico & Di Matteo, 2009; Guasti et al., 2018; Villata & Lorusso, 2020). In the current study, we cover this gap in the literature by investigating the online

processing of subject and object relative clauses in Italian by healthy Italian-speaking (monolingual) adults.

Developmental literature has also reported similar findings by investigating how accurate children are during the comprehension of subject and object relative clauses, by using techniques such as the sentence-picture matching task. In particular, several studies have shown that children are less accurate in the comprehension of ORCs compared to SRCs (e.g., in English: Brown, 1971; Cilibrasi et al., 2019; Kidd & Bavin, 2002; Roth, 1984; Sheldon, 1974; Tavakolian, 1981 among others; in Italian: Adani, 2011; Arosio et al., 2009; Belletti et al., 2012 among others).

Interestingly, developmental literature also reports that the comprehension accuracy of ORCs can improve when the head and the subject of the relative clause are both lexical noun phrases that mismatch in relevant morphosyntactic features (for number and/or gender see e.g., Adani et al., 2014, 2017, 2010; Bentea & Durrleman, 2017) and as a function of the language under investigation (e.g., Belletti et al., 2012).

Adani et al., 2010) tested how Italian children comprehend object relative clauses containing noun phrases can either match or mismatch in gender or number features, as shown in (3) and (4) respectively.

(3) *Il gatto che il topo/la capra sta lavando è salito/a sullo sgabello.*

"The cat-M that the mouse-M/the goat-F is washing has climbed-M/F on the stool."

(4) *Il leone che il gatto/i coccodrilli sta/stanno toccando è seduto per terra.*

"The lion-SG that the cat-SG/the crocs-PL is/are touching is sitting–SG on the floor."

The results of the sentence-picture matching task showed that children comprehension improves when there is a feature mismatch compared to when the two

noun phrases share the same features. Moreover, accuracy increases to a larger extent when there is a number mismatch compared to when a gender mismatch is present.

Along the same lines, Belletti et al. (2012) tested how Hebrew and Italian children comprehend subject and object relative clauses through a sentence-picture matching task. All relative clauses contained either a match or a mismatch in gender features between the relative lexical noun phrase head and the subject/object of the relative clause. Examples in (5) and (6) report the object relative clause conditions of direct interest here.

(5) *Tare li et ha-yalda she-ha-isha mecayeret.* (Hebrew)
Mostrami la bambina che la signora disegna. (Italian)
"Show me the girl$_{FEM}$ that the woman$_{FEM}$ draws$_{FEM}$"

(6) *Tare li et ha-yalda she-ha-rofe mecayer.* (Hebrew)
Mostrami la bambina che il dottore disegna. (Italian)
"Show me the girl$_{FEM}$ that the (male-)doctor$_{MAS}$ draws$_{MAS}$"

All children comprehended subject relative clauses better than object relative clauses. Moreover, in the head-subject gender mismatch condition (see (6) compared to (5)), the comprehension of object relative clauses improved for Hebrew children but not for Italian children. The authors concluded that a head-subject mismatch at the feature level can also modulate the relative clause processing, in line with previous work (e.g., Adani et al., 2010), and does so in a selective way. More specifically, the cross-linguistic difference of the facilitation effect for gender mismatches is related to the different morphosyntactic status that the gender feature has in Hebrew and Italian. In Hebrew, but not in Italian, finite verbs are inflected for gender (agreeing with the subject), which thus plays an active syntactic role: It is among the features that trigger syntactic movement (of

the subject from the vP-internal position into the subject position of the clause; below for more). On the other hand, Italian finite verbs are inflected for number (agreeing with the subject), which is thus expected to play an active role in Italian.

To summarize, previous studies have clearly shown that object relative clauses are more demanding than subject relative clauses, and that object relative clauses can be less demanding when the lexical noun phrase head and the lexical subject of the object relative clause show relevant forms of dissimilarity (e.g., feature mismatch between the two noun phrases, depending on the language), for both adults and children. Developmental literature has provided crucial evidence indicating that when the relative head and the subject of the relative clauses are both lexical noun phrases, object relative clauses are better comprehended if the two noun phrases mismatch in relevant morphosyntactic features, and that which morphosyntactic features are the relevant ones varies as a function of the language under investigation.

The following natural new question is raised by these findings: Are adults sensitive to the same feature-related mismatch during online sentence comprehension, with the same constraints unveiled in development? The current study is the first study that directly compares the role of two distinct morphosyntactic features, number and gender, during adults' online processing of subject and object relative clauses.

The role of structure and morphosyntactic features: the linguistic perspective

Formal syntactic theory has dedicated great attention to the study of A' dependencies, that is to the relation between a dislocated constituent and its original position where it receives its thematic interpretation (first merge position). In the case of object relative clauses as "the waiter that the boy is greeting __" the A' dependency is established between the noun phrase *the waiter*, head of the relative clause and the internal

argument/object position of the verb *is greeting* (as indicated by the underscore in the example).

One crucial property of these dependencies is that they are subject to intervention locality (Rizzi, 1990, 2004). According to the featural approach to the syntactic principle Relativized Minimality, fRM henceforth, Rizzi, 1990, 2004; Starke, 2001; Friedmann et al., 2009; Grillo, 2008; Martini et al., 2020 in the domain of aphasia) if there is an element Z that hierarchically intervenes between the dislocated element X (the target) and its original position Y in the sentence (the origin), as shown in (7), the dependency is perceived as deviant in certain cases, hard for adults and impossible for children in other cases (see (Rizzi, 2018) for comparison between children and adults in this connection).

(7) X … Ⓩ … Y

In other words, according to fRM, ORCs like (9) are more complex to comprehend compared to SRCs like (8). In ORCs as in (9), the head of the relative clause (target position X) and its original position in the following relative clause (origin Y) are structurally separated by an intervener (Z). Such intervener Z, besides being a lexically restricted NP as the target, also shares relevant morphosyntactic features with it (Number: singular; Gender: masculine).

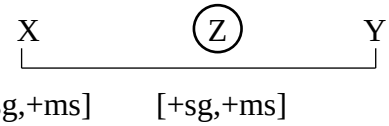
(8) *Il cameriere che __ saluta il ragazzo lavora in questo pub.* SRC

"The waiter that __ greets the boy works in this pub"

X Y

(9) *Il cameriere che il ragazzo saluta __ lavora in questo pub.* ORC (all match)

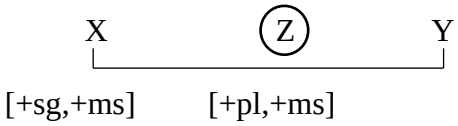
"The waiter that the boy greets __ works in this pub"



Not all conceivable features are computed by the fRM locality principle. Since the principle deals with dependencies created by movement, the hypothesis has been put forth (Friedmann et al., 2009 and subsequent literature) that the features to which the principle is sensitive are those involved in the triggering of a syntactic movement operation. In Italian, Number is part of the features encoded in the verb morphology (e.g., singular: *salut-a* , "greets"; plural: *salut-ano,* "greet") and thus it is among the features that trigger the syntactic movement of the subject from its vP-internal position into the subject position of the clause (i.e., Spec-TP henceforth, following current terminology); in contrast, Gender is not encoded in the morphology of the finite verb (e.g., masculine/feminine: *salut-a,* "greets"), hence it is assumed not to be among the features triggering syntactic movement into the subject position. As a consequence, a sentence where the target and the intervener match in Number features as (9) is predicted to be more complex to comprehend than a sentence where the target and the intervener mismatch in Number features, as in (10). Conversely, no difference is predicted between sentences in (9) and (11), where the target and the intervener respectively match and mismatch in Gender features.

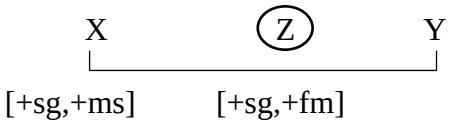
(10) *Il cameriere che i ragazzi salutano __ lavora in questo pub.* ORC (number mismatch)

"The waiter that the boys greet __ works in this pub"



(11) *Il cameriere che la ragazza saluta __ lavora in questo pub.* ORC (gender mismatch)

"The waiter that the girl greets __ works in this pub"



Interestingly, by reinterpreting previous results (e.g., Gordon et al., 2001, 2004; Warren & Gibson, 2005) on the online adult comprehension of subject and object relative clauses, Belletti and Rizzi (2013) showed that featural Relativized Minimality can account for both children's and adults' difficulties associated with the comprehension of grammatical dependencies involving a configuration of intervention. In other words, the same fRM principle may be at play in children and adults and modulate their (offline) accuracy data and (online) reading time data respectively. This proposal is in line with other accounts proposing a continuum between children's and adults' parsing mechanisms (e.g., Clahsen & Felser, 2006): Children's only interpretation appears to be adults' first interpretation during online sentence comprehension (Phillips & Ehrenhofer, 2015).

