

## Article

# The Influence of Case and Word Order in Child and Adult Processing of Relative Clauses in Greek

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**Abstract:** Previous cross-linguistic studies have shown that object relative clauses (ORCs) are typically harder to parse than subject relative clauses (SRCs). The cause of difficulty, however, is still under debate, both in the adult and in the developmental literature. The present study investigates the on-line processing of SRCs and ORCs in Greek-speaking 11- to 12-year-old children and adults, and provides evidence on relative clause processing in Greek—a free word order language. We conducted a self-paced listening task in which we manipulated the type of relative clause (SRC vs. ORC), the RC internal word order (canonical vs. scrambled), and the type of relativizer (relative pronoun vs. complementizer). The results showed that SRCs were overall processed faster than ORCs, providing evidence that children follow similar processing strategies to adults. In addition, accusative case marking facilitated the processing of non-canonical structures in adults but less so in children. Children showed heavy reliance on word order, as they processed nominative and accusative pre-verbal NPs in exactly the same way, while they were strongly garden-pathed in ORCs with post-verbal nominative NPs. We argue that these results are compatible with the Competition Model.



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## 1. Introduction

Although the psycholinguistic literature includes a large number of studies on adult on-line sentence processing, only very few studies have been conducted in the last 30 years focusing on the real-time processing of complex or ambiguous structures in children (e.g., Felsler et al. 2003). In this study, we investigate the moment-to-moment processing of subject and object relative clauses in adults and 11- to 12-year-old children in Greek, with the aim of examining the extent to which certain morphosyntactic properties of Greek, such as case and word order, play a role in the real-time processing of complex structures in monolingually-raised Greek-speaking children and adults. Our study includes structures such as those in (1):

1. a. *O majiras pu \_\_ esprokse ton servitoro ekapse to fajito.* (SRC)  
the.NOM cook.NOM that pushed the.ACC waiter.ACC burned the food  
'The cook that pushed the waiter burned the food'
- b. *O majiras pu o servitoros esprokse \_\_ ekapse to fajito.* (ORC)  
the.NOM cook.NOM that the.NOM waiter.NOM pushed burned the food  
'The cook that the waiter pushed burned the food'

Subject (SRCs) and object relative clauses (ORCs) such as (1a) and (1b) are instances of filler-gap dependencies involving movement of a noun (NP) from a canonical thematic position to a higher position in the structure. Even though both (1a) and (1b) include a displaced NP, the two structures differ crucially in the position of the extraction site (indicated by   ). In SRCs such as (1a), the extracted NP moves from the subject of the

relative clause position (*o majiras esprokse ton servitoro*, 'the cook pushed the waiter') to the left periphery, whereas in ORCs such as (1b) the extracted NP moves from the direct object of the verb to the left periphery (*o servitoros esprokse ton majira*, 'the waiter pushed the cook').

Previous cross-linguistic studies have shown that ORCs are typically harder to parse than SRCs. The cause of difficulty, however, is still under debate, both in the adult and in the developmental literature (e.g., Adani 2010; Arosio et al. 2009; Arnon 2010; Friedmann et al. 2009; Diessel and Tomasello 2005; Gibson 1998; Gordon et al. 2001; King and Just 1991; Bates and MacWhinney 1982; Mak et al. 2006). We believe that Greek real-time processing data can contribute to a better understanding of the nature of the processing between SRCs and ORCs in adults and children for two reasons. First, because of its configurational properties: Greek is a relatively free word order language that allows all possible word order combinations subject to pragmatic restrictions<sup>1</sup>. Thus, we can create and contrast SRC and ORC versions with different word orders. The second reason is because of its rich morphology. The rich morphology of the Greek language gives us the chance to examine possible effects of morphosyntactic cues (here, the cue of case) in the moment-to-moment processing of relative clauses. The aim of the present study is thus twofold: first, we aim to examine on-line relative clause processing in Greek, with a focus on specific morphosyntactic properties of Greek. Second, we aim to investigate the extent to which real-time processing patterns in 11- to 12-year-old children are similar to those of adults. In the next two sections, we summarize results and theories of relative clause processing in different languages in adults and children.

