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Similarity effects in the online and offline comprehension of relative clauses: Evidence from L1 and L2 Greek

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In this study we explore similarity effects in the processing and comprehension of subject (SRCs) and object relative clauses (ORCs) in Greek as a first (L1) and second (L2) language. Increased disruption in the processing of ORCs in the L1 due to featural similarity in the nominal domain (e.g., number match) is accounted for by approaches such as the featural Relativized Minimality, and similarity-based interference models. Similarity effects are much less researched in the L2 and the findings are thus far inconclusive. We report online and offline data obtained by means of a self-paced reading task with native and non-native speakers of Greek. Our findings reveal processing and comprehension costs for ORCs as well as similarity effects modulated by the RC type during L1 and L2 online sentence processing. The non-native speakers show some indication of increased interference due to ORCs at the end of the sentences, and also lower accuracy than the native speakers. However, their accuracy is positively affected by proficiency scores. Our findings show that number match affects the processing of RCs alike in both groups, implying that native and non-native speakers of Greek overall employ similar parsing routines.

1 Introduction

Relative clauses (RCs) exemplify a syntactic structure that has been extensively explored in linguistic and psycholinguistic research. More specifically, RCs constitute a case of filler-gap dependency that involves movement of an element from a position within the RC to a position outside the RC.[1] In subject RCs (SRCs), as in (1a), the moved element (*the boy)* serves as the subject of the RC, whereas in object RCs (ORCs), as in (1b), the moved element serves as the object of the RC. In both cases, a dependency is created between the displaced determiner phrase (DP) and the gap created in its original position (marked with brackets and indexes in (1a) and (1b) and the reader needs to resolve this dependency, by integrating the moved element to its extraction site, in order to achieve successful comprehension of the sentence.

(1) a. The boy$_i$ that <the boy$_i$> met the girl yesterday was kind.
b. The boy$_i$ that the girl met <the boy$_i$> yesterday was kind.

Although both SRCs and ORCs contain a displaced DP, a number of studies examining RC processing and comprehension in structures like (1) have convincingly shown that ORCs induce greater processing load than SRCs, establishing the well-known asymmetry between SRCs and ORCs. (e.g., King & Just 1991; Gordon & Hendrick & Johnson 2001; Traxler & Morris & Seely 2002; Gordon & Hendrick & Johnson 2004; Staub & Dillon & Clifton Jr 2017; Villata & Lorusso 2020 a.o.; for counter evidence see Carreiras et al. 2010 for Basque and Hsiao & Gibson 2003 and Chen et al. 2008 for Chinese but cf. Vasishth et al. 2013).

The SRC-ORC asymmetry has been captured by several sentence processing as well as a syntactic account. The sentence processing accounts can broadly be divided into two categories. The first category includes memory-based accounts (Dependency Locality Theory, Gibson 1998; 2000; Activation and Cue-Based Retrieval theory, Lewis & Vasishth 2005; Lewis & Vasishth & Van Dyke 2006; Vasishth & Lewis 2006; Self-Organizing Sentence Processing approach, SOSP, Villata & Franck 2020) and the second category includes frequency-based accounts (Word Frequency, Bever 1970; MacDonald & Christiansen 2002; Surprisal, Hale 2001; Levy 2008; Smith & Levy 2008; 2013 a.o.). Memory-based accounts expect processing difficulty to arise at the ORC verb, *met* in (1b), where the parser needs to retrieve from memory the extracted element, *the boy*, in order to fill the gap. This difficulty has been accounted for by two mechanisms (see Gibson & Wu 2013 for an overview): (a) decay in the activation of the target item, either as a function of the number of new discourse referents intervening between the target item and the gap site (e.g., Gibson 1998; 2000) or as a function of time and history of retrievals of the target

[1] Here, we adopt a generative analysis of relative clauses, which assumes that relative clauses are derived via movement. Moreover, we follow a matching analysis for relative clauses, which postulates that the entire DP is moved to the spec,CP position (Bianchi 2000; Salzmann 2006; 2019; but cf. Chomsky 1977 for an operator analysis and Kayne 1994 for a noun raising analysis).

item (e.g., Lewis & Vasishth 2005; Lewis & Vasishth & Van Dyke 2006), and (b) similarity-based interference due to the presence of distractor items with similar features which is further discussed in the next section (e.g., Gordon & Hendrick & Johnson 2001; 2004; Lewis & Vasishth 2005; Gordon et al. 2006; Lewis & Vasishth & Van Dyke 2006; Villata & Franck 2020).

Frequency-based accounts, on the other hand, assume that the parser anticipates the most frequent structure during incremental processing. Again, this prediction favors English SRCs such as the one in (1a) as they are found to be more frequent (Hale 2001; Reali & Christiansen 2007; Roland et al. 2007; Levy 2008) than the respective ORCs[2]. Moreover, configurational, i.e. the word order within the RC, as well as morphosyntactic properties, i.e. morphological marking on nominal constituents, affect the expectations the parser builds during incremental processing (see Vasishth & Lewis 2006; Levy & Fedorenko & Gibson 2013; Katsika & Lialiou & Allen 2022, for such effects in Hindi, Russian and Greek respectively). For example, Levy & Fedorenko & Gibson (2013) found that position and case of the RC DP modulate the processing of Russian RCs in that pre-verbal accusative DPs cause greater difficulty than post-verbal accusative DPs in SRCs and pre-verbal nominative DPs in ORCs. These asymmetries were accounted for by Levy & Fedorenko & Gibson (2013) on the basis of corpus frequency data showing that pre-verbal RC DPs are more frequent in ORCs than SRCs.

Featural Relativized Minimality (fRM, Rizzi 2004; Friedmann & Belletti & Rizzi 2009; Grillo 2009; Biondo et al. 2023) is a syntactic account that also expects (1b) to be harder than (1a). According to fRM, there is an element Z that intervenes between the two terms of a dependency, X (the head of the RC) and Y (the trace of X), as shown below. (1b) is expected to be deviant because the intervening element will be recognized as a possible candidate for the establishment of the relation between the two terms of the dependency (i.e., X and Y). As a result, processing and comprehension overload is expected in (1b), particularly if X and Z share the same features, a point we elaborate on in the following paragraphs.

(1) b. The boy_i that the girl met $<$the $\text{boy}_i>$ yesterday was kind.
X Z Y

The SRC-ORC asymmetry has been found to be attenuated by several factors (see Guasti & Vernice & Franck 2018 for facilitatory effects due to word order, and Mak & Vonk & Schriefers 2002 for animacy). In this vein, featural similarity between the head of the RC and the DP within the RC (object in SRCs and subject in ORCs) has been the focus of many recent studies. In (2) we see two instances of ORCs: in (2a) the RC head (*the boy*) and the RC subject (*the girl*) share several features such as animacy, definiteness, number etc., whereas in (2b) the two DPs differ in the morphosyntactic feature of number.

[2] We refer to frequency-based accounts to provide some of the most prominent models which account for the SRC-ORC asymmetry. However, we do not explore the predictions made by these accounts.

(2) a. The boy$_i$ that the girl met <the boy$_i$> yesterday was kind.
b. The boy$_i$ that the girls met <the boy$_i$> yesterday was kind.

A number of accounts in sentence processing (featural Relativized Minimality, Rizzi 2004; Friedmann & Belletti & Rizzi 2009; Grillo 2009; Biondo et al. 2023; similarity-based interference models such as Cue-based models, McElree & Foraker & Dyer 2003; Van Dyke & Lewis 2003; Lewis & Vasishth 2005; Lewis & Vasishth & Van Dyke 2006 and Self-Organizing Sentence Processing, Villata & Franck 2020) posit that featural similarity is expected to inhibit the comprehension of ORCs such as the one in (2b). Indeed, this inhibitory effect has been attested in several studies investigating RC processing in the first language (L1) (for example see Gordon et al. 2006 and Biondo et al. 2023). Recently, however, there has been a debate on whether similarity effects are observed in second language (L2) RC processing with findings not being conclusive yet (Hopp 2017; Xia & White & Guzzo 2022; Cunnings & Fujita 2023).

In this paper, we explore similarity effects in RCs in Greek as a first and second language by means of a self-paced reading task, in which we manipulate similarity with regard to number (mis)match between the head of the RC and the embedded DP. Our study is motivated by the fact that similarity effects in online processing and comprehension of RCs have thus far been explored only in four L2 studies (Franciotti & Martohardjono 2022; Xia & White & Guzzo 2022; Cunnings & Fujita 2023; White & Xia & Guzzo 2023) three of which test L2 English. Moreover, as will be shown in section 3, findings from these L2 studies are inconclusive regarding similarity effects in L2 processing. Additionally, findings from Greek offer the opportunity to gain a deeper insight into RC processing and comprehension cross-linguistically, especially since in Greek intervention arises hierarchically but not linearly, in contrast to English (see section 5 for more details). In sections 2 and 3 we discuss the accounts that have been put forward to explain similarity effects in the processing and comprehension of RCs in the first and the second language, and we present previous relevant Greek studies in section 4. In section 5, we describe the aims, the research questions and the predictions of our own study as well as the method we employed. The results are presented in section 6, while our findings are discussed in section 7. In the final section, we wrap up the main conclusions of our study (section 8).