The role of structure and morphosyntactic features: the psycholinguistic perspective

From the psycholinguistic perspective, various accounts have been proposed to explain the source of the so-called subject-object relative clause asymmetry (see Gordon &

Lowder, 2012 for an overview). Still, one aspect that is left unclear is the role that morphosyntactic features play during online sentence comprehension in general, and during the processing of relative clauses more specifically. Previous studies testing the processing of (e.g., subject-verb, determiner-noun) agreement errors have shown that the processing of features such as number, person, gender, and tense are differently treated by the parser (e.g., Barber & Carreiras, 2005; Biondo et al., 2018; Mancini et al., 2011, 2014; Muralikrishnan & Idrissi, 2021; Tucker et al., 2021; Zawiszewski et al., 2016).

In other words, there is evidence showing that the adult language system deals with distinct morphosyntactic features differently during online sentence comprehension. Yet, many models of sentence comprehension, even the ones that are more informed by linguistic theory, do not provide a specific formalization that can account for feature-related processing differences (e.g., Frazier & Clifton, 1996; Friederici, 2002, 2011; Gibson, 1998, 2000; Hagoort, 2003, 2013).

Cue-based retrieval models (e.g., Lewis & Vasishth, 2005; Lewis et al., 2006; McElree, 2006; Van Dyke & McElree, 2006), on the other hand, do mention morphosyntactic features in their formalizations, as they represent some of the cues[ii] that allow identifying the right antecedent in a long-distance dependency. In order to successfully comprehend a relative clause such as "The waiter that the boys greet __", the reader has to retrieve the right element (*the waiter*) that can fill the "gap" encountered when reading the verb *greet* (e.g., Cunnings & Sturt, 2018; Fujita & Cunnings, 2022). Yet, which features can actually modulate processing and why, and whether the same set of features acts as cues cross-linguistically are still debated open questions (Smith & Vasishth, 2020; see also Mertzen et al., 2020). Finally, top-down models such as the one proposed by Chesi (2015) and Chesi and Canal (2019) also assign an important role to morphosyntactic features, since they can either increase or mitigate the cost involved to

access the memory buffer involved during the processing of long-distance dependencies. In particular, Chesi and Canal (2019) predict both feature mis/match and cross-linguistic differences to play a role during the processing of a long-distance dependency. For example, in an Italian sentence such as "*I camerieri che il ragazzo saluta* _ (The waiters that the boy greets)", the number (but not a gender) mismatch between two noun phrases *i camerieri* and *il ragazzo* stored in memory would increase the number of distinct cued features (dF in their formalization) thus leading to lower costs/shorter RTs to access the memory buffer when reading the verb *saluta* and correctly interpret the sentence. In both cue-based and top-down formalizations, the features that can make a difference during the processing of long-distance dependencies are the features expressed by verb morphology (e.g., number but not gender, in Italian).

The current study

In this study, we investigated whether the different morphosyntactic features number and gender play a role during the adult online comprehension of subject and object relative clauses, in Italian. The selection of these features was directly inspired by the results from development summarized above. The main aim of the study was indeed to clarify whether the syntactic constraints formalized by fRM and already found to be operative in development also hold for adults during online sentence comprehension. In particular, we wanted to test whether morphological information is analysed in a selective way (i.e., depending on the nature of the morphosyntactic feature involved) during the processing of different A' dependencies, which may generate or not generate intervention effects (ORCs and SRCs respectively), based on the fRM principle. Previous studies on relative clause processing have provided a fragmentary picture of how different features are treated during the processing of different types of relative clauses. Indeed, previous

studies that investigated the processing of relative clauses in adults either did not test morphosyntactic mismatches explicitly (e.g., Gordon et al., 2001, 2004; Grodner & Gibson, 2005; Staub, 2010; Staub et al., 2017) or did test morphosyntactic mismatches, but partially, e.g., by including only feature mismatch conditions, by testing one morphosyntactic feature at time and/or by limiting the investigation to one type of (subject, or object) relative clause (e.g., Dillon et al., 2013; Franck et al., 2015; Guasti et al., 2018; Lago et al., 2015; Nicenboim et al., 2018; Tucker et al., 2021; Vernice et al., 2016; S. Villata et al., 2018; Sandra Villata & Franck, 2020; Wagers et al., 2009). Given the coarse formalization of the role of morphosyntactic features in current models of sentence comprehension, and given the growing evidence suggesting that different parsing routines may be at play when dealing with different morphosyntactic features, the current study fills a gap in the literature and offers novel evidence to better understand the role of morphosyntactic features during sentence parsing in general and during relative clause processing in particular.

Our study thus enriches the current state of the art, by comparing two different structures (subject, object relative clauses) and two different features (number, gender) in Italian within the same (within-subject and within-item) experimental design. The main assumption behind our research questions was that structural configurations that are challenging in language acquisition (e.g., see the match condition in ORCs) may give rise to processing difficulties during online adult sentence reading. In both experiments, ORCs were thus expected to trigger longer reading times compared to SRCs, in line with previous studies in both adult processing and child language acquisition. Moreover, in the ORC condition, we expected to find a facilitation effect (shorter reading times) when the target and the intervener mismatched in Number features compared to the all-match condition, while no difference was expected when comparing the two sentences

containing a Gender mis/match, in line with previous developmental literature. This pattern of results was expected to arise on the region where the dependency needs to be established, i.e., on the verb of the relative clause.

Experiment 1

The design of Experiment 1 was similar to the one adopted by Adani et al., (2010), who first tested the role of number and gender features in Italian children. However, differently from Adani et al. (2010), we decided to have a unique *matching condition* (all match, gender mismatch, number mismatch), that is to compare gender and number mismatches with the same all match condition (containing singular masculine noun phrases), as shown in Table 1. This choice allowed us to simplify the experimental design and add another crucial factor to the design, that is *sentence type* (subject-relative clause, object-relative clause). By testing both subject and object relative clauses, we were able to investigate whether the facilitation related to a feature mismatch was present only in presence of a structural intervener (i.e., in ORC, but not in SRC). The predictions for the self-paced reading study were the following: In general, we expected the object-relative clause condition to show longer reading times compared to the subject-relative clause condition. Moreover, in the object-relative condition, i.e., the configuration instantiating structural intervention, we expected the number mismatch condition to show a facilitation effect (shorter reading times) compared to the all-match condition while we did not expect the same effect for gender. Based on the fRM approach, we expected these effects to arise at the relative clause verb region, that is the region where the relevant A' dependency needs to be established. Moreover, we could not exclude that these effects could carry over to the post-target regions. As a consequence, we decided to explore whether similar (spillover) effects were present on the region following the target (the matrix verb).

Methods

Participants

Forty-six Italian adult native speakers (29 women and 16 men, age range 18-45 years, mean = 31.4, SD = 6.39) voluntarily participated in this web-based experiment. They all had no reading disorders. All participants gave their informed consent in line with the Declaration of Helsinki.

Material

The experimental material consisted of 102 experimental sentences of the type shown in Table 1. Participants were thus exposed to 6 different experimental conditions. The experimental sentences were divided into 6 different lists following a Latin square design so that the participant read only one version of each experimental item (17 items per condition). Sixty filler sentences were also included. All sentences were grammatical. The participants read a total of 162 sentences.

All the experimental sentences had the same shape (see Appendix B for the complete list). All the noun phrases that were used in the sentences were animate, human, and with transparent masculine/feminine form[iii]. All noun phrases entailed human entities with a different natural gender[iv] that was expressed grammatically through the use of different suffixes (e.g., *il*$_{\text{MAS}}$ *nonno*$_{\text{MAS}}$ – the granpa, *la*$_{\text{FEM}}$ *nonna*$_{\text{FEM}}$ – the granma). The subject of the main clause (the target) was always a 3rd person singular masculine noun phrase while the subject/object of the relative clause was manipulated to match (All-match: singular, masculine) or mismatch the target either in gender (Gender-mismatch: singular, feminine) or in number (Number-mismatch: plural, masculine). All the verbs used in the experimental material were present tense inflected forms[v].

[Table 1 here]

Procedure

The experiment was programmed on Ibex Farm (Drummond, 2013), a javascript-based web platform that has been largely used in psycholinguistics research because of its accuracy in reaction/reading time data collection.

Sentences were presented constituent by constituent using the *moving-window paradigm*. Each trial began with the sentence masked with as many underscores as the number of characters per word. Participants began a trial by pressing the spacebar, upon which the first constituent of the sentence appeared. In order to get the next constituent displayed participants needed to press the spacebar again.

Participants were instructed to read at a natural pace and to make sure they understood what they were reading so that they could respond to comprehension questions accurately. Each sentence was followed by a yes/no comprehension question. The questions targeted any constituent within the sentence indiscriminately, in order to prevent participants to develop biased behaviours (e.g., towards our specific manipulation). Accuracy to the comprehension questions were also collected.

To familiarize participants with the experimental procedure, the session started with a short practice block of 5 trials (featuring sentences that were similar to but not included among those in the experimental list). The experiment lasted approximately 30 minutes, including practice and breaks after the end of each of the three experimental blocks.