### 1.1. Relative Clause Processing in Adults

One of the main foci of the sentence processing research in the past thirty years has been to investigate the extent to which parsing strategies are universal, and at the same time to identify language-specific properties that actively contribute to the real-time parsing of complex structures. The investigation of relative clause processing, and more specifically the potential differences in processing difficulty between SRCs and ORCs, gives us the opportunity to explore these questions. One of the first studies that discussed the processing asymmetry between SRCs and ORCs is the study by King and Just (1991). In this study, King and Just (1991) investigated structures such as those in (2).

2. a. The reporter that attacked the senator admitted the error. (SRC)
- b. The reporter that the senator attacked admitted the error. (ORC)

In the examples from King and Just (1991) in (2a) and (2b), both sentences include an extracted noun phrase (NP) (the reporter) which must be maintained in working memory (WM) until the moment that it is integrated in the structure. King and Just (1991) showed that ORCs caused substantial processing difficulty, especially in participants with a low WM span. A large amount of experimental research in adult populations has subsequently revealed that ORCs (such as 2b) are processed more slowly and are thus harder to comprehend than SRCs (2a) (e.g., Bates and MacWhinney 1982; Gibson 1998; Gordon et al. 2001; King and Just 1991; Mak et al. 2002, 2006; Traxler et al. 2002; Warren and Gibson 2002). The main hypotheses that have been put forward to account for this processing discrepancy have been based on perspective shifting (e.g., Bever 1970; MacWhinney and Pléh 1988), syntactic and discourse factors (e.g., Clifton and Frazier 1989; Frazier and Clifton 1989; Frazier and Flores d'Arcais 1989), working memory limitations (e.g., Gibson 1998), and expectation-based processing (e.g., Levy 2008). We broadly divide these accounts into two categories: universal complexity accounts, which assume similar parsing strategies cross-linguistically, and parametric differences accounts, which hypothesize that RC parsing complexity depends to a large extent on language-specific morphosyntactic features and probabilistic constraints.

The main claim of universal complexity accounts is that SRCs should always be easier to comprehend than ORCs because subjects are inherently more salient than objects. Two

prominent approaches that can be characterized as universal complexity accounts are the Accessibility Hierarchy (e.g., Keenan and Comrie 1977; Keenan and Hawkins 1987) and the Perspective Shift Hypothesis (e.g., Bever 1970; MacWhinney and Pléh 1988). The Accessibility Hierarchy claims that certain NPs are hierarchically more accessible than others when they act as antecedents of relative clauses. In this hierarchy, subjects are more accessible than objects and thus SRCs should always be easier to process than ORCs. The Perspective Shift Hypothesis claims that SRCs should always be favored, because they do not involve any change in perspective shift (i.e., the subject of the main clause is also the subject of the relative clause). In contrast, the difficulty of ORCs stems from switching perspectives (from subject of the main clause to object of the relative clause) and this requires additional cognitive resources. Although the predictions of universal complexity accounts are verified for SVO languages such as English and French, they do not seem to hold for head-final and ergative languages (e.g., Chinese: Hsiao and Gibson (2003) and Basque: Carreiras et al. (2010)).

Accounts positing that the processing of SRCs and ORCs may vary depending on cross-linguistic or parametric differences among languages can be broadly categorized into two distinct groups: memory limitation theories and expectation-based theories. Theories that assume that working memory limitations play an important role in the processing of relative clauses include the Active Filler Strategy (Clifton and Frazier 1989; Frazier and Flores d'Arcais 1989), the Minimal Chain Principle (De Vincenzi 1991), the Decay/Reactivation/Retrieval-Interference Theory (Lewis and Vasishth 2005), the Similarity-based Interference Model (e.g., Gordon et al. 2001; Lewis and Vasishth 2005; McElree et al. 2003), the Self-Organized Sentence Processing Model (SOSP) (e.g., Tabor and Hutchins 2004), and the Dependency Locality Theory (DLT: Gibson 1998, 2000). The DLT (Gibson 1998, 2000), for example, predicts that the most integration-intensive word should be the verb of the ORC (*attacked* in (2b)), as it is the point at which both the preceding subject and object NPs must simultaneously be integrated in the structure, whereas this is not the case in SRCs (such as (2a)). The DLT thus places considerable importance on the linear distance of the retrieved element from the integration site. In other words, the greater the linear distance between the retrieved element and the integration site, the larger the processing difficulty. A very important advantage of the DLT is that it makes clear predictions concerning the exact point of parsing difficulty during on-line processing, and thus makes it easier to test experimentally. Several studies (e.g., Grodner and Gibson 2005; Hsiao and Gibson 2003; Traxler et al. 2002, 2005; Vasishth et al. 2013;) have provided experimental support for the DLT from data in English and Chinese (cf. Xiaoxia et al. 2016 for Chinese). Experimental support for working memory limitation theories has also been provided from French (e.g., Cohen and Mehler 1996).