2 Similarity effects in L1 RC processing

The similarity effects in examples (2a) and (2b) that have been introduced in the previous section are the focus of fRM (Rizzi 2004; Friedmann & Belletti & Rizzi 2009; Grillo 2009; Biondo et al. 2023 a.o.), and memory-based accounts predicting similarity-based interference (henceforth SBI models, e.g., Gordon & Hendrick & Johnson 2001; McElree & Foraker & Dyer 2003; Van Dyke & Lewis 2003; Gordon & Hendrick & Johnson 2004; Lewis & Vasishth 2005; Gordon et al. 2006; Lewis & Vasishth & Van Dyke 2006; Kush & Johns & Van Dyke 2015; Villata & Franck 2020).

Regarding fRM, the intervention effects expected in ORCs such as (1b) (see previous section) are assumed to be intensified by similarity, which is perceived as matching in the morphosyntactic features of the intervening and the moved element, and, more specifically, the morphosyntactic features that are relevant for the operation of movement. In (2a), the intervening element (*the girl*) matches the moved element (*the boy*) in the number feature (Friedmann & Belletti & Rizzi 2009; Grillo 2009; Biondo et al. 2023 a.o.), which is relevant for the triggering of movement and, therefore, (2a) is expected to evoke stronger disruption as compared to (2b), in which the number feature of the intervening element (*the girls*) is different from the one of the head of the RC (*the boy*).

There is extensive research in L1 development that has investigated the predictions of fRM in the comprehension of RCs and has provided evidence in support of it. More specifically, several studies have demonstrated that match in syntactically active morphosyntactic features (i.e., features triggering movement) inhibits the comprehension of ORCs (Adani et al. 2010; 2014; Belletti et al. 2012; Guasti & Stavrakaki & Arosio 2012; Varlokosta & Nerantzini & Papadopoulou 2015; Adani & Stegenwallner-Schütz & Niesel 2017; Bentea & Durrleman 2017; Peristeri & Kamona & Varlokosta 2023, a.o.).

In a very recent study, Biondo et al. (2023) tested the predictions of fRM in adult online processing. Biondo et al. investigated the effect of gender and number (mis)match in the processing and comprehension of center-embedded RCs like (3) and right-branching RCs like (4) in adult speakers of Italian by means of two self-paced reading tasks. For example, the intervening subject of the ORC either matched or mismatched the head of the RC in number or gender, as shown in (3) and (4). Accuracy was measured via comprehension questions targeting any constituent within their experimental sentences.

(3) Il professore che **lo studente /gli studenti /**
the.SG.M professor.SG.M that the.SG.M student.SG.M /the.PL.M students.PL.M/
la studentessa chiama/chiamano apre la porta dell'aula.
the.SG.F student.SG.F calls.SG/call.PL opens the door of the classroom
'The professor that the student(s) call(s) opens the door of the classroom.'

(4) Gianni osserva il professore che **lo studente /gli**
Gianni observes the.SG.M professor.SG.M that the.SG.M student.SG.M /the.PL.M
studenti/ la studentessa chiama/chiamano
students.PL.M /the.SG.F student.SG.F calls.SG/call.PL
durante la pausa in aula.
during the break in classroom
'Gianni observes the professor that the student(s) call(s) during the break in the classroom.'

Offline performance in center-embedded RCs showed an ORC disadvantage but no effect of feature match. On the other hand, Reaction Times (RTs) on the RC verb (critical region) showed an ORC disadvantage intensified by number match. The ORC disadvantage was evident on the main verb (post-critical region) as well, while there also appeared an inhibitory match effect irrespective of RC type and feature. With regard to right-branching RCs, no effects of RC type and feature match were observed in the accuracy data. However, RTs on the RC verb showed an interaction between RC type and number (mis)match, namely ORCs with number match were harder than ORCs with number (mis)match, in line with RTs from the center-embedded RCs. RTs on the post-critical adverbial region (*durante la pausa in aula*) revealed only an ORC disadvantage. These findings support fRM because similarity effects are attested only with number and not with gender feature as predicted by this model based on the assumption that number but not gender triggers movement in Italian (Friedmann & Belletti & Rizzi 2009; Adani et al. 2010; Belletti et al. 2012; but see Villata & Tabor & Franck 2018 for gender matching effects in Italian ORCs).

Within memory-based approaches of sentence processing there are specific predictions regarding similarity-based interference which is expressed in higher processing times and/or more comprehension errors (Gordon & Hendrick & Johnson 2001; McElree & Foraker & Dyer 2003; Van Dyke & Lewis 2003; Gordon & Hendrick & Johnson 2004; Lewis & Vasishth 2005; Gordon et al. 2006; Lewis & Vasishth & Van Dyke 2006; Kush & Johns & Van Dyke 2015; Villata & Franck 2020). Features that play a role in the computation of similarity might be of different kinds, such as morphosyntactic, e.g. number and gender, or semantic ones, e.g. animacy. Two types of similarity-based interference have been identified in the literature: retrieval and encoding interference. Retrieval interference arises at retrieval sites when the to-be-retrieved element matches with the distractor items in the retrieval cues. Encoding interference arises when the parser first encounters an item with similar features to previously encoded items and these features are not relevant for retrieval in the current context, but is also expected to affect subsequent retrieval processes (Villata & Tabor & Franck 2018: 2).

Let us now explain the two types of interference with respect to example (2). Encoding interference is expected to arise when the parser first encounters the subject DP of the ORC, *the girl* in (2a), since it carries similar features with the head DP, *the boy*. What is more, a retrieval process is triggered on the ORC verb related to the integration of the extracted object (*the boy*). During this process, retrieval interference might arise if the extracted object and the subject DP of the ORC match in features cued at the verb and encoding interference might arise if they match in features not cued at the verb. In the case of (2), the number of the object filler is not cued at the verb, i.e. the verb does not ask for an object of specific number, so potential similarity-based interference effects in (2a) compared to (2b) on the ORC verb, *met,* should reflect encoding. Interference is also expected to arise on the matrix verb, *was* in (2a) compared to (2b), due to retrieval processes related to the integration of the matrix subject, *the boy*. This interference might be either retrieval-based, due to the fact that number feature is cued at the

verb (*was* is in singular and due to subject-verb agreement a singular subject must be retrieved) or encoding-based, due to previously encoding DPs with similar number features[3].

Gordon et al. (2006) examined sentences such as (5) and found that on the RC Region as well as the matrix verb, the ORC disadvantage is attenuated when the subject of the ORC is dissimilar from the head of the RC, in that it is a proper name and not a common noun.

(5) a. The banker that praised **the barber/Sophie** climbed the mountain just outside of town.
b. The banker that **the barber/Sophie** praised climbed the mountain just outside of town.

These results were interpreted by Gordon et al. (2006) as providing evidence for similarity-based interference effects in RC processing.

Notice that both fRM and SBI models predict similarity effects in ORCs but differ with respect to the nature of features triggering interference. fRM predicts similarity interference only on the basis of features that are involved in syntactic movement, while SBI models do not have such restrictions on the type of the features involved. Another difference between fRM and SBI models is that fRM does not predict similarity effects on the matrix verb (see also Biondo et al. 2023) while interference effects are expected on the main verb according to SBI models, as illustrated above. We will come back to this issue at the Discussion section.

3 Similarity effects in L2 RC processing

The well attested SRC vs. ORC asymmetry has also been documented by previous studies exploring the processing and comprehension of RCs in the second language (Baek 2012; Lim & Christianson 2013; Street 2017; Franciotti & Martohardjono 2022). These studies argue in favor of the adoption of similar parsing routes in L1 and L2, at least as far as RCs are concerned. However, only a limited number of studies have thus far examined similarity effects in real-time L2 processing and comprehension of RCs. All the studies reviewed below have examined L2 English and their findings are not yet conclusive, as will be discussed below. Both the scarcity of relevant studies as well as the lack of consistent findings have motivated our study on similarity effects in L2 Greek.

[3] Retrieval interference is assumed by similarity-based interference models such as cue-based models (e.g., Lewis & Vasishth 2005; Lewis & Vasishth & Van Dyke 2006) and SOSP (Villata & Franck 2020). Encoding interference is implied in cue-based models (Lewis & Vasishth 2005: 412; Lewis & Vasishth & Van Dyke 2006: 449, 453) and there have been recently some attempts to incorporate it within cue-based models (see for example Villata & Tabor & Franck 2018), while it is explicitly assumed and implemented within the SOSP approach (Villata & Tabor & Franck 2018; Villata & Franck 2020). Our study was not designed to disentangle the two types of interference which, in any case, are difficult to dissociate empirically, as also highlighted by Villata & Tabor & Franck (2018: 2). Therefore, in this paper we use the more general term similarity-based interference and we refer to the models accounting for it as similarity-based interference models (SBI models).

Cunnings & Fujita (2023) examined similarity-based interference in L2 English RC processing and comprehension by means of an eye-tracking and an offline comprehension experiment. Participants had various L1 backgrounds. In the similar condition, the RC head (*the boy*) and the subject of the ORC (*the girl*) were both common nouns, whereas in the dissimilar condition the RC head was a common noun but the subject of the ORC was a proper name (*Rebecca*), as shown in (6).

(6) The boy that **the girl/Rebecca** saw yesterday afternoon, walked through the park. The weather was beautiful.