Data analysis

We analysed accuracy data to the comprehension questions as well as reading time data of the relative clause verb region and also of the main verb region. Data analyses were performed on 45 participants' data. Data of 1 participant were excluded because of low accuracy (below 75%) in the comprehension question task. Data of 2 items were also excluded because of an error in the codification of the regions of interest. Outliers (0.12% of the data) were removed from reading time data by adopting a fixed threshold (reading time data below 100ms and above 8000ms) as in previous studies (e.g., Staub, 2010; Villata et al., 2018).

The analysis of reading time data was conducted by comparing reading time data by constituent type, i.e., by comparing reading time data on the relative clause verb region and on the main clause verb region in the two relative clause types (Grodner & Gibson, 2005; Staub, 2010; Staub et al., 2017). Reading time data were analysed through a two-stage analysis (Hofmeister, 2011; Hofmeister & Vasishth, 2014; see also Villata et al., 2018). In the first stage, reading times were log-transformed to normalize residuals and regressed against word length and within-list trial position, two factors that are known to affect reading times in self-paced reading tasks. In the second stage, the residual log reading times resulting from the first-stage regression model were used as the dependent variable of the linear mixed-effect model analysis performed through the R package *lme4* (Bates et al., 2014).

By using the *stats* package (R Core Team, 2013), we contrast-coded our fixed-effect factors based on our hypotheses (Schad et al., 2020). In particular, we included three contrasts in our model. : The contrast *clause_c* (SR vs OR) was used to test whether reading times changed as a function of the clause type. The contrasts *gender_c* (all-match vs gender mismatch) and *number_c* (all-match vs number mismatch) were adopted to investigate whether reading time changed as a function of different featural mismatches

(number, or gender) between the target and the intervener. We also included the interaction between *clause_c* and *gender_c*, as well as the interaction between *clause_c* and *gender_c* to test whether the gender and number morphosyntactic mismatches led to different effects in the two types of relative clauses. SR and the mismatch conditions were coded as -0.5; OR and the all-match condition were coded as 0.5. Given an interaction between these contrasts, we fitted a second linear mixed-effect model with separate nested contrasts for gender and number in the SR and OR conditions. In this model (called "interaction model" henceforth), match and mismatch were also coded as 0.5 and -0.5, respectively. Moreover, we included crossed random intercepts and random slopes for all fixed-effect parameters for subject and item grouping factors (Barr et al., 2013) in all models. We reduced the complexity of the random effect structure of the maximal model by performing a Principal Component Analysis so as to identify the most parsimonious model properly supported by the data (Bates et al., 2015). Logit mixed-effect models (Jaeger, 2008) were employed for the analysis of accuracy data. P-values were derived by using the *lmerTest* package (Kuznetsova et al., 2017). The structure of the best-fitting models is reported in Appendix A.

Results

Comprehension accuracy

Mean by-subject accuracy to the comprehension question task are illustrated in Figure 1. The analysis of the accuracy data revealed an effect of *clause_c* (Estimate: -.3, SE: .15, z = -2.01, $p < .05$), that is higher accuracy scores for the SR condition compared to the OR condition. No other effect was significant (*gender_c* Estimate: .3; SE: .23; z= 1.28, p = .2; *number_c* Estimate: .33; SE: .19; z = 1.76; p = .08; *clause_c* x *gender_c* Estimate: .09; SE: .33; z = .27; p = .78; *clause_c* x *number_c* Estimate: -.05; SE: .33; z = -.2; p = .88).

[Figure 1 here]

Constituent-by-constituent self-paced reading time data

The full set of mean reading time data for each sentence constituent is illustrated in Figure 2. Non-transformed millisecond per character reading time data are plotted here for readability reasons, but the analyses were conducted on residual log reading times (where word length and trial position were factored out).

Target region. Figure 2 also illustrates the reading time data of the relative clause verb while Table 2 reports the model estimates, standard errors, *t*- and *p*-values of the statistical analysis. The analysis of the reading time data related to the relative clause verb region revealed an effect of *clause_c*, an effect of *number_c*, and a *clause_c* x *number_c* interaction. No effects of *gender_c* or *clause_c* x *gender_c* interaction were found. The interaction models showed that the number mismatch effect, that is shorter reading times for the number-mismatch condition compared to the all-match condition, was present only in the OR condition while no number mismatch effect was found in the SR condition.

[Figure 2 here]

[Table 2 here]

Post-target region. Figure 3 and Table 3 illustrate respectively the reading time data of the post-target region, that is the verb of the main clause, and the model estimates, standard errors, *t*- and *p*-values of the statistical analysis. The analysis of reading time data on the main clause verb region showed an effect of *clause_c*, an effect of *number_c* and also an effect of *gender_c*. No interactions were found.

[Figure 3 here]

[Table 3 here]

Discussion of Experiment 1

In this study, we aimed to test structure-related and feature-related effects during the adult online sentence comprehension of relative clauses. Previous studies from developmental literature showed that children comprehend subject-relative clauses more accurately than object-relative clauses in offline comprehension tasks. Moreover, ORC comprehension improves when the two NPs (the head of the RC the subject of the RC) mismatch in Number features, while there is no improvement when the two NPs mismatch in Gender features, in Italian. Adults are expected to be able to comprehend both subject and object relative clauses since these sentences are all grammatical in Italian. However, we expected adults to be subject to similar constraints during online sentence reading. We expected object relative clause conditions to inflate reading times compared to subject relative clauses, in particular on the relative clause verb. We also expected to find a facilitation effect (shorter reading times) when the head of the relative clause and the subject of the relative clause mismatched in number in the object-relative clause condition, while we did not expect the same facilitation effect when the two noun phrases mismatched in gender.

Results from the comprehension question task showed that, as expected, adults were able to comprehend both subject and object relative clauses (mean accuracy above 90%) although the comprehension for subject relative clauses was higher compared to the comprehension of object relative clauses.

Results from the self-paced reading task showed longer reading times at the target region for the object-relative clause condition compared to the subject-relative clause condition, thus confirming our first prediction. We also found the predicted facilitatory number mismatch effect on the verb of the relative clause in the object relative clause condition. Shorter reading time data were found in the number mismatch compared to the all-match object relative clause condition, while no significant facilitatory gender mismatch effect was found. So our expectations/predictions were met.

In this study, we also decided to check whether the processing of the A' dependency, at the target region, could spill over the following region. Indeed, this was the case: On the post-target region (i.e., the matrix verb), we found longer reading times for the object relative clause condition compared to the subject relative clause condition. At the matrix verb, we also found a facilitatory feature mismatch effect. This effect was non-selective both as for the type of feature mismatch (both number and gender compared to all-match) and for relative clause type (both in SRC and ORC). We leave the discussion of this further non-selective effect for the dedicated section *Further findings in the post-target region of Experiment 1 and 2.*

Experiment 2

Whereas in Experiment 1 all relative clauses were of the centre-embedded type, in this study, we tested the processing of right-branching subject and object relative clauses with number and gender mis/matches, as shown in Table 4. This study thus allowed us to further test the validity of the structure-based and feature-based processing differences reported in Experiment 1 by going beyond previous studies, which tested number and gender mismatches in center-embedded Italian object relative clauses on children (e.g., Adani et al., 2010). Moreover, the adoption of this sentence structure allowed us to better

compare our data on adult sentence processing with the studies formalizing the featural Relativized Minimality approach (based on developmental results e.g., (Belletti et al., 2012; Friedmann et al., 2009), where similar right branching relatives were also used). As in center-embedded relative clauses, in right-branching relative clauses (e.g., "Show me the chicken that the cow is kissing __"), there is an element (*the cow*) that structurally intervenes between the origin (i.e., the gap after the verb *kissing*) and the target (e.g., *the chicken*). As a consequence, we expected to replicate the results of Experiment 1, that is longer reading times for object-relatives compared to subject-relatives and a facilitation effect only for number and not for gender in the object-relative clause conditions, at the target region (i.e., the relative clause verb). The use of right-branching relative clauses also eliminated the long-distance subject-verb agreement relation between the noun phrase modified by the relative clause and the main verb at work in centre-embedded structures. As a consequence, the adoption of the right-branching relative structure also allowed us to better explore the nature of the spillover effects on the post-target region.

Methods

Participants

Fifty Italian native speakers (27 women and 23 men, age range 18-44 years, mean = 25.4, SD = 5.86) were recruited through the Prolific platform in exchange for a small payment. They all had no reading disorders. All participants gave informed consent in line with the Helsinki Declaration.

Materials

The experimental material was built based on the material used in the first study. We kept the number of items (17 per condition), the filler sentences (60 items), and the linguistic

properties of the relative clauses equal across the two experiments. The main difference between the experimental material in Experiment 1 and Experiment 2 was the sentence structure. The head of the relative clause was built to be the direct object of the verb of the main clause. This eliminated a possible interference between the processing of the relative clause verb and the subsequent establishment of the subject-verb agreement dependency in the main clause at work in the relative clauses of Experiment 1 (centre-embedded). An example is provided in Table 4. All sentences were grammatical. The participants read a total of 162 sentences, as in Experiment 1.