The second main group of accounts that take into consideration possible parametric differences across languages are expectation-based theories. Expectation-based theories include word-order frequency theories (e.g., Bever 1970; MacDonald and Christiansen 2002), which assume that surface word orders with higher frequency in a language are easier to process than orders with lower frequency (e.g., Reali 2014), and syntactic surprisal accounts (e.g., Gennari and MacDonald 2008; Hale 2001; Levy 2008), which predict difficulty in processing for less frequent structures on the assumption that the parser takes longer to integrate less expected input in an incremental structure. More specifically, Surprisal (Hale 2001; Levy 2008; Smith and Levy 2013) predicts that the parser creates and updates fine-grained expectations for the upcoming input at multiple levels of the linguistic structure. This means that structural frequencies have a direct relation to comprehenders' moment-to-moment parsing decisions. For example, under the Verb Predictability Hypothesis (Levy 2008) pre-verbal RC NPs such as *the senator* in (2b) are expected to be harder to process because NP Comp NP structures are less frequent and thus less expected. In contrast, the verb of the ORC (*attacked* in (2b)) is expected to be easier to process than the verb in the SRC because in the ORC the occurrence of a verb after an NP is more probable. This prediction directly contrasts with the prediction of the DLT, under which the ORC verb is expected to

be the hardest to process. Experimental support for expectation-based theories comes from languages that are predominantly verb-final, have a relatively high flexibility in scrambling nominal constituents, and have rich morphological systems, such as Hindi (Vasishth and Lewis 2006), German (Konieczny 2000; Konieczny and Döring 2003), and Japanese (e.g., Miyamoto and Nakamura 2003; Nakatani and Gibson 2009).

Parametric difference hypotheses, such as the DLT and Surprisal, have been tested in studies that include data from free word order languages, such as Russian and Hungarian. In Russian, Levy et al. (2013) and Price and Witzel (2017) examined the on-line processing of SRCs and ORCs introduced by the case-marked relative pronoun *kotoryj* ‘who’ / *kotorogo* ‘whom’ and the case-syncretized relative pronoun *chto* ‘who’, ‘whom’. Levy et al.’s study found support for the DLT (e.g., Gibson 1998) in the case-marked relative pronoun condition, but also partial evidence for expectation-based processing (Levy 2008) in the syncretized pronoun condition. More specifically, Levy et al. (2013) investigated structures such as (1a) and (1b) in Russian, manipulating RC word order (either RC verb or RC NP immediately following the relative pronoun) and case (the relative pronoun was in nominative case in SRCs and accusative case in ORCs). This case manipulation did not of course apply in the case-syncretized relative pronoun condition with *chto*, in which only word order was manipulated. In total, there were four experimental conditions: SRC canonical (SVO), SRC scrambled (SOV), ORC canonical (OSV), and ORC scrambled (OVS), as in (3).

3. a. *Elektrik, kotoryj udaril slesarja so vsego rasmaksa . . .* (SRC, default/SVO)  
Electrician, who.NOM hit repairman.ACC with all strength
- b. *Elektrik, kotoryj slesarja udaril so vsego rasmaksa . . .* (SRC, Scrambled/SOV)  
Electrician, who.NOM repairman.ACC hit with all strength  
‘The electrician, who hit the repairman with all his strength . . . ’
- c. *Elektrik, kotorogo slesar’ udaril so vsego rasmaksa . . .* (ORC, default/OSV)  
Electrician, whom.ACC repairman.NOM hit with all strength
- d. *Elektrik, kotorogo udaril slesar’ so vsego rasmaksa . . .* (ORC, scrambled/OVS)  
Electrician, whom.ACC hit repairman.NOM with all strength  
‘The electrician, whom the repairman hit with all his strength . . . ’