Regression path times and total viewing times on the RC region indicated a disadvantage for the similar as compared to the dissimilar conditions for both native speakers (NSs) and non-native speakers (NNSs). Moreover, this similarity effect was revealed mainly in the ORCs. No similarity effect in the expected direction was found on the matrix verb for either group. However, accuracy data from the offline task targeting the interpretation of the matrix verb indicated a small similarity effect for both groups and only for ORCs, namely lower performance in the similar than in the dissimilar conditions. Additionally, NNSs performed overall more accurately than NSs in the comprehension task.

Another recent study by Xia & White & Guzzo (2022) investigated similarity effects in L1 and L2 English RC processing and comprehension testing the theoretical predictions of fRM (Rizzi 2004; Friedmann & Belletti & Rizzi 2009; Grillo 2009; Biondo et al. 2023 a.o.). Their participants were native speakers of Chinese. More specifically, Xia & White & Guzzo (2022) explored the effect of number match by means of a self-paced reading task and a picture identification task in sentences like (7). The items in the self-paced reading task were followed by a paraphrase verification task targeting the RCs.

(7) I know/Show me the musician who the **waiter(s)** touched.

Total RTs of the entire sentence pointed towards an ORC disadvantage for NSs and NNSs at the advanced level, while there was no effect of number match in either group. What is more, RTs in the critical region of ORCs (i.e., *the waiter(s)* in (7)) revealed that, contrary to the authors' expectations, NNSs took more time to process mismatch than match conditions, while NSs showed no effect of feature match. Accuracy results from the paraphrase verification task, targeting the interpretation of the RC verb, as well as the picture identification task indicated an overall high performance for both groups as well as an ORC disadvantage for NSs and intermediate NNSs but not for advanced NNSs. Additionally, and rather unexpectedly, NNSs were less accurate with mismatch than match conditions.

Overall, while Xia & White & Guzzo's (2022) results confirm the well attested asymmetry between SRCs and ORCs, they provide no evidence of similarity effects in the expected direction,

in contrast to Cunnings & Fujita (2023). Xia & White & Guzzo (2022) attributed the lack of matching effects in ORCs to participants' L1 (Chinese) not having obligatory number marking on nouns, perhaps leading them to allocate more attention and time to mismatch conditions, which contained a singular and a plural DP, than to their match conditions, which contained only singular DPs. However, White & Xia & Guzzo (2023) recently tested L2 English RCs in Spanish and Mandarin speakers and replicated the SRC advantage and the lack of number similarity effects in both NS and NNSs but did not obtain an effect of L1 number marking on participants' performance.

Hopp (2017) has also investigated similarity effects in the processing of subject and object *wh*-questions such as (8) by means of a visual world paradigm task in German intermediate, high-intermediate and advanced NNSs of English. In object *wh*-questions we expect to find intervention effects due to the intervening subject, similarly to ORCs.

(8) a. Which cow(s) is/are pushing the goat?
b. Which cow is/are the goat(s) pushing?

The NNSs' accuracy scores showed an object disadvantage, which was modulated by number match only in the high-intermediate group in that NNSs were more accurate in the mismatch object *wh*-questions than in the match ones. It is interesting to note that German marks number by means of affixation which may account for the emergence of similarity effects in Hopp (2017) in contrast to Xia & White & Guzzo (2022).

Summarizing the L2 studies presented in this section, results regarding similarity effects are not conclusive. Only Cunnings & Fujita (2023) demonstrated an ORC disadvantage modulated by similarity effects in both offline and online measures. Moreover, all studies conducted thus far have examined the processing of English sentences, leaving an important gap with regard to similarity effects in L2 RC processing in other languages.

Regarding accounts that make predictions about L2 sentence processing, the Shallow Structure Hypothesis (SSH, Clahsen & Felser 2006; 2018) postulates that NNSs will experience persistent problems when processing abstract syntactic representations. More specifically, Clahsen and Felser (2006; 2018) argue that NNSs are expected to parse non-local dependencies differently from NSs, exhibiting an overreliance "on semantic, associative and surface information than on syntactic cues to interpretation" (2006: 565). ORCs exemplify a non-local dependency, since the object of the RC verb must be integrated back to the head of the RC across the subject of the RC (see 1b). In contrast, in SRCs no additional element intervenes between the dislocated element and its gap (see 1a). Based on the above, SSH would postulate that NNSs would experience difficulty in establishing the dependency in ORCs. This difficulty might result in NNSs exhibiting particularly increased processing times and lower accuracy in ORCs compared to NSs. Alternatively, this difficulty could entail similar processing times and

offline comprehension in SRCs and ORCs, as an indication that NNSs are not sensitive to the structural differences between SRCs and ORCs.[4]

A recent alternative account of L1–L2 differences in sentence processing is the one proposed by Cunnings (2017). More specifically, Cunnings argues that L1–L2 differences do not stem from NNSs' inability to construct fully specified syntactic parses but are due to their increased susceptibility to interference during memory retrieval involved in sentence processing (2017: 662). With regard to filler-gap dependencies, Cunnings claims that "potential differences in dependency resolution in L1/L2 speakers can be characterized in terms of how different populations may utilize different memory retrieval cues" (2017: 662). In a later study, Cunnings & Fujita (2023) also predicted increased interference during RC processing and comprehension in L2. Cunnings (2017) and Cunnings & Fujita (2023) do not explicitly describe the exact mechanism underlying NNSs' increased susceptibility to interference. We could assume that NNSs may weigh cues differently than NSs for reasons related to their L1 properties or to specificities of L2 acquisition, even though we acknowledge that this issue still remains rather unclarified. In any case, according to Cunnings's account and given the retrieval operations taking place during the processing of RCs (see section 1), we would expect greater interference in L2 compared to L1 speakers when processing ORCs that involve a feature match.

4 RC processing and comprehension in Greek

In Greek, RCs are introduced either with the relative pronoun *o opíos,* which is fully inflected for gender (masculine, feminine or neuter), case (nominative, accusative, genitive) and number (singular and plural), or with the complementizer *pu,* which is totally unspecified for gender, case and number, as shown in (9).

(9)[5] a. o ðáskalos **o opíos /pu**
the.NOM.SG.M teacher.NOM.SG.M the.NOM.SG.M who.NOM.SG.M /that
plisíase ton maθití kratúse vivlía
approached.3SG the.ACC.SG.M student.ACC.SG.M held.3SG books
'The teacher who/that approached the student held books.'

b. o ðáskalos **ton opío /pu**
the.NOM.SG.M teacher.NOM.SG.M the.ACC.SG.M who.ACC.SG.M /that
plisíase o maθitís kratúse vivlía
approached.3SG the.NOM.SG.M student.NOM.SG.M held.3SG books
'The teacher who/that the student approached held books.'

[4] Notice that we cannot test SSH with regard to similarity effects in RCs, as these effects can be accounted for, even in L1, not only by syntactic approaches such as fRM, but also by memory-based approaches as has been illustrated in the previous section.

[5] We use the International Phonetic Alphabet throughout the manuscript to represent the Greek examples.

Greek is a language with a rich morphological system and relatively flexible word order. Greek verbs are inflected for person and number, among other grammatical features such as tense, aspect etc. Moreover, Greek determiners and nominal elements are marked for number, gender and case, i.e. nominative is used for subjects and accusative for the complements of verbs and prepositions, while genitive is mainly employed in possessive constructions (Holton et al. 2012).

Additionally, the subject normally occurs post-verbally in constructions involving A' movement and, thus, the subject of ORCs surfaces in post-verbal position, as shown in (9b). This means that, at a surface linear level, there seems not to be intervention between the head of the RC and the post-verbal extraction position, as is the case in similar English structures (1b). Notice, however, that intervention is at play, because, under standard syntactic assumptions, subjects in ORCs occupy a VP-internal position (Kotzoglou 2006; Angelopoulos & Geronikou & Terzi 2022; for *wh*-questions) and the post-verbal position of the subject arises after the movement of the verb to the Tense Phrase (TP) (e.g., Anagnostopoulou 1994; Kotzoglou 2006). Thus, the underlying structure of an ORC is as in (10), in which the RC object has moved from the post-verbal position within the vP to the specifier position of Complementizer Phrase (CP), the verb has moved to TP, and the subject DP is in the specifier of vP; thus, the moved object crosses the intervening subject DP, resulting in a structure that is subject to intervention effects (see also Varlokosta & Nerantzini & Papadopoulou 2015 and Angelopoulos & Geronikou & Terzi 2022 for similar arguments).

(10) [CP o ðáskalos.NOM puC [TP plisíaseT [vP o maθitís.NOM <plisíase> <ton ðáskalo.ACC>]]]

The structure of Greek ORCs illustrated in (10) makes Greek an intriguing case for exploring similarity effects, because, as highlighted in section 1, intervention occurs hierarchically rather than linearly.

Frequency data further corroborate the fact that post-verbal subjects in Greek ORCs are the default option. More specifically, a corpus analysis of written texts in Greek (Hellenic National Corpus)[6] conducted by Katsika & Lialiou & Allen (2022) revealed that in ORCs the subject normally appears in post-verbal position.

The processing of SRCs and ORCs has not been thus far systematically examined in Greek. Most studies have employed offline measures to test the predictions of fRM. Here we focus on the findings from Greek neurotypical adults who were used either as the experimental group (Tsiousia 2023) or as a control group in studies that have primarily focused on impaired individuals (Nerantzini et al. 2014; Terzi & Nanousi 2018; Arfani & Tsapkini & Varlokosta 2021) or typically developing children (Alexandri et al. 2017).