[Table 4 here]

Procedure

The procedure was kept constant across studies. Therefore, the sentences were presented constituent-by-constituent through the Ibex Farm platform, and participants were asked to answer yes/no comprehension questions after each sentence. The comprehension questions targeted different constituents within the sentence as in the first study.

Data analysis

We performed the same data analysis adopted in Experiment 1. Data from 1 participant were discarded because of low accuracy (below 75%). The outlier removal procedure on the self-paced reading time data (removal of reading times above 8000ms and below 100ms) led to a 0.4% of data removal.

Results

Comprehension accuracy

Mean by-subject accuracy to the comprehension question task is illustrated in Figure 4. The data analysis revealed no effects (*clause_c* Estimate: -.08; SE: .1; z = -.77; p = .44; *gender_c* Estimate: -.13; SE: .13; z= -.97, p = .33; *number_c* Estimate: .2; SE: .17; z = 1.18; p = 0.24; *clause_c* x *gender_c* Estimate: .35, SE: .27, z = 1.32, p = .19; *clause_c* x *number_c* Estimate: -.04; SE: .26; z = -.15; p = 0.88).

[Figure 4 here]

Constituent-by-constituent self-paced reading time data

The full set of mean reading time data for each sentence constituent is illustrated in Figure 5.

Target region. Figure 5 also illustrates the reading time data at the relative clause verb region. The model estimates, standard errors, *t*- and *p*-values of the statistical analysis are reported in Table 5. The analysis of the reading time data related to the relative clause verb region revealed an effect of *clause_c*, an effect of *number_c*, and a *clause_c* x *number_c* interaction. No effect of *gender_c* or *clause_c* x *gender_c* interaction was found. The interaction models showed that the number mismatch effect, that is shorter reading times for the number-mismatch condition compared to the all-match condition, was present only in the OR condition while no number mismatch effect was found in the SR condition.

[Figure 5 here]

[Table 5 here]

Post-target region. Figure 6 illustrates the reading time data at the adverbial phrase region ("during the break") while the model estimates, standard errors, *t*- and *p*-values of the statistical analysis are reported in Table 6. The analysis of reading time data on the post-target region only showed an effect of clause. No other effects were found.

[Figure 6 here]

[Table 6 here]

Discussion of Experiment 2

The main aim was to test whether the structure-based and feature-based differences found in Experiment 1, at the target region, could be replicated in a further study where the sentence structure was as similar as possible to some of the structures tested in language acquisition studies (as in Belletti et al., 2012), that is right-branching relative clauses. The results of Experiment 2 replicated the findings of Experiment 1 and are in line with the results from development. We found longer reading times for the ORC condition compared to the SRC condition. Crucially, we also replicated a clear facilitation effect (i.e., shorter reading times) for the number-mismatch ORC condition compared to the all-match ORC condition. As for the post-target region, we only found an effect of clause type, that is longer reading times in the ORC condition compared to the SRC condition. The reading time effects at the post-target region are discussed in the dedicated section following.

Further findings in the post-target region of Experiment 1 and 2.

In both experimental studies, we analysed the reading time data related to the processing of the region following the target (i.e., the relative clause verb). In Experiment 1, the

post-target region was the matrix verb of the main clause (e.g., “The professor [that the student greets] opens the door of the classroom”). We found longer reading times for the object relative clause condition compared to the subject relative clause condition. A further finding also emerged, which was a facilitatory effect that was non-selective both as for the type of feature (shorter reading times for both gender and number mismatches compared to all-match), and for the type of relative clause (facilitatory effect both in subject and object relative clauses).

In Experiment 2, the post-target region was an adverbial phrase (e.g., “Gianni observes the professor [that the student greets] during the break in the classroom). In this experiment, we only found longer reading times for the object relative clause condition compared to the subject relative clause condition, as in Experiment 1. No feature mis/match effects were found.

In summary, the reading time data coming from the post-target regions in both experiments show that the processing of the verb of the relative clause does carry over to the following region. Our findings also suggest that the post-target effects related to the processing of the relative clause verb appear to be qualitatively different depending on the sentential context in which the relative clause verb is embedded. There is a large body of evidence showing that right-branching relative clauses are easier to parse compared to centre-embedded relative clauses (e.g., (Blaubergs & Braine, 1974; Caplan et al., 2000; Kidd & Bavin, 2002; Miller & Isard, 1964; Stromswold et al., 1996; Thomas, 1995). Along the same lines, we found that only structural information (being in presence of ORCs or SRCs) appeared to affect the processing of the post-target region, in a simpler sentential context (i.e., right-branching relative clauses of Experiment 2). Conversely, we found that both structural information (being in presence of ORCs or SRCs) and featural information (presence of number and/or gender mis/match) appeared to influence the

processing of the post-target region in a more complex sentential context (i.e., centre-embedded relative clauses of Experiment 1). A previous eye-tracking study by (Staub et al., 2017) showed that during the processing of centre-embedded relative clauses, such as the one we tested in Experiment 1, reading time data on the matrix verb region mirror two different mechanisms, namely spillover effects related to the processing of the relative clause verb, and effects related to the processing of the verb of the main clause, which needs to agree with its own distantly located subject. Assuming this line of analysis, the non-selective facilitation effect in both feature mismatch conditions that we found in Experiment 1, could also have been influenced by the presence of the long-distance agreement relation that needed to be computed at the matrix verb region between the matrix verb and the distantly located subject.

General discussion

In this study, we aimed at investigating whether the featural Relativized Minimality principle, which has been found to influence children's ability to comprehend relative clauses, also plays a role during online sentence reading, in adults. We tested our research question by running two self-paced reading studies where Italian adults were asked to read both subject and object relative clauses. In the first study, we tested centre-embedded relative clauses, while in the second study we tested right-branching relative clauses. In both experiments, we manipulated in ORs the morphosyntactic features of the head and the subject of the relative clause preceding the relative clause verb so as to match or mismatch in number and in gender.

The results from the two studies can be summarized as follows: Adults took longer to read the region of interest, that is the verb of the relative clause, in the object-relative clause configuration than in the subject relative clause configuration. Moreover, in the

object-relative clause condition, our participants read the verb of the relative clause faster in presence of a relative head-subject number mismatch (e.g., “The professor … the students…”) than in the relative head-subject number match condition (e.g., “The professor … the student…”). Conversely, no significant differences were found in presence of a relative head-subject gender mis/match. We also found that the processing of the relative clause verb may spill over the following word. These spillover effects change as a function of the sentential context where the relative clause verb is embedded in.

In the next sections, we first discuss these new empirical findings in light of the theoretical approach that inspired our research question. Subsequently, we discuss our findings in relation to current formalizations of sentence parsing. Finally, we highlight some open questions generated by our findings and we suggest some ways to address these questions in future research.

Featural Relativized Minimality and the child-adult continuum

Featural Relativized Minimality assumes that when two elements that enter into a local relation (i.e., the moved noun phrase and the position where it is first merged) are hierarchically separated by an intervening element (another noun phrase) matching the featural specification of the elements it separates, an intervention effect arises and the sentence is more complex to comprehend. This is the case of object relative clauses as opposed to subject relative clauses tested in this study. Moreover, the featural Relativized Minimality principle proposes that comprehension is specifically difficult when the moved and the intervening elements share relevant properties expressed in featural terms: A full match in relevant morphosyntactic features that trigger syntactic movement, namely Number, make object relative clause comprehension difficult, in Italian.

In both experiments, we expected the fRM principle to influence the reading time data at the verb of the relative clause, i.e., the region where the A' dependency needs to be established. We also contemplated the possibility that the effects may spill over the post-target regions (the matrix verb in Experiment 1, an adjunct Prepositional Phrase in Experiment 2). In particular, we expected to observe longer reading times for ORCs compared to SRCs. Specifically, in the ORC condition, we expected to find shorter reading times when the target and the intervener mismatched in Number features compared to the all-match condition, while no difference was expected when comparing the two sentences containing a Gender mis/match.

The reading time data on the relative clause verb, in both experiments, are in line with our predictions based on the fRM principle. Empirical findings in the developmental literature have extensively provided evidence for the modulation of comprehension based on the fRM principle (e.g., Adani et al., 2010; Belletti et al., 2012; Bentea, 2016; Bentea et al., 2016; Friedmann et al., 2009; Hu et al., 2016; Martini, 2020; for intervention effects in other A' dependencies see also Belletti & Manetti, 2019; Bentea & Durrleman, 2017; Friedmann et al., 2017; Manetti et al., 2016). In the current study, we provided further empirical support to the intervention effects related to fRM principle by offering new data on adult online sentence comprehension of relative clauses (for similar findings during the adult processing of other A' dependencies see e.g., Contemori et al., 2018; Contemori & Marinis, 2014; Franck et al., 2015; Villata et al., 2016).

The first conclusion that can be thus drawn from these results is that both children and adults appear to be influenced by intervention effects during sentence comprehension, in line with previous studies. Our empirical findings support the idea of a child-adult continuum of language processing, according to which the parser is the same for children and adults and any performance difference may be due to other factors (e.g., (Clahsen &

Felser, 2006; Contemori & Marinis, 2014; Crain & Wexler, 1999; Felser et al., 2003; Friedmann et al., 2009; Love, 2007; Phillips & Ehrenhofer, 2015; Roberts et al., 2007).