After conducting a self-paced reading task, Levy et al. (2013) found no statistically significant difference between SRCs and ORCs in the inflected relative pronoun condition, but a statistically significant time penalty for the two conditions in which the RC verb was linearly distant from the relative pronoun (i.e., SRC scrambled and ORC canonical). Levy et al. (2013) thus argued in favor of the DLT in the inflected relative pronoun condition. In the case-syncretized pronoun condition, however, there was an overall time advantage for SRCs, which is the most frequent word order in Russian. Thus, contrary to the inflected relative pronoun condition, the syncretized pronoun condition provided evidence for expectation-based accounts. It should be noted here that the DLT does not make any specific predictions for case-inflected vs. case-syncretized relative pronouns. Accordingly, Levy et al. (2013) originally predicted a time penalty on the RC verb in non-local conditions (RC verb not adjacent to relative pronoun), independently of the properties of the relative pronoun. In addition, in a study including self-paced reading and eye-tracking data in Russian SRCs and ORCs with full and pronominal NPs, Price and Witzel (2017) also found mixed evidence for working memory limitation and expectation-based theories. In Hungarian, Kovács and Vasishth’s (2013) study on SRCs and ORCs introduced by the case-marked relative pronoun *aki* ‘who’ / *akit* ‘whom’ provided support for the DLT. As we can see, the very limited number of previous studies does not help us to reach clear conclusions on the real-time processing strategies of speakers of free word order/rich morphology languages. We thus hope that by providing data from Greek we can shed more light onto the real-time processing of complex structures in adults and 11- to 12-year-old children, as well as contribute to the understanding of the role that certain language-specific morphosyntactic cues play in the on-line processing of complex structures in Greek.

In the current study, we present relative clause processing data in Greek. Greek is traditionally classified as an SVO language, although it allows all possible word order combinations (e.g., [Catsimali 1990](#); [Horrocks 1994](#); [Tsimpli 1990](#); [Tzanidaki 1998](#)). In addition, Greek has a rich nominal inflectional system, with a three-partite gender system and a four-partite case system. Although Greek has a certain degree of case syncretism (mainly involving the neuter gender), syntactic relations can most of the time be identified no matter in which position of the clause an element occurs. Relative clauses in Greek are post-nominal and are introduced with either the complementizer *pu* 'that' or the inflected relative pronoun *o opios / i opia / to opio* 'who-MASC-FEM-NEU' ([Alexiadou 1997](#); [Holton et al. 2012](#); [Joseph 1983](#); [Mackridge 1992](#)). Under the hypothesis, then, that specific morphosyntactic characteristics of a language play an active role in on-line processing, we can broadly categorize Greek into a group of languages with free word order and rich morphology. In contrast to languages with rigid word order such as English, on-line relative clause studies in free word order languages in adults are very limited and, to our knowledge, there is no previous study examining on-line RC processing in a free word order language in children.

Following the word order manipulation of the above-mentioned free word order language studies, our study also manipulates word order so as to include an SRC and an ORC condition in which the RC verb is adjacent to the relative pronoun, and an SRC and ORC condition in which the RC verb is linearly distant from the relative pronoun. In addition, similar to [Levy et al. \(2013\)](#), [Price and Witzel \(2017\)](#) and [Kovács and Vasishth \(2013\)](#), the RCs in our experimental sentences were headed by the inflected relative pronoun *o opios* 'who' / *ton opio* 'whom', and parallel to [Levy et al. \(2013\)](#), our RCs were also headed by a non-inflected relativizer, namely the complementizer *pu* 'that'. Thus, on the basis of previous evidence from free word order languages, we predict that monolingually raised Greek speakers follow the DLT strategy in the case-inflected pronoun condition. This means that local structures (RC verb adjacent to relative pronoun) are expected to be processed faster than non-local ones, independently of whether or not the RC is subject- or object-modifying. This strategy is not expected to hold for RCs introduced by the complementizer, as in this case we expect frequency to take precedence over locality. In other words, the fact that canonical word order SRCs introduced by the complementizer *pu* 'that' in Greek are much more frequent than any of the other SRC or ORC, word order configuration is expected to facilitate SVO SRCs. These predictions may or may not hold in the case of 11- to 12-year-old children. We discuss this issue in more detail in the next section after we first provide an overview of previous relative clause studies in children.