[6] https://hnc.ilsp.gr/index.php?current_page=main&lang=en.

Concerning the asymmetry between SRCs and ORCs, a marginal ORC disadvantage has only been reported by Tsiousia (2023) who employed a sentence picture matching task with Greek young adults, whereas other Greek studies either have not explored this asymmetry (Alexandri et al. 2017; Arfani & Tsapkini & Varlokosta 2021) or have not found any effects (Nerantzini et al. 2014; Terzi & Nanousi 2018). With regard to similarity effects in the comprehension of Greek RCs, studies investigating gender and case, i.e. features that do not trigger movement in Greek (Belletti et al. 2012), did not report any inhibition due to feature match (Terzi & Nanousi 2018; Tsiousia 2023), supporting, thus, the predictions of fRM. With regard to number, which is an active morphosyntactic feature in Greek, findings are not yet conclusive. Alexandri et al. (2017) reported no similarity effects in a sentence-picture matching task, whereas Arfani & Tsapkini & Varlokosta (2021) observed an inhibitory number match effect for ORCs in a similar task. Note, however, that participants' average age in Arfani & Tsapkini & Varlokosta was 76 years in contrast to the much younger average age (25;3 years) of participants in Alexandri et al.'s study.

Recently, Katsika & Lialiou & Allen (2022) explored word order effects in the processing of SRCs and ORCs and, in particular, they tested SRCs with post- and pre-verbal objects as well as ORCs with post- and pre-verbal subjects. They conducted a self-paced listening task, followed by a grammaticality judgment task, with Greek adults and children. Here we focus on the adult data only from the conditions that involve post-verbal DPs within the RC, either objects (11a) or subjects (11b), as they are more relevant to the present discussion.

(11) a. SRC, post-verbal object

o	ðáskalos	pu	çerétise	ton	
the.NOM.SG.M	teacher.NOM.SG.M	that	waved-at.3SG	the.ACC.SG.M	
maθití	bíce	se	éna	leoforío	
student.ACC.SG.M	got.3SG	onto	a	bus	

'The teacher that waved at the student got onto a bus.'

b. ORC, post-verbal subject

o	ðáskalos	pu	çerétise	o	
the.NOM.SG.M	teacher.NOM.SG.M	that	waved-at.3SG	the.NOM.SG.M	
maθitís	bíce	se	éna	leoforío	
student.NOM.SG.M	got.3SG	onto	a	bus	

'The teacher that the student waved at got onto a bus.'

With respect to the structures described in (11), Katsika & Lialiou & Allen (2022) found no evidence of the SRC-ORC asymmetry in the online listening task. However, the asymmetry was attested in the offline task, since participants judged SRCs as grammatical more often than ORCs.

5 The present study

The aim of the present study is to explore similarity effects in RC processing and comprehension in L1 and L2 Greek. More specifically, the goal of the study is to investigate the effect of number match in SRCs and ORCs by means of a self-paced reading task which also incorporates an offline comprehension measure. Since previous findings on similarity interference in L2 are not compelling, as already discussed in the previous section, we aim to contribute to the ongoing discussion by providing additional evidence on the effects of feature (mis)match in L2.

In line with the observations made in section 4, our experimental items, as will be shown below, include ORCs with post-verbal subjects. Since similarity effects have not yet been explored online in a language in which intervention arises hierarchically but not linearly (see (10)), we believe that the Greek data presented in our study offer the opportunity to gain a deeper insight into these effects.

5.1 Research questions and predictions

As previously noted, the main goal of the present study is to investigate feature similarity effects in Greek L1 and L2 RC processing by means of a self-paced reading task. Our study addresses the following research questions:

1. Are ORCs more difficult to parse and comprehend than SRCs in L1 and L2 Greek?
2. Does feature similarity tested via number match play a role in the processing and comprehension of ORCs in L1 and L2 Greek?
3. Does proficiency play a role in the processing and comprehension of RCs in L2 Greek?

For each of the aforementioned questions, we make separate predictions:

1. If ORCs are harder to parse and understand due to intervention (e.g., Rizzi 2004) or memory processes related to object retrieval (e.g., Lewis & Vasishth & Van Dyke 2006), we expect higher RTs and lower accuracy in ORCs than SRCs in NSs. Moreover, an interaction between RC type and Group would provide evidence in favor of SSH (Clahsen & Felser 2006; 2018). If this interaction reflects increased RTs and lower accuracy in ORCs for NNSs as compared to NSs, this would indicate that NNSs experience particular difficulty with establishing non-local dependencies such as ORCs. Alternatively, if the interaction points towards a lack of ORC disadvantage in NNSs, this would imply similar processing times and offline comprehension in SRCs and ORCs for the group of NNSs.
2. If feature similarity modulates the processing and comprehension of ORCs according to fRM (e.g., Rizzi 2004) and SBI models (e.g., Gordon & Hendrick & Johnson 2001; Lewis & Vasishth 2005; Lewis & Vasishth & Van Dyke 2006; Kush & Johns & Van Dyke 2015;

Villata & Franck 2020), we expect ORCs, in which the RC head and the subject of the ORC match in number, to be harder to parse and comprehend than ORCs, in which these two DPs mismatch in number. What is more, in the case of ORCs with a number match SBI models also predict similarity-based interference on the matrix verb following the ORCs, e.g. match conditions are expected to be harder than mismatch ones on the matrix verb after ORCs. Moreover, an interaction between RC type, Match and Group in our online and offline measures, i.e. increased RTs and lower accuracy, in ORCs and matrix verbs for NNSs as compared to NSs, would provide evidence for increased L2 interference, as predicted by Cunnings (2017).

3. According to previous studies (Lim & Christianson 2013), which report a positive effect of proficiency on NNSs' performance, we expect that NNSs with a higher proficiency score are more likely to be faster and less error-prone across conditions. Additionally, we expect that more advanced learners will be less affected by similarity-based interference.

5.2 Participants

Participants included 33 L2 Greek speakers (18 males, mean age = 30, range = 19–53) and 34 L1 Greek speakers (17 males, mean age = 29.31, range = 18–48), matched with L2 speakers for age, gender, and educational attainment. The L2 speakers were recruited from the School of Modern Greek Language of the Aristotle University of Thessaloniki in Greece. At the time of testing, all L2 participants were attending classes for the C1 level of proficiency in Greek. They had all been exposed to Greek in adulthood and they had had courses of Greek for at least two years. Their proficiency in Greek was further measured by means of a cloze task that was created on the basis of the French cloze task designed by Tremblay & Garrison (2010) and consisted of a text with 50 gaps to be filled in by participants. 25 gaps corresponded to content words and 25 gaps to function words. Overall, the NNSs' average score was 40.12/50 (Range: 30–48, SD = 5.58). No participants were excluded based on their proficiency score. With regard to their L1s, L2 participants had a wide variety of linguistic backgrounds (e.g., Arabic, Chinese, Croatian, Czech, English, Estonian, Georgian, Italian, Japanese, Korean, Spanish, Ukrainian, Russian, Serbian and Slovak). Most of the L1s of our NNSs (30 out of 33) exhibit subject verb agreement and nominal number marking, an issue to which we return in the discussion. All participants took part in the study voluntarily.

5.3 Experimental tasks

Each participant completed an online questionnaire on personal information such as age, amount of exposure in Greek etc., a cloze task (described in the previous section), a familiarization task, a self-paced reading task and a written production task. The familiarization task was used to

ensure that all 36 nouns contained in the experimental items of the self-paced reading task (see below) were familiar to the NNSs and consisted of a word-picture matching task, implemented in Microsoft PowerPoint in such a way that each item corresponded to a separate PowerPoint slide. Each slide contained the target word written in Greek at the bottom of the slide as well as three pictures above the word.[7] Each participant had to orally choose the picture corresponding to the meaning of the target word. Feedback was immediately given. In case of error, the researcher explained the word in more detail and examples were given to enhance understanding of the word meaning. Overall, participants' performance was at ceiling, meaning they knew all nouns used in the experimental sentences.

In the written production participants were presented with two topics and were asked to choose one of them and to produce a written text of about 150 to 300 words[8]. One topic was to narrate a book, a movie or a theater play they like, and the second topic was to describe the city and the neighborhood they live in. We used this task as an independent measure for the NNSs' knowledge on RCs, subject verb agreement, nominal inflection, and word order. Overall, the NNSs used 72 RCs, while SRCs (56) outnumbered ORCs (16). The NNSs never used a pre-verbal subject in ORCs in line with the native data from the corpus analysis conducted by Katsika & Laliou & Allen (2022). Moreover, subject verb agreement and nominal inflection were always accurately used.

Turning to the self-paced reading task, the experimental sentences manipulated RC type (subject vs. object) and number match (match vs. mismatch) between the RC head and the object of the SRC or the subject of the ORC, resulting in four conditions, as illustrated in (12). Note that we use brackets to indicate the regions the sentences have been divided into.

(12) a. **SRC – number match**

[**o**	**ðáskalos**]$_{R1}$	[**pu**]$_{R2}$	[**plisíase**]$_{R3}$	[**ton**	
the.NOM.SG.M	teacher.NOM.SG.M	that	approached.3SG	the.ACC.SG.M	
maθití]$_{R4}$	[**kratúse**]$_{R5}$	[**vivlía**]$_{R6}$			
student.ACC.SG.M	held.3SG	books			

'The teacher that approached the student was holding books.'

b. **SRC – number mismatch**

[**o**	**ðáskalos**]$_{R1}$	[**pu**]$_{R2}$	[**plisíase**]$_{R3}$	[**tus**	
the.NOM.SG.M	teacher.NOM.SG.M	that	approached.3SG	the.ACC.PL.M	
maθités]$_{R4}$	[**kratúse**]$_{R5}$	[**vivlía**]$_{R6}$			
student.ACC.PL.M	held.3SG	books			

'The teacher that approached the students was holding books.'