Morphosyntactic features matter during sentence comprehension

The new findings reported in the current study show that structural and, more crucially, morphosyntactic constraints can modulate sentence comprehension. Our results are in line with a large body of literature showing that morphosyntactic features matter and are arguably processed through distinct parsing routines during sentence reading (e.g., Barber & Carreiras, 2005; Biondo et al., 2018; Mancini et al., 2011, 2014; Muralikrishnan & Idrissi, 2021; Zawiszewski et al., 2016). Together with previous findings, the current study shows that current models of sentence processing should account for feature-related differences.

To date, only cue-based retrieval models consider morphosyntactic features in their formalizations (as retrieval cues). The basic assumption behind cue-based parsing is that when a grammatical relation needs to be processed (e.g., the relation between the noun phrase subject modified by a relative clause and the verb of the main clause) a fast, associative, cue-based retrieval mechanism is triggered (i.e., from a grammatical head as the verb) to find the right antecedent of the dependency (i.e., the subject in a subject-verb agreement relation), based on a set of cues. The cues triggering retrieval seem to be the ones that can be grammatically derived from the word under computation (e.g., a verb such as "greets" overtly expresses singular features while it does not express gender features; number cues can be derived from the verb while gender cues cannot). Retrieval takes longer (e.g., in Lewis & Vasishth's model) if there are two items in memory that both match the cues provided by the verb, such as in the all-match ORC conditions tested

in our study, leading to a processing slowdown (*inhibitory interference*, following the terminology of (Jäger et al., 2017).

The findings reported in this study show that feature-related differences should be considered in a reliable formalization of sentence processing and that models that predict feature-related differences, such as cue-based retrieval models and top-down minimalist models, are on the right track. However, more needs to be made precise, especially with reference to the key property that makes features "relevant" during online sentence comprehension. The contribution of our study is that, in line with fRM, not all morphosyntactic features matter in the same way. Only some are relevant for the operation of the principle.

In the following section, we discuss some new questions that are raised by our results and the proposed interpretation that should be addressed in future research in order to refine the role of features during sentence comprehension.

Relevant open/new questions for future research

In the previous sections, we have shown that our new findings support the idea that the featural Relativized Minimality principle is at play during adult online sentence comprehension. We have also shown that our findings are compatible with cue-based and top-down parsing approaches. One question that naturally arises is therefore whether there is a specific reason for interpreting these data in terms of featural Relativized Minimality. Recent findings coming from developmental and adult literature suggest the key factor affecting processing is relevance of morphosyntactic features involved in syntactic movement (whether or not they are overtly realized), as theorized in the fRM, rather than feature overtness as commonly assumed by cue-based parsing models and top-

down models. In particular, we want to mention three studies directly relevant to this point.

The first piece of evidence is provided by Bentea and Durrleman (2017), who tested how French children comprehend right-branching subject and object relative clauses with number mis/matches presented auditorily, in a sentence picture matching task. The main aim of the study was to disentangle whether children's comprehension of relative clauses was influenced by the grammatical relevance *per se* of the feature (in terms of triggering syntactic movement), or by the overt realization of the feature in the linguistic stimulus. French is a suitable language to address this research question since number features are morphologically realized (as in Italian) but they can be either phonologically silent or audible depending on the conjugation of inflected verb. For example, verb forms such as *lave* ("(I/She) washes") and *lavent* ("They wash") are homophonous (pronounced [lav]), although they express singular vs. plural number features respectively, in contrast with verb forms such as *mord* (pronounced [mɔʁ]) and *mordent* (pronounced [mɔʁd]) where the singular vs. plural number is audible. The authors tested relative clauses where the number mis/match was either audible or non-audible. Results showed the classical subject-object relative clause asymmetry, with higher accuracy for subject relative clauses compared to object relative clauses independently from the audibility of number features. Crucially, children performed better in the number mismatch condition than in the number match object relative clauses, independently of the presence of an audible or non-audible number feature. The authors concluded that number features are relevant in French (as features triggering syntactic movement) independently of their overtness.

The second piece of evidence comes from two studies on the role of grammatical Case. Friedmann et al., (2017) tested the role of Case features during the processing of

A’ dependencies in different populations of (unimpaired and impaired) Hebrew speaking children. Intuitively speaking, Case is a salient feature (especially in languages with overt Case distinctions), since it makes it possible to identify the subject and the object of the sentence and related thematic roles. However, formally, Case is not a feature that triggers syntactic movement, so, in principle, it is not expected to play an active role during the processing of A’ dependencies based on the fRM approach. In order to test whether children use Case information to better understand A’ dependencies, the authors tested different structures in Hebrew (*which* object questions, object topicalization) with object marking expressed through the marker *et*. Both experiments led to similar results: Participants were not completely insensitive to the presence of the Case marker (there was a slight but yet not significant amelioration), most likely due to its saliency. However, children were unable to use Case marking for the interpretation of the object A’ dependencies (see exp. 2), as expected due to its formal status.

Compatible results were reported in a study by Avetisyan et al., (2020) testing whether Case marking affects agreement attraction (e.g., “The painter/s that the sculptor ignored during the exhibition…”) during adult sentence comprehension in Eastern Armenian, a language with a productive Case system. Self-paced reading time data (see exp. 3) showed that participants were sensitive to Case marking, that is Case-match conditions triggered longer reading times than Case-mismatch conditions but only later on in processing. In particular, the Bayesian analysis reported that in grammatical sentences there was inconclusive evidence for a Case effect during the processing of the target region, i.e., the relative clause verb, while a facilitatory effect of Case mismatch was found at the post-target region (the noun phrase of a temporal adverbial, e.g., “during the exhibition”). The Bayesian analysis also showed that agreement attraction effects are present in Armenian, although the analysis resulted inconclusive as for the modulation of

agreement attraction related to Case mis/matches. Avetisyan et al., (2020) proposed that the absence of a Case modulation of number attraction effects may reflect the fact that Case and number features are differentially used during language comprehension.

Besides agreeing with the authors on this point, we also want to discuss their findings in connection with our findings related to the processing of the post-target region. In particular, we notice that the late facilitatory effect of Case found in the grammatical sentences in their study resembles the non-selective facilitatory effects of gender that we found in Experiment 1, at the post-target region. Based on the fRM principle, both Case and gender are not expected to play an active role in Armenian and Italian respectively. Still, there is evidence for a late facilitation effect related to these features (faster reading times for the mismatch condition compared to the match condition) in the post-target regions of both studies. Note that Avetisyan et al.'s study and our Experiment 1 both tested embedded relative clauses but different post-target regions (i.e., adverbial in the former, and matrix verb in the latter). Our speculation is that morphosyntactic features may all matter and also be resorted during the comprehension of relatively difficult A' dependencies (e.g., centre-embedded relative clauses, as in our Experiment 1), however only the features that have a special morphosyntactic status, i.e., they trigger syntactic movement, such as number in Italian, are immediately deployed to solve the hard dependency. Thus, in contrast, the parser may resort to deploying also other features that do not have the same formal morphosyntactic relevance (e.g., gender in Italian or Case in Armenian) only later on in processing (and, we speculate, particularly so in complex sentential contexts, e.g., centre-embedded relative clauses compared to right-branching relative clauses). More studies should focus on the comparison of features with a different morphosyntactic "status" in the intended formal sense within the same experimental

design, and possibly in sentential contexts with varying complexity (e.g., different types of relative clauses), in order to further test this hypothesis.

Conclusions

This study tested whether number and gender mis/matches modulate the adult online comprehension of Italian subject and object relative clauses. We found faster reading times for subject than object relative clauses, thus offering new evidence for the widely attested subject-object relative clause asymmetry, in Italian. The crucial finding is that number mismatches between the head and the lexical subject of the relative clause can facilitate the comprehension of object relative clauses, while gender mismatches do not during online sentence reading. We claimed that these data, together with the large body of empirical findings provided by the developmental literature, show that both adults and children are subject to intervention effects as predicted by the featural Relativized Minimality. The relevance of these findings is twofold. On the one hand, these findings offer new evidence in favour of the children-adult continuum: Children and adults share the same language system, and taking into account evidence coming from language development and language processing in adults is mutually advantageous and should be promoted in order to better assess how the human language system works. On the other hand, these findings show that morphosyntactic features matter and that current models of sentence comprehension should include more fine-grained formalizations of the parsing routines that can account for the differential impact of different morphosyntactic features during comprehension. Accounts such as the featural Relativized Minimality, which offers formal theoretically-driven reasons for a different status of different morphosyntactic features that hold cross-linguistically, should thus inform current psycholinguistic models of sentence comprehension.

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Declaration of interest

The authors report no conflict of interest.

Authors' contribution

N.B. wrote the original draft and was responsible for the design, the experimental material and the data acquisition/analysis/interpretation of Experiment 1 and 2.