[7] Pictures were all retrieved from https://www.freepik.com/ and https://unsplash.com/.

[8] Participants' written productions were incorporated in the Greek Learner Corpus (Papadopoulou et al. 2024).

c. **ORC – number match**
[o **ðáskalos]**$_{R1}$ **[pu]**$_{R2}$ **[plisíase]**$_{R3}$ **[o**
the.NOM.SG.M teacher.NOM.SG.M that approached.3SG the.NOM.SG.M
maθitís]$_{R4}$ **[kratúse]**$_{R5}$ **[vivlía]**$_{R6}$
student.NOM.SG.M held.3SG books
'The teacher that the student approached was holding books.'

d. **ORC – number mismatch**[9]
[o **ðáskalos]**$_{R1}$ **[pu]**$_{R2}$ **[plisíasan]**$_{R3}$ **[i**
the.NOM.SG.M teacher.NOM.SG.M that approached.3PL the.NOM.PL.M
maθités]$_{R4}$ **[kratúse]**$_{R5}$ **[vivlía]**$_{R6}$
student.NOM.PL.M held.3SG books
'The teacher that the students approached was holding books.'

RCs were always introduced with the complementizer *pu* ('that'). All experimental items were semantically reversible and contained only masculine, definite, human DPs. Moreover, our items included all possible combinations of number match, i.e., SG.SG, PL.PL and mismatch, i.e., SG.PL, PL.SG, equally distributed across the experimental items, although the type of combination was not examined as a separate variable. In SRCs (12a) and (12b) the object of RC was marked for accusative case, while the subject DP in ORCs (12c) and (12d) was marked for nominative case. We constructed 24 quartets as in (12), which were pseudorandomly distributed across four versions (Latin square design), so that each version contained 24 experimental sentences and all conditions but the same sentence never appeared twice. 48 filler sentences were also included containing various long-distance dependencies. We decided to expose our participants to all conditions of our experimental items to reduce potential individual differences in NNSs (similar designs have been used in child sentence processing studies, Felser & Marinis & Clahsen 2003; Roberts et al. 2007). This is why we merged the 4 lists in two blocks so that each block contained 48 experimental sentences (equally distributed across the four conditions) and 96 fillers[10].

All items were followed by a paraphrase verification task, as shown in (13). Paraphrases following the experimental items probed the interpretation of the sentence as an SRC or ORC. For example, if the participant replies that the paraphrase (13) is true for sentence (12c), this implies that (s)he has analyzed and comprehended sentence (12c) as involving an SRC instead

[9] Notice that only in the ORC mismatch condition (12d) the RC verb unambiguously signals that the RC is an object one. This is because the head DP and the verb of the RC do not agree in number, and, thus, the RC could not be a subject one. In contrast, in (12a, b and c) the head DP and the verb of the RC agree in number. This means that until the RC DP is encountered, it is not clear whether the RC is a subject or an object one (Region1, Region2 and Region3 are identical up to this point), given that post-verbal subjects in ORCs are the default option in Greek (see the discussion above). We come back to this point in the results and discussion sections.

[10] The 96 fillers were equally distributed in the two blocks (48 per block) and represented different filler items.

of an ORC. One half of the paraphrases had to be responded as being accurate interpretations of the sentences and the other half as inaccurate and this manipulation was counterbalanced across conditions.

(13)	o	ðáskalos	plisíase	ton	maθití
	the.NOM.SG.M	teacher.NOM.SG.M	approached.3SG	the.ACC.SG.M	student.ACC.SG.M

'The teacher approached the student.'

Paraphrases also followed the filler items and probed various types of information.

5.4 Procedure

Due to COVID-19 restrictions, the self-paced reading task was run online using Gorilla Experiment Builder (https://gorilla.sc/, for the validity of the tool see Anwyl-Irvine et al. 2020). Each participant was tested in two sessions. The first session lasted approximately 1 hour and included the completion of the following: a) the online questionnaire on personal information such as age, amount of exposure in Greek etc., b) the cloze task, c) the familiarization task, d) the first block of the self-paced reading task and d) the written production task. The second session was completed at least one week after the first one. It included only the second block of the self-paced reading task and lasted approximately 20 minutes. The order of the self-paced reading blocks was counterbalanced across participants.

With regard to the self-paced reading task, participants initially saw a cross in the middle of the screen that automatically disappeared after 450ms. Each sentence was then presented with only the first region visible while the rest of the sentence was covered with a thick black line hiding words and punctuation. Participants read the sentence in a self-paced, region by region, non-cumulative paradigm using the spacebar.

After reading each sentence, a paraphrase verification sentence (see (13)) was presented on the screen requiring the participant to reply either True or False based on the content of the sentence (s)he had just read. No feedback was given at any point of the experimental procedure. Before the experiment, participants read the instructions and completed a training of four sentences similar to fillers.

All participants provided informed consent.

6. Results

6.1 Data analysis

For the statistical analysis, accuracy in the offline paraphrase verification task and RTs by region were analyzed using the lme4 package and mixed-effects logistic regression models in R (R Core Team, 2017). For accuracy, binary logistic regression was conducted employing the *glmer*()

function and for RTs, linear mixed-effects models were conducted employing the *lmer*() function. The fixed effects were Group (NSs, NNSs), the type (RC_Type) of relative clause (i.e., ORCs, SRCs) and Matching (match, mismatch), i.e., whether the DP within the RC matches or mismatches the RC head in number. For all fixed effects, sum contrasts (0.5, –0.5) were applied assimilating ANOVA contrasts. When interactions occurred, pairwise comparisons adjusting the *alpha*-level (Bonferroni correction) were conducted. The random structure of the models included random intercepts by participants and items. Furthermore, random slopes for both participants and items were also used for RC_Type and Matching, as well as their interaction, each time with the maximal factor specification that converged (Barr et al. 2013) and which did not lead to –1/1 correlations of the random effects and/or singularity warnings to avoid overfitting (Matuschek et al. 2017). Finally, proficiency (centered around the mean) was also explored in both accuracy and RTs, when differences between NSs and NNSs occurred. We report effect sizes using the model estimates (β), standard errors (*SE*), *z*-statistics, and *p*-values.

6.2 Data handling and Descriptives

For the RT analysis, only trials in which participants had correctly responded to the end-of-sentence paraphrases were included. Extreme values below 100 ms and above 3,500 ms were excluded from the analysis based on previous literature (Marinis & Saddy 2013) affecting less than 15% (Ratcliff 1993) of the initial dataset for both groups across regions (NSs: R2 0.2%, R3 0.2%, R4 3.2%, R5 1%, R6 1.5%; NNSs: R2 0.8%, R3 3.6%, R4 13.8%, R5 3%, R6 2.5%). The regions analyzed were R2 (the complementizer), R3 (the verb of the RC clause), R4 (the DP within the RC), R5 (the main verb), and R6 (the final segment) to explore potential wrap-up effects in the end-of-sentence processing times. RTs by region were transformed using the logarithmic transformation based on the *boxcox* function (Lago & Felser 2018; Lago & Stutter Garcia & Felser 2019; Paspali & Rizou & Alexiadou 2022).

6.3 Accuracy

Accuracy on the filler items was very high, 98% for both NSs and NNSs. **Figure 1** shows participants' accuracy in the offline paraphrase verification task.

There was a main effect of Matching (**Table 1**) such that participants were less accurate in the match compared to the mismatch condition, a main effect of RC_Type such that participants were more accurate in SRCs compared to ORCs, and a main effect of Group such that NSs were more accurate than NNSs.

Furthermore, proficiency reliably predicted NNSs' accuracy (**Figure 2**) in the end-of-sentence paraphrases ($\beta = 0.474$, $se = 0.192$, $z = 2.48$, $p = .013$, *cor*(Kendall) = .25), reflecting that NNSs with higher proficiency scores were more likely to answer correctly the end-of-sentence paraphrases.

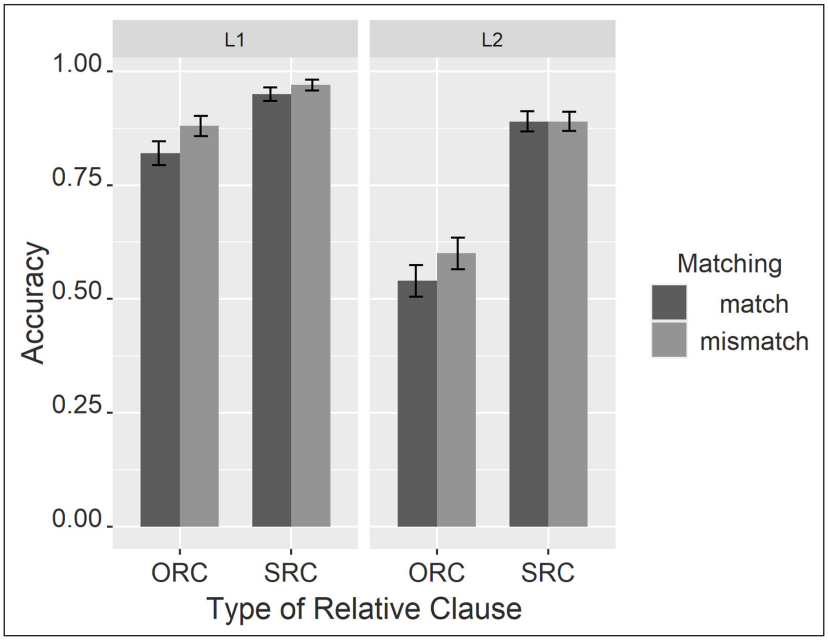

Figure 1: Mean accuracy by group and condition. Error bars represent confidence intervals (CIs).

	β	*se*	*z*	*p*
(Intercept)	2.19	0.147	14.884	**<.001**
Matching	–0.488	0.109	–4.48	**<.001**
RC_Type	1.670	0.190	8.94	**<.001**
Group	1.455	0.289	5.04	**<.001**
Matching:RC_Type	0.099	0.188	0.525	.600
Matching:Group	–0.302	0.192	–1.57	.117
RC_Type:Group	–0.524	0.364	–1.440	.150
Matching:RC_Type:Group	–0.204	0.366	–0.558	.577

Table 1: Model results for accuracy in the end-of-sentence paraphrases.

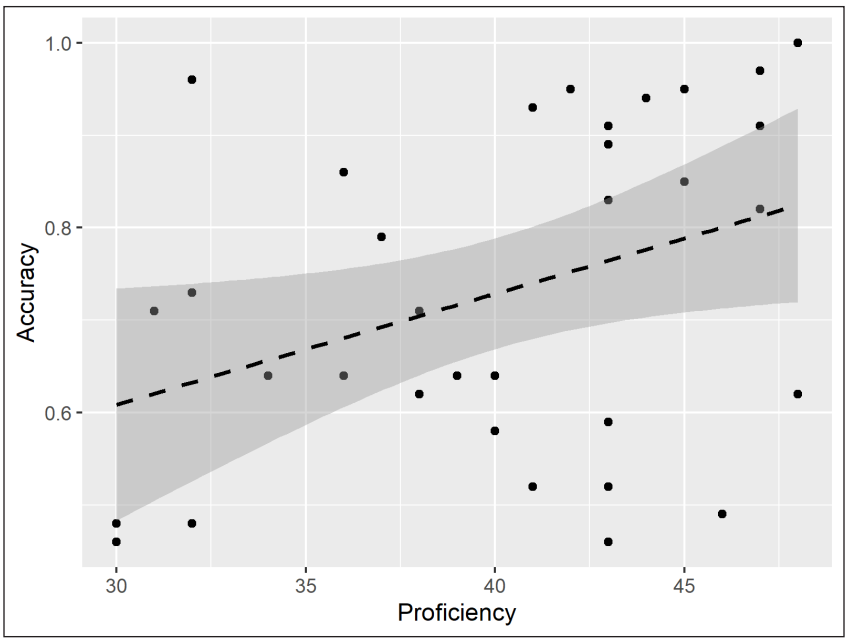

Figure 2: Accuracy predicted by proficiency in the end-of-sentence paraphrases.

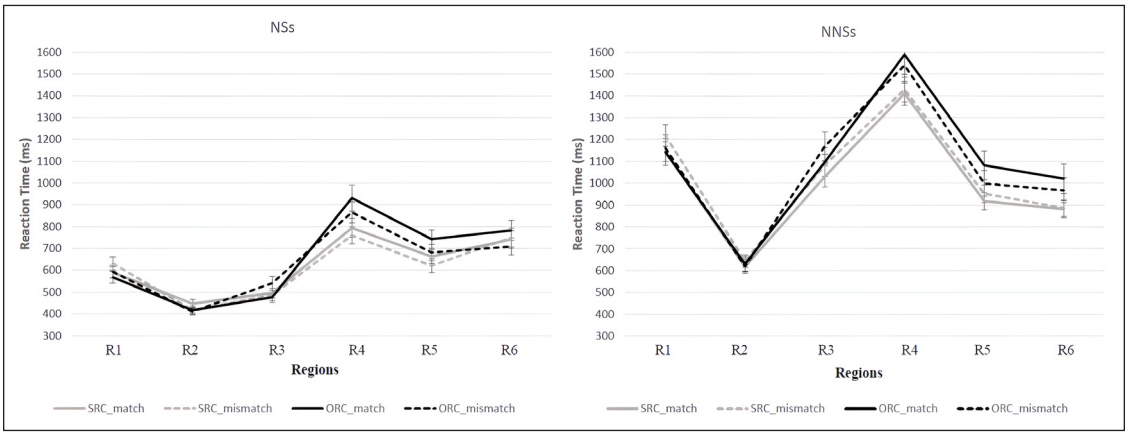

Figure 3: Mean RTs by region per condition for each group of participants. Error bars represent CIs.

6.4 RTs

Figure 3 illustrates participants' RTs by Group per condition and **Figure 4** focuses on RTs in regions where significant differences were found.

Table 2 shows the model coefficients for the models applied per region. In Region 2 (complementizer), there was a main effect of Group such that NNSs exhibited higher RTs compared to NSs. In Region 3 (RC verb), there was a main effect of Group with higher RTs for NNSs, a main effect of Matching such that RTs in the match condition were shorter than the mismatch

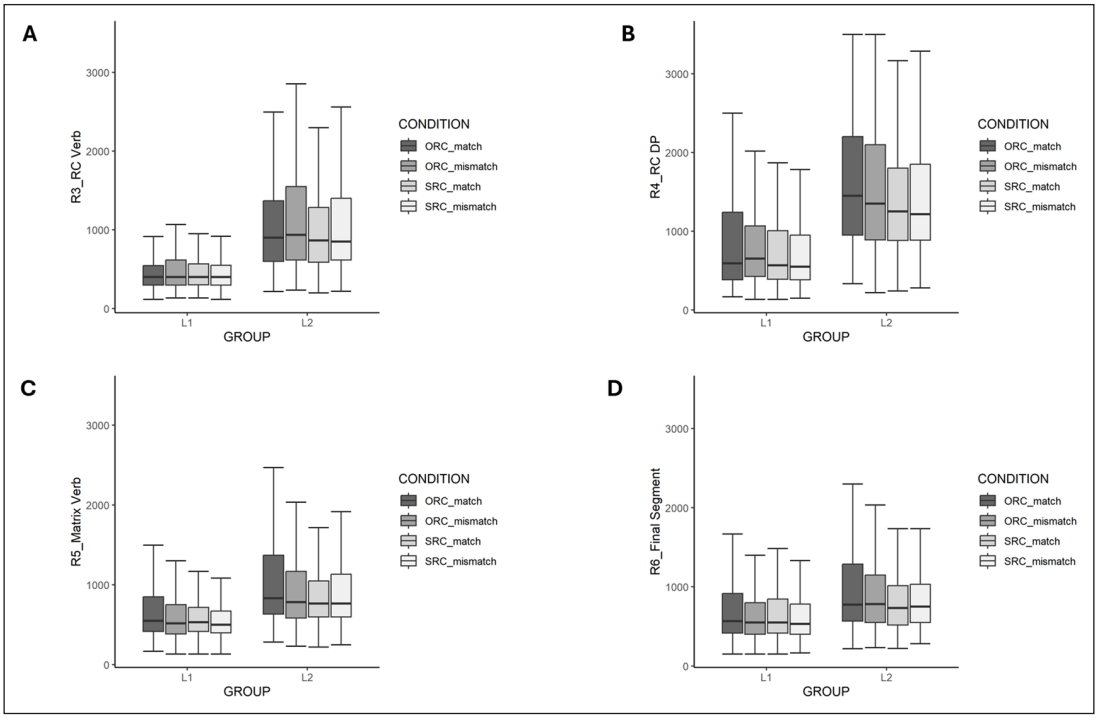

Figure 4: Mean RTs by condition by group in the RC verb/region 3 (**A**), the RC DP/region 4 (**B**), the matrix verb/region 5 (**C**), and the final segment/region 6 (**D**).

condition, and an interaction between RC_Type and Matching such than RTs were shorter for match only in ORCs. Pairwise comparisons confirmed this finding: only ORCs were affected by Matching (ORCs: β = –0.065, *se* = 0.020, *t* =–3.34, *p* = <.001; SRCs: β = –0.007, *se* = 0.016, *t* = –0.46, *p* = .645). Notice, however, that what appears as a disadvantage for mismatch over match conditions in ORCs is actually an indication of the participants' detection of the ORC structure. This is because the RC verb in ORC mismatch conditions carries a different number feature from the one of the head of the RC (see (12d)) and, thus, indicates an ORC structure.

In Region 4 (DP within the RC), there was a main effect of Group signaling higher RTs for NNSs compared to NSs and a main effect of RC_Type such that ORCs exhibited higher RTs than SRCs.

In Region 5 (the main verb), there was a main effect of Group such that NNSs exhibited higher RTs than NSs, a main effect of Matching such that match exhibited longer RTs compared to mismatch, a main effect of RC_Type such that ORCs exhibited higher RTs than SRCs, and an interaction between Matching and RC_Type reflecting significantly greater inhibition (longer RTs) for the match in ORCs compared to SRCs. Pairwise comparisons confirmed this finding (ORCs: β = 0.071, *se* = 0.022, *t* = 3.26, *p* = .001; SRCs: β = 0.018, *se* = 0.016, *t* = 1.11, *p* = .266).