E.P. read and commented the manuscript, and designed the experimental material of Experiment 1.

V.M. read and commented the manuscript, collaborated in the conceptualization of the study and in the interpretation of the results.

L.R. read and commented the manuscript, worked at the theoretical underpinning of the analysis and at the interpretation of the results.

A.B. critically revised the manuscript, and contributed to all theoretical aspects related to the research question, and to the analysis and interpretation of the results.

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Table 1. Example of the experimental conditions in Experiment 1.

Subject-relative clause	
All-match	*Il professore che chiama lo studente apre la porta dell'aula.* "The professor$_{(SG,MAS)}$ that calls the student$_{(SG,MAS)}$ opens the door of the classroom"
Gender-mismatch	*Il professore che chiama la studentessa apre la porta dell'aula.* "The professor$_{(SG,MAS)}$ that calls the student$_{(SG,FEM)}$ opens the door of the classroom"
Number-mismatch	*Il professore che chiama gli studenti apre la porta dell'aula.* "The professor$_{(SG,MAS)}$ that calls the students$_{(PL,MAS)}$ opens the door of the classroom"
Object-relative clause	
All-match	*Il professore che lo studente chiama apre la porta dell'aula.* "The professor$_{(SG,MAS)}$ that the student$_{(SG,MAS)}$ calls opens the door of the classroom"
Gender-mismatch	*Il professore che la studentessa chiama apre la porta dell'aula.* "The professor$_{(SG,MAS)}$ that the student$_{(SG,FEM)}$ calls opens the door of the classroom"
Number-mismatch	*Il professore che gli studenti chiamano apre la porta dell'aula.* "The professor$_{(SG,MAS)}$ that the students$_{(PL,MAS)}$ call opens the door of the classroom"

Table 2. Summary of model estimates, standard errors, t-values for the data in the target region.

	Target			
	Estimate	***SE***	***t***	***p***
General model				
Clause	.35	.05	7.44	2.13e-09
Gender	-.02	.02	-1.52	.5
Number	-.05	.02	-2.93	.004
Clause x Gender	-.03	.03	-1.07	.28
Clause x Number	-.1	.04	-3.01	.004
Interaction model (SR)				
Number	-.01	.02	0.74	.46
Interaction model (OR)				
Number	-.08	.03	-2.96	.005

Table 3. Summary of model estimates, standard errors, t-values for the data in the post-target region.

	Post-target			
	Estimate	***SE***	***t***	***p***
General model				
Clause	.06	.02	4.07	.002
Gender	-.04	.01	-2.46	.01
Number	-.03	.02	-2.002	.048
Clause x Gender	-.01	.03	-.34	.73
Clause x Number	-.01	.03	-.36	.73

Table 4. Example of the experimental conditions in Experiment 2.

Subject-relative clause	
All-match	*Gianni osserva il professore che chiama lo studente durante la pausa in aula.* "Gianni observes the professor$_{(SG,MAS)}$ that calls the student$_{(SG,MAS)}$ during the break in the classroom"
Gender-mismatch	*Gianni osserva il professore che chiama la studentessa durante la pausa in aula.* "Gianni observes the professor$_{(SG,MAS)}$ that calls the student$_{(SG,FEM)}$ during the break in the classroom"
Number-mismatch	*Gianni osserva il professore che chiama gli studenti durante la pausa in aula.* "Gianni observes the professor$_{(SG,MAS)}$ that calls the students$_{(PL,MAS)}$ during the break in the classroom"
Object-relative clause	
All-match	*Gianni osserva il professore che lo studente chiama durante la pausa in aula.* "Gianni observes the professor$_{(SG,MAS)}$ that the student$_{(SG,MAS)}$ calls during the break in the classroom"
Gender-mismatch	*Gianni osserva il professore che la studentessa chiama durante la pausa in aula.* "Gianni observes the professor$_{(SG,MAS)}$ that the student$_{(SG,FEM)}$ calls during the break in the classroom"
Number-mismatch	*Gianni osserva il professore che gli studenti chiamano durante la pausa in aula.* "Gianni observes the professor$_{(SG,MAS)}$ that the students$_{(PL,MAS)}$ call during the break in the classroom"

Table 5. Summary of model estimates, standard errors, t-values for the data in the target region.

				Target
	Estimate	***SE***	***t***	***p***
General model				
Clause	.12	.02	6.6	2.8e-08
Gender	-.001	.01	0.7	.48
Number	-.03	.01	-2.02	.04
Clause x Gender	-.01	.03	0.5	.62
Clause x Number	-.01	.03	-2.12	.03
Interaction model (SR)				
Number	-.0003	.02	.17	.99
Interaction model (OR)				
Number	-.06	.02	-3.6	.0005

Table 6. Summary of model estimates, standard errors, t-values for the data in the post-target region.

	Post-target			
	Estimate	***SE***	***t***	***p***
General model				
Clause	.04	.01	2.92	.004
Gender	.02	.01	1.05	.3
Number	.003	.02	.20	.84
Clause x Gender	-.009	.03	-.32	.75
Clause x Number	.03	.03	.97	.33

Figure 1. Mean accuracy data in the two types of relative clauses, subject-relative (SR) and object-relative clause (OR), and in each sub-condition (all-match, gender-mismatch, number-mismatch). The bars represent standard errors.

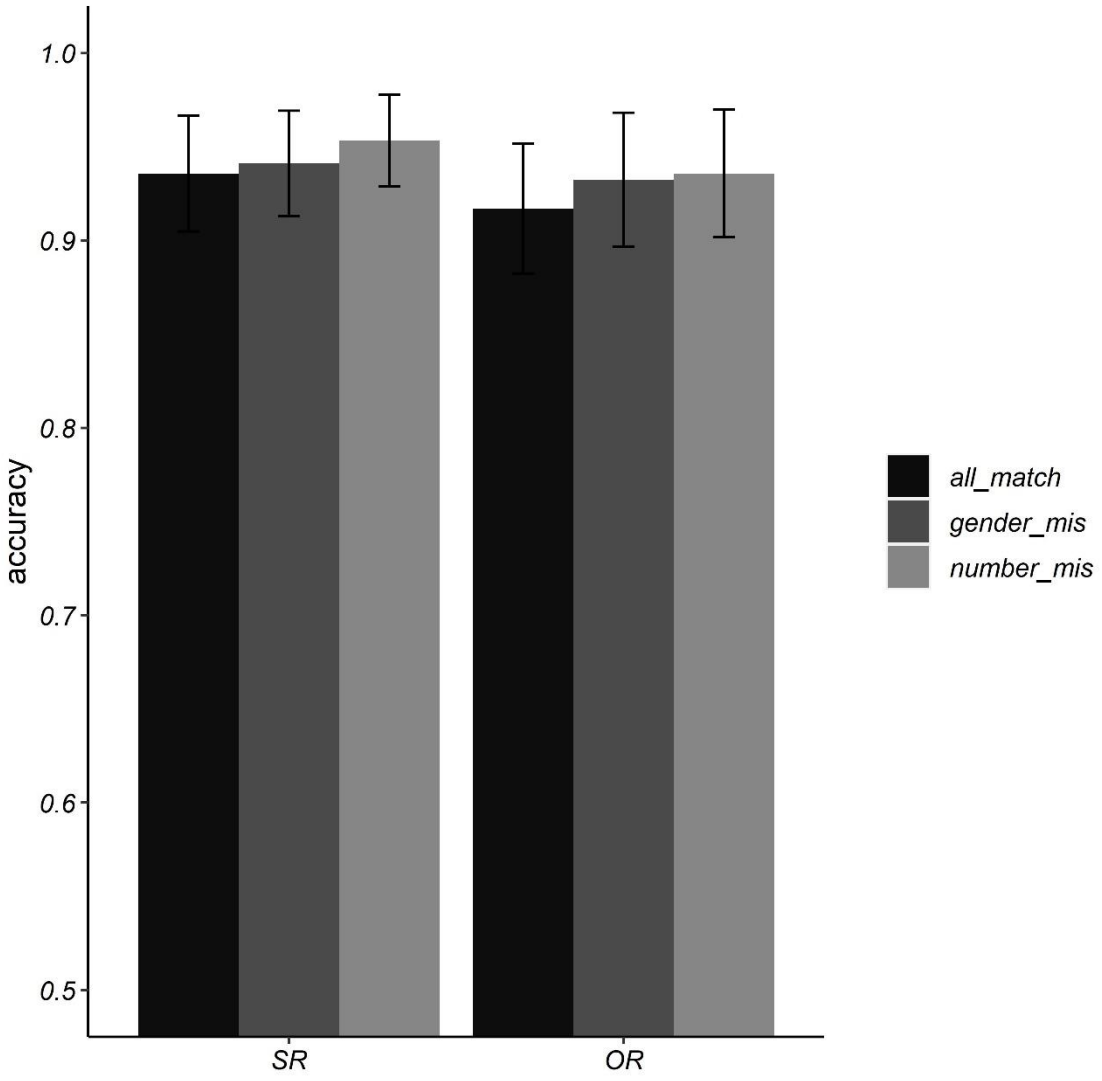


Figure 2. Mean reading time data per character in the two relative clauses (SR, OR) and in each condition (all-match, gender-mismatch, number-mismatch) for each constituent (on the left) and at the target region (on the right). Bars represent standard errors.