In Region 6 (final segment), there was a main effect of Group such that NNSs exhibited longer RTs compared to NSs, a significant interaction between Group and RC_Type reflecting longer RTs in ORCs for the group of NNSs, as pairwise comparisons revealed (NNSs: β = 0.065,

se = 0.021, *t* = 3.17, *p* = .002; NSs: β = –0.008, *se* = 0.018, *t*= –0.43, *p* = .666). Finally, there was a marginal interaction between Matching and RC_Type such that match exhibited elevated RTs only in ORCs as pairwise comparisons revealed (ORCs: β = 0.059, *se* = 0.021, *t* = 2.76, *p* = .006 SRCs: β = 0.007, *se* = 0.017, *t* = 0.40, *p* = .690).

Region 4	***β***	***se***	***t***	***p***
(Intercept)	6.131	0.028	218.16	**<.001**
Matching	0.007	0.012	0.558	.580
RC_Type	–0.035	0.023	–1.558	.133
Group	0.374	0.055	6.770	**<.001**
Matching:RC_Type	0.013	0.048	0.261	.797
Matching:Group	–0.023	0.020	–1.145	.252
RC_Type:Group	–0.002	0.021	–0.107	.914
Matching:RC_Type:Group	0.072	0.041	1.762	.078
Region 3				
(Intercept)	6.43	0.044	145.58	**<.001**
Matching	–0.038	0.013	–2.97	**.003**
RC_Type	0.024	0.013	1.81	.071
Group	0.759	0.076	9.97	**<.001**
Matching:RC_Type	–0.054	0.026	–2.10	**.036**
Matching:Group	–0.036	0.026	–1.40	.161
RC_Type:Group	0.040	0.026	1.52	.128
Matching:RC_Type:Group	0.054	0.051	1.06	.290
Region 4				
(Intercept)	6.819	0.05	136.18	**<.001**
Matching	0.020	0.016	1.26	.211

(Contd.)

Region 4	***β***	***se***	***t***	***p***
RC_Type	0.074	0.018	4.05	**<.001**
Group	0.687	0.096	7.16	**<.001**
Matching:RC_Type	0.018	0.029	0.61	.543
Matching:Group	–0.023	0.032	–0.71	.481
RC_Type:Group	–0.039	0.037	–1.06	.296
Matching:RC_Type:Group	0.012	0.059	0.20	.841
Region 5				
(Intercept)	6.538	0.036	183.174	**<.001**
Matching	0.042	0.019	2.271	**.030**
RC_Type	0.061	0.021	2.878	**.007**
Group	0.408	0.059	6.871	**<.001**
Matching:RC_Type	0.054	0.027	1.992	**.046**
Matching:Group	–0.034	0.033	–1.022	.310
RC_Type:Group	0.017	0.034	0.500	.619
Matching:RC_Type:Group	0.078	0.054	1.436	.150
Region 6				
(Intercept)	6.546	0.038	170.791	**<.001**
Matching	0.031	0.017	1.82	.082
RC_Type	0.032	0.034	0.96	.344
Group	0.267	0.074	3.62	**.001**
Matching:RC_Type	0.050	0.027	1.83	.067
Matching:Group	–0.022	0.028	–0.81	.419
RC_Type:Group	0.076	0.036	2.10	**.040**
Matching:RC_Type:Group	–0.012	0.054	–0.22	.830

Table 2: Model coefficients by region.

We further explored Region 4 (the DP within the RC) by conducting an additional analysis on the untrimmed log-transformed RTs. This decision was motivated by the fact that the number of observations for this Region on RC_Type was lower for ORCs compared to SRCs (NSs: 1311 vs. 1543; NNSs: 695 vs. 1283 respectively), especially for NNSs (i.e., data loss due to trimming was 13% for NNSs) reflecting that ORCs caused great difficulties during comprehension. Thus, we proceeded with an analysis of the untrimmed RTs, which allowed us to retain more observations, which is crucial and informative for ORCs. The analysis revealed a main effect of Group with longer RTs for NNSs compared to NSs, a main effect of RC_Type with higher RTs for ORCs compared to SRCs and an interaction between RC_Type and Matching, reflecting that match yielded longer RTs compared to mismatch on ORCs. Pairwise comparisons confirmed these findings, in which match marginally[11] yielded longer RTs in ORCs ($\beta = 0.092$, $se = 0.040$, $t = 2.32$, $p = .0295$) and not in SRCs ($\beta = –0.0007$, $se = 0.030$, $t = –0.02$, $p = .981$). No interactions with Group were found.

Proficiency was further explored across the findings in which NNSs significantly differed from NSs but it was not found to reliably predict RTs.

Finally, although, as mentioned in the methodology section, we did not analyze effects of number combination in the match and the mismatch conditions (SG.SG, PL.PL and SG.PL, PL.SG respectively), we provide below a table to illustrate accuracy results per combination (**Table 3**). At least at a numerical level, we do not detect substantial differences between the conditions.

	MATCH		***MISMATCH***	
	sgsg	**plpl**	**sgpl**	**plsg**
	NSs			
SRC	96% (0.21)	95% (0.22)	97% (0.18)	97% (0.17)
ORC	80% (0.40)	84% (0.37)	89% (0.31)	86% (0.35)
	NNSs			
SRC	89% (0.31)	88% (0.33)	90% (0.31)	89% (0.31)
ORC	51% (0.50)	56% (0.50)	61% (0.49)	59% (0.49)

Table 3: Accuracy results per number combination (standard deviations in parentheses).

[11] Significance level adjusted to $p = .025$ using Bonferroni correction.

7 Discussion

In this study, we carried out a self-paced reading task manipulating RC type and number (mis) match in order to investigate similarity effects in the processing and comprehension of RCs in NSs and NNSs of Greek. Our findings indicated that the two groups employ similar routes when processing SRCs and ORCs. More specifically, ORCs were harder than SRCs for both groups as the RTs on the RC verb, the DP within the RC, and the main verb as well as the accuracy data revealed. Moreover, both groups exhibited similarity effects modulated by the RC type on the main verb and the final segment. This means that ORCs, in which the embedded subject matched the RC head in number feature, were processed slower than those in which the two DPs carried different number features. Additionally, a matching effect irrespective of RC type was attested in the accuracy data of both groups, namely the match conditions were more error prone than the mismatch ones. The two groups differed in that (a) the NNSs were overall less accurate and slower than the NSs, and (b) the NNSs experienced a greater cost induced by ORCs as compared to the NSs, as the data on the final segment show.

We now turn back to our theoretical predictions to further discuss our findings. Our first question concerned whether ORCs are more difficult to parse and comprehend than SRCs in NSs and NNSs of Greek. Our data show that the well attested asymmetry in the processing of SRCs vs. ORCs also holds for L1 and L2 Greek and is evident in the online processing, namely from the RC verb onwards, and also in the offline comprehension data. This is the first Greek processing study that reports a very robust ORC disadvantage with regard to both processing times and accuracy performance. Hence, our data provide online evidence in support of intervention even when this occurs only hierarchically and not linearly (see Varlokosta & Nerantzini & Papadopoulou 2015 and Peristeri & Kamona & Varlokosta 2023 for similar effects in offline child data).

Regarding L2 processing, our findings from the NNSs are in accordance with previous studies that also report processing and comprehension costs for ORCs compared to SRCs in L2 English (Baek 2012; Lim & Christianson 2013; Street 2017; Xia & White & Guzzo 2022). Moreover, we predicted that an interaction between RC type and Group in our online and offline measures would provide evidence for the SSH (Clahsen & Felser 2006; 2018). This interaction arose only on the final segment and showed that the disruption produced by ORCs was bigger for NNSs than for NSs. Even though this finding supports SSH, we think that it should be taken with caution for the following reasons: (a) because it arises only on the final segment that is typically related to wrap-up comprehension processes, (b) because NSs and NNSs exhibit qualitatively identical processing patterns on all previous segments, and (c) because a significant interaction between RC type and Group was not attested in the offline paraphrase verification task.

Our second question concerns whether similarity, tested via number feature (mis)match, plays a role in the processing and comprehension of RCs in NSs and NNSs of Greek. Our data reveal that similarity affects both NSs and NNSs of Greek alike, since we did not get an

interaction between RC type, similarity and group neither in the on-line processing nor in the comprehension of the RCs. This result is in line with the study by Cunnings & Fujita (2023) but in contrast with the study by Xia & White & Guzzo (2022) who did not attest number similarity effects in the expected direction in either group. Note, however, that the earlier detection of the ORC in the mismatch as compared to the match conditions in our study (see footnote 9 in the Methodology section) may have contributed to the discrepancy between the Greek and the English data reported by Xia & White & Guzzo (2022). This issue requires further investigation.