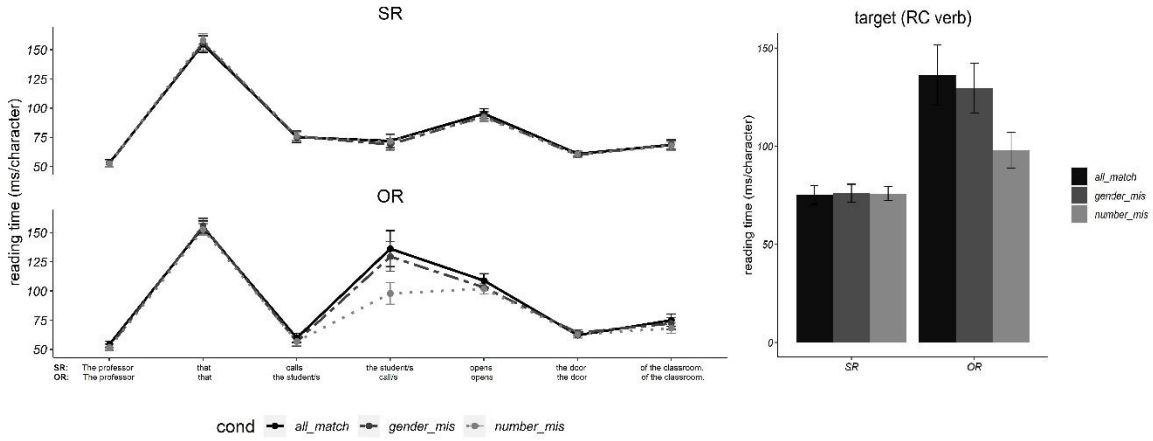


Figure 3. Mean reading time data per character in the two relative clauses (SR, OR) and in each condition (all-match, gender-mismatch, number-mismatch), at the post-target region. Bars represent standard errors.

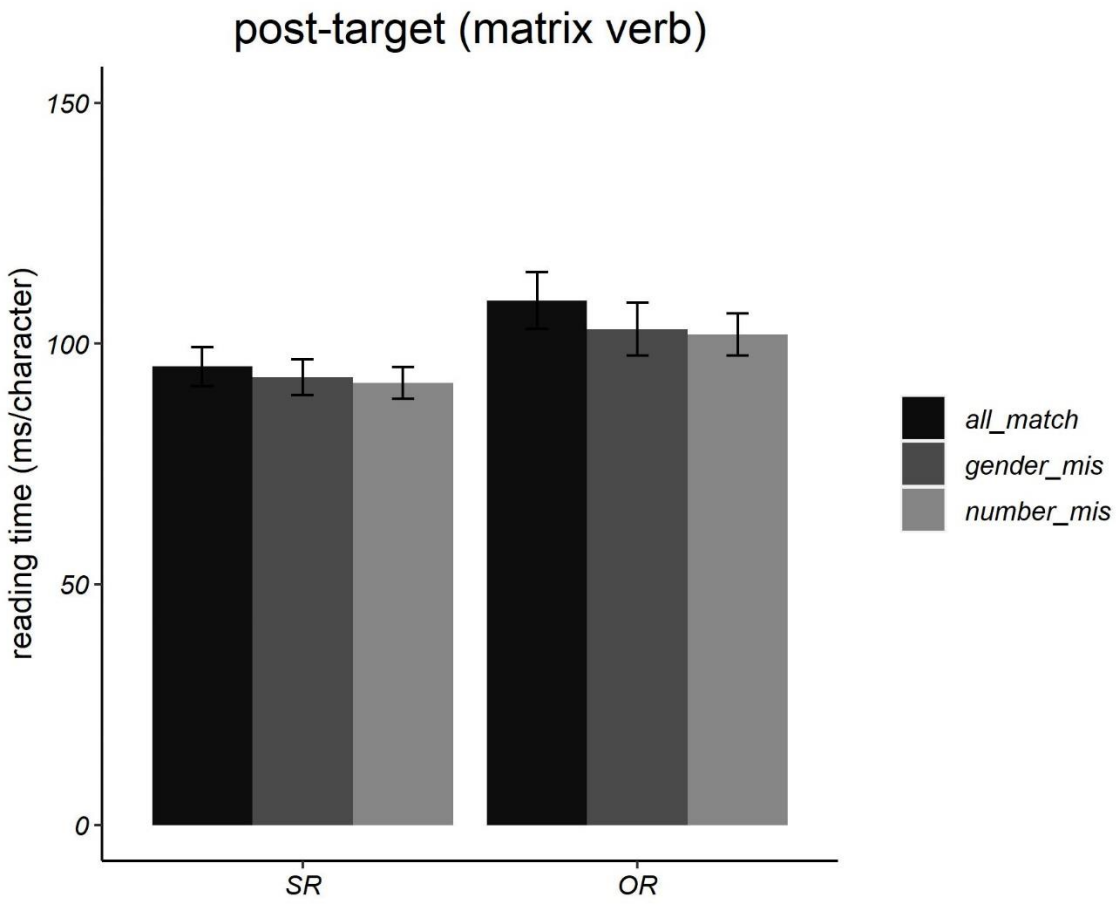


Figure 4. Mean accuracy data in the two types of relative clauses, subject-relative (SR) and object-relative clause (OR), and in each condition (all-match, gender-mismatch, number-mismatch). The bars represent standard errors.

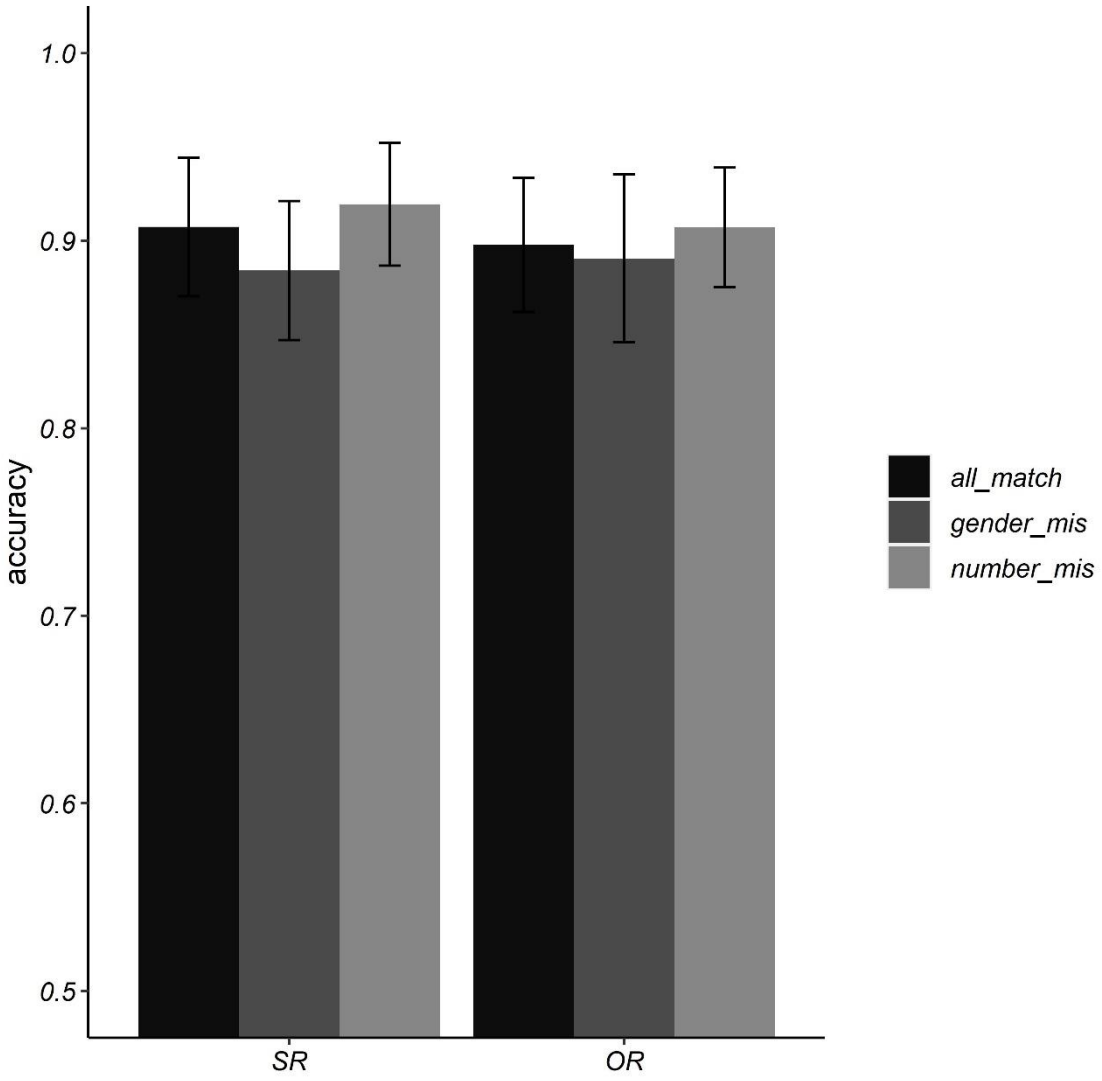


Figure 5. Mean reading time data per character in the two relative clauses (SR, OR) and in each condition (all-match, gender-mismatch, number-mismatch) for each constituent (on the left) and at the target region (on the right). Bars represent standard errors.