The lack of an interaction between RC type, similarity and group shows parallel parsing routes for NSs and NNSs and argues against increased susceptibility to interference in the L2 (Cunnings 2017), as has also been reported by a number of recent L2 processing studies (Lago & Felser 2018; Fujita & Cunnings 2022; Cunnings & Fujita 2023; Cunnings & Alaskar & Fujita 2024). However, one could argue that L1/L2 similarities regarding interference can be attributed to most participants' L1 encoding number marking. As already mentioned in the Methodology section, 30 out of our 33 L2 participants exhibit subject verb agreement and nominal number marking in their L1. In an attempt to gain some insight into the effect of L1 number marking on similarity interference, we followed the suggestion of an anonymous reviewer and reran our analysis without the 3 participants whose L1 does not instantiate number marking. Similar results were obtained, i.e., a significant interaction between RC type and Matching without being modulated by Group (Region 5, see Appendix 1). This indicates that, similarly to the initial model, for both groups the match conditions exhibited higher RTs than the mismatch ones only in ORCs. In any case, the role L1 number marking plays in similarity interference during L2 processing of RCs remains open for further investigation, even though White & Xia & Guzzo (2023) did not find an L1 effect in L2 English RCs.

Let us now discuss the online similarity effects we attested in both groups with regard to our theoretical assumptions. Our findings on the DP within RCs (at least the secondary analysis on the untrimmed RTs), the main verb as well as the final segment revealed a similarity effect modulated by RC type meaning that processing slows down when the head of the RC and the subject of the ORC match in number feature. This result can be accounted for by both syntactic (fRM) and SBI accounts. Regarding fRM, the intervention effects in ORCs are predicted to be attenuated by number mismatch, as number is an active morphosyntactic feature in Greek (in line with Biondo et al. 2023)[12]. SBI models also expect similarity-based interference to arise either at the embedded subject of ORCs when this matches in features with the head DP or at the main verb following ORCs with a feature match.

[12] fRM does not predict similarity effects on the matrix verb . However, we cannot exclude the possibility that the effect manifested on the matrix verb reflects a spillover effect from the processing of the ORC (see Biondo et al. 2023).

Let us now take a closer look at the accuracy data. Both groups manifested a mismatch advantage in comprehension irrespective of RC type. In other words, mismatch conditions were comprehended more successfully than match conditions in both SRCs and ORCs. This finding might appear, at first sight, contradictory with the inhibitory effect of number match found in ORCs by Arfani & Tsapkini & Varlokosta (2021). However, Arfani & Tsapkini & Varlokosta included only ORCs in their study and, therefore, it remains unclear whether the similarity effect observed would have also been attested with SRCs. Nevertheless, a mismatch advantage irrespective of RC type has also been reported by Gordon et al. (2006), Villata & Tabor & Franck (2018) and Villata & Franck (2020). Villata & Franck (2020: 184) attribute this finding to the fact that at the stage of question answering participants have to rebuild from memory the structure they just read. During this structure regeneration phase, all the DPs in the sentence participate simultaneously and, thus, interference is expected to arise in both SRCs and ORCs. Such an explanation can be accommodated within SBI accounts (see Villata & Franck 2020 for more details) but cannot be easily reconciled with fRM, which would expect similarity effects to arise only in ORCs. This issue definitely needs further investigation by means of methods that may burden the comprehension system to a lesser extent than self-paced reading tasks (Gordon et al. 2006: 1309).

Our final research question concerned the role of proficiency in the processing and comprehension of RCs by NNSs of Greek. Our results suggest that proficiency scores do not modulate processing of RCs although they are predictive of the NNSs' offline performance. This finding implies that the comprehension of RCs can improve in higher proficiency levels and is in line with Lim & Christianson (2013) who also report that proficiency significantly modulated NNSs' performance in the experimental tasks. The accuracy data from Xia & White & Guzzo (2022) also point to this direction, as only the intermediate group, and not the advanced one, exhibited lower performance in ORCs than SRCs. Additionally, proficiency affected accuracy but not online processing, because the offline task required that the participants reconstruct and recall the sentence they previously read, which makes the task rather demanding and, thus, susceptible to proficiency effects.

Notice that our NNSs exhibit an overall lower performance on RCs as well as slower RTs than NSs, which indicates that these constructions are challenging for them. However, the NNSs' lower accuracy scores as compared to those of the NSs cannot be attributed to incomplete acquisition of number or case, because their written texts revealed accurate production of subject verb agreement and case in the nominal paradigms. On the other hand, the NNSs produced rather few RCs, which may be another indication of the difficulties they experience with such structures.

8 Limitations and future directions

Before concluding, we would like to briefly discuss some issues that arose in the present study and need to be considered as well as further investigated in future research.

First of all, although our study did not include significantly fewer participants than previous L2 studies (e.g., Xia & White & Guzzo 2022 tested 39 NNSs of English, split into 2 groups of intermediate (n = 13) and advanced proficiency (n = 26); Lim & Christianson 2013 tested 36 NNSs of English; Street 2017 tested 27 NNSs of English), we do acknowledge that a larger sample size would increase the power of our study and ensure clearer and safer results (see the discussion in Brysbaert 2021: 815, for studies involving a between-groups design). Importantly, we would like to highlight that our study was conducted in a language with a much smaller number of L2 speakers compared to languages such as English, Spanish, German etc., which means that it is very challenging to find large numbers of participants.

Additionally, in our study participants saw all experimental items in all conditions, which may have induced repetition effects, and this is in contrast to the common practice of Latin square design, according to which participants see all experimental sentences but only in one of the conditions. The rationale behind this methodological choice was that L2 speakers' linguistic performance is not as homogeneous as that of native speakers, even if factors affecting their performance are controlled for (e.g., proficiency, hours of L2 teaching, amount of exposure to the L2, current use of the L2 etc.). Therefore, we used this design to minimize the influence of individual variation by exposing our L2 participants to all experimental items in all conditions (as also noted in the Methodology section, similar designs have been used in child sentence processing studies, Felser & Marinis & Clahsen 2003; Roberts et al. 2007). Importantly, we made sure there was an at least one-week interval between the two sessions to eliminate possible repetition effects. However, we conducted an additional analysis[13] (see Appendix 2) with the data only from the first block to explore whether our results are subject to repetition effects. Importantly, this analysis confirmed the interaction between RC type and Matching only on the untrimmed data of Region 4, such that the match conditions were slower than the mismatch ones in ORCs and not SRCs. Although the rest of the findings are highly similar to those of our main analysis, there remain some discrepancies which indicate the need for replication with a Latin square design.

Finally, the distribution of the word familiarization task prior to the main experiment might have drawn L2 participants' attention to the critical DPs. However, we believe that distributing the word familiarization task prior to the main experiment cannot account for the ORC disadvantage and the similarity effects manifested in our study since the same DPs are found in all experimental conditions. Moreover, participants exhibited a very high performance in the comprehension of filler sentences (mean: 98.11%) which included DPs that were not presented in the familiarization task. If the task had affected participants' attention to the critical items,

[13] We thank an anonymous reviewer for raising this issue and the Editor for suggesting the additional analysis. Here, we focus on the most relevant effect, namely the interaction between RC type and Matching.

we would expect that their performance in experimental items would be at least as good as their performance in the filler items, which was not the case in our study. Nevertheless, we do acknowledge that participants may have been encouraged to process the sentences more consciously than they would otherwise have done, due to the fact that they have been previously exposed to the DPs included in the experimental sentences.

9 Conclusions

In this study we explored the processing and comprehension of RCs in L1 and L2 Greek in conditions in which the head of the RC and the DP within the RC either matched or mismatched in their number feature. Our findings revealed a processing load and a comprehension cost for ORCs as compared to SRCs in both NSs and NNSs of Greek, while the processing disruption induced by ORCs was stronger in the NNSs' RTs at the end of the sentences, which provides only partial support of the SSH. Moreover, the number match between the RC head and the intervening subject of the ORCs intensified the processing load of ORCs in both NSs and NNSs of Greek, in line with fRM and SBI accounts. Thus, our findings point towards similar processing routes between NSs and NNSs as far as similarity interference is concerned, in contrast to the L2 increased susceptibility to interference account. Finally, despite the NNSs' lower accuracy scores in the comprehension questions in relation to those of the NSs, our findings provide evidence that proficiency modulates their performance and show signs for the possibility of native-like attainment. Overall, our study enhances our understanding of similarity effects in L1 and L2 by demonstrating their presence both online and offline, and, notably, by providing evidence of these effects in a language where intervention operates hierarchically rather than linearly, unlike the languages explored in previous research.

Abbreviations

3 = third person; ACC = accusative; C = complementizer; CI = confidence interval; CP = Complementizer Phrase; DP = determiner phrase; fRM = featural Relativized Minimality; L1 = first language; L2 = second language; M = masculine; ms = milliseconds; N = neuter; NNS = non-native speaker; NS = native speaker; NOM = nominative; PL = plural; RC = relative clause; RT = reading time; SD = standard deviation; SE = standard error; SG = singular; SRC = subject relative clause; SSH = shallow structure hypothesis; ORC = object relative clause; TP = tense phrase; V = verb; VP = verb phrase

Data availability

All data associated with this study (dataset and analysis script, Appendix 1 and 2 containing supplementary analyses, experimental items translated into English) is openly available at https://doi.org/10.17605/OSF.IO/9WKQP.

Ethics and consent

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Research Ethics Committee of the Aristotle University of Thessaloniki (protocol code: 62503/2022, date of approval: 09/03/2022).

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Competing interests

The authors have no competing interests to declare.

Author contributions

Conceptualization: D.P and G.D; Methodology: D.P and G.D; Data Collection: G.D; Data analysis: A.P. and G.D.; Writing-original draft preparation: D.P. and G.D; Writing-Review and editing: D.P., G.D and A.P.

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