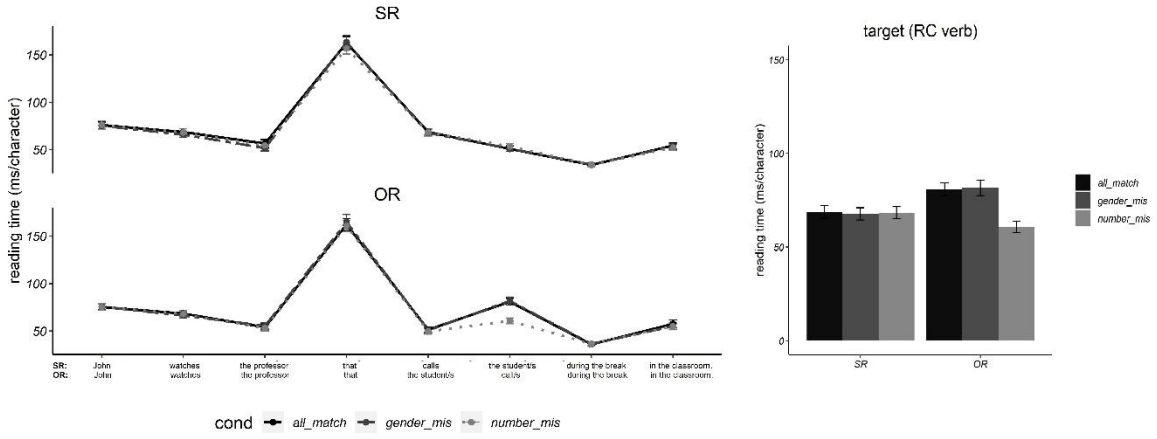
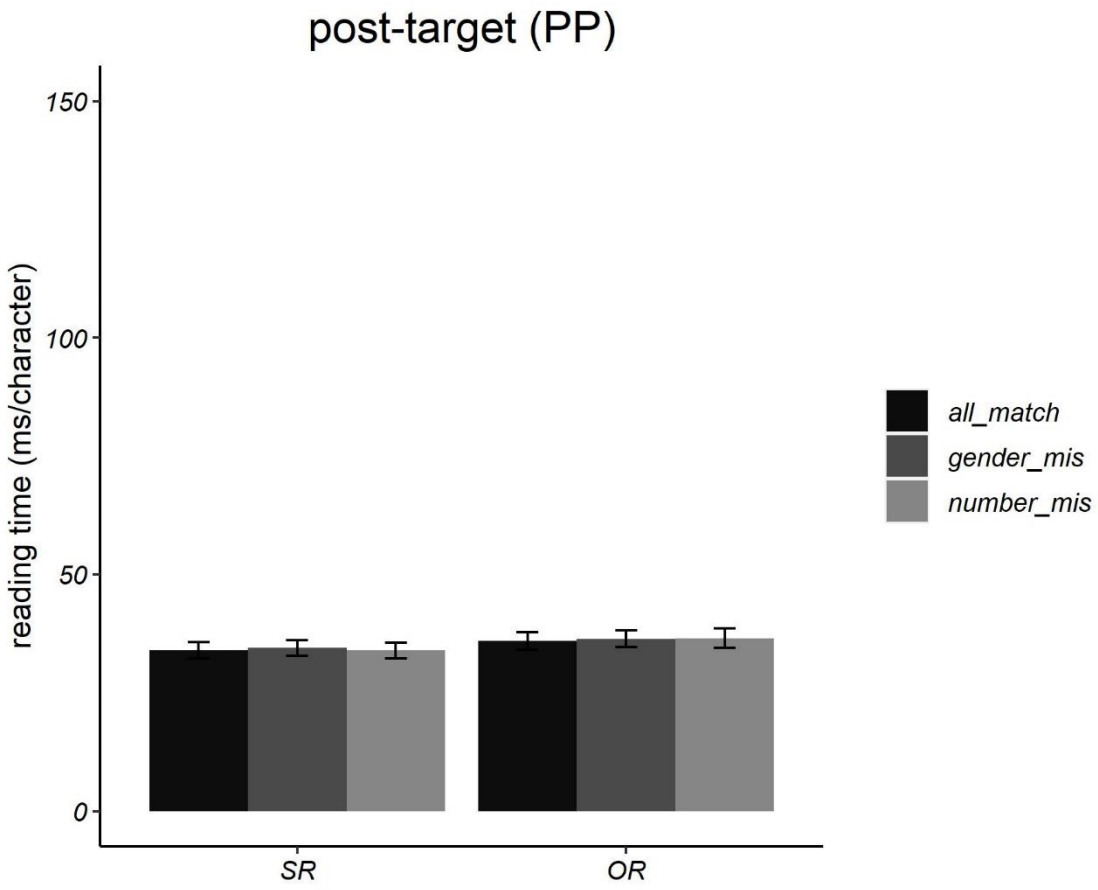


Figure 6. Mean reading time data per character in the two relative clauses (SR, OR) and in each condition (all-match, gender-mismatch, number-mismatch), at the post-target region. Bars represent standard errors.



[i] We have indicated 'headed' relative clauses, as the asymmetry only concerns ORCs with a lexical head (e.g., *the waiter* in 2) and a lexical subject in relative clause (e.g., *the boy* in 2) has been clearly shown by the developmental results presented in Friedmann et al. 2009: Free ORCs that do not have a lexical noun phrase head and ORCs in which the subject of the relative clause is a pronoun (not a lexical noun phrase) are well mastered in development (for an overview, see Belletti & Rizzi, 2013). In this article we will often use the short abbreviations SRC and ORC to only refer to lexically headed relative clauses, with a lexical subject in relative clause in the case of ORCs, as currently done in the literature. However, the domain of the asymmetry should be kept in mind, throughout.

[ii] The retrieval cues generally mentioned are notions such as subjecthood, animacy, noun phrase and morphosyntactic features such as number, gender and Case.

[iii] Nouns that had the same masculine and feminine form, such as *insegnante*$_{MAS/FEM}$ (teacher) or *regista*$_{MAS/FEM}$ (director) were avoided.

[iv] Human entities were preferred (over animal entities as in some previous developmental studies, e.g., Adani et al., 2010) for methodological reasons. Language acquisition studies generally adopt sentence-picture matching tasks, where sentences are presented auditorily and only response accuracy/reaction times are recorded. However, in our study with an adult population, we adopted self-paced reading, where sentences are presented in written format, and word-by-word reading times are analyzed. The adoption of animal entities with different gender (e.g., "cane", dog$_{MAS}$; "capra", goat$_{FEM}$) would have led to pre-target regions (the NP intervener in the ORC condition) with completely different lemmas in the gender mismatch condition. The adoption of different pre-target regions could have affected the reading times of our target region.
It is worth mentioning that some developmental studies also used human entities in their experimental material. E.g., in Belletti et al., (2012) the same stimuli were used in Hebrew and Italian. Results showed different gender mismatch effects in the two languages. As discussed in the text, the authors reported a gender mismatch amelioration only in Hebrew, where there is gender verbal agreement (hence gender has the relevant status as feature attracting syntactic movement). We believe that this finding indicates that the use of human entities should not prevent gender effects to be found or not found based on the status of the feature in the language under investigation.

[v] We decided to avoid auxiliary plus past participle verb forms, that is the near past known as *passato prossimo* in Italian (e.g., "ha chiamato", has called), used in a previous study by Villata et al. 2018 because of a peculiar property of Italian past participles. Past participles within the *passato prossimo* can be inflected for gender and number in Italian in some structures, see e.g., in preverbal object clitic constructions (e.g., "Gianni l'ha chiamata, (Maria)", Gianni CL$_{FEM/SG}$ has called$_{FEM/SG}$, (Maria); "Gianni li ha chiamati, (Paolo e Roberto)", Gianni CL$_{MAS/PL}$ has called$_{MAS/PL}$, (Paolo and Roberto)). In the type of constructions we tested, the past participle could not be inflected for number and gender. However, to our knowledge, no study has ever investigated whether Italian readers process or do not process gender/number information during the comprehension of the past participle of a *passato prossimo* verb form, and whether this process could interact with the processing of the auxiliary verb (and its own morphosyntactic features). Given that the main focus of the study was indeed the processing of different morphosyntactic features at the relative clause verb region, we decided to avoid this potential confound by adopting another verb form (the present).