### 1.2. Relative Clause Processing in Children

The timing of information processing and cue integration during real-time processing has been widely investigated in adults across different languages. There are, however, to date very few studies focusing on the moment-to-moment structural processing in children. When it comes to morphosyntax, for example, a number of studies investigate the comprehension and production of filler-gap dependencies such as relative clauses in children (e.g., [Guasti et al. 2012](#); [Arosio et al. 2009](#); [Friedmann et al. 2009](#); [Stavrakaki et al. 2015](#); [Varlokosta et al. 2015](#)). In comparison, however, very few studies have used temporally sensitive measures to study the comprehension of complex structures in children (for a review, see [Sekerina et al. 2008](#)). The main reason for this is that it is quite challenging to apply on-line methods (e.g., self-paced reading, eye tracking) that are used in the adult population to children, especially when dealing with filler-gap structures which are cognitively demanding. Nonetheless, such studies are crucial. On the one hand, the investigation of children's comprehension and production skills in their early stages of linguistic development provides us with valuable insight into children's linguistic knowledge, and on the other hand, the study of children's real-time processing can inform us about how children apply their linguistic knowledge in the moment-to-moment parsing of

linguistic structures. Studying real-time processing in children can also inform us whether children's sentence-parsing mechanisms are similar to or different from those of adults.

The idea of continuity in language processing (Crain and Thornton 1998; Crain and Wexler 1999; Fodor 1998) was incorporated into Clahsen and Felser's Continuity of Parsing Hypothesis (Clahsen and Felser 2006b; see also Felser et al. 2003), which predicts no qualitative differences between child and adult parsing strategies. Felser et al. (2003) provide experimental support for the continuity of parsing hypothesis in a study on 6- to 7-year-old English children and adults processing temporarily ambiguous RC structures in English. Their experimental material included sentences such as those in (4).

4.
  - a. The doctor recognized the nurse *of* the pupil who was feeling very tired.
  - b. The doctor recognized the nurse *with* the pupil who was feeling very tired.

Structures such as (4a) and (4b) are ambiguous in that the RC can either modify the immediately preceding NP *the pupil* (low attachment) or the complex NP *the nurse of (with) the pupil* (high attachment). After conducting a self-paced listening task, Felser et al. (2003) found a significant interaction between type of preposition (*of* vs. *with*) and attachment type (high vs. low) only in the adult group. This means that adult English speakers preferred high attachment in structures including the preposition *of* and low attachment in structures including the preposition *with*. Therefore, the lexical choice of preposition affected adults'—but not children's—RC attachments. Children showed a preference for high attachment irrespective of preposition, but an additional short-term memory span test indicated that 6- to 7-year-old children's attachment preferences significantly interacted with their listening span; low-span children showed an overall preference for low RC attachment, while high-span children showed a preference for high attachment irrespective of preposition. Felser et al. (2003) thus argue that, depending on their listening span, children apply one of two locality principles during on-line ambiguous RC attachment; similar to adults, high-span children follow the "predicate proximity" principle (Gibson et al. 1996), whereas low-span children apply a linear locality strategy by associating the RC to the most recently processed NP. Thus, contrary to adults whose on-line parsing is affected by the semantics of the preposition (*of* vs. *with*), younger children's on-line parsing is based on the semantic associations between NPs. Older children follow a more structural-based strategy (predicate proximity), which favors RC attachment to the NP that is closest to the IP node (Gibson et al. 1996). Overall, Felser et al. (2003) claim that their study provides evidence for the continuity of parsing hypothesis, as it shows that although the high-span children's self-paced listening pattern differed from that of adults (evidenced by children's lack of significant time difference between the processing of structures with the two types of preposition), the pattern in the grammaticality judgment task that immediately followed the on-line task was the same. Felser et al.'s interpretation of this result is that children's use of semantic and contextual information is not yet fully developed and automatized (Felser et al. 2003 provide similar evidence from 10- to 11-year-old children) for effects to appear on-line. The fact, however, that children and adults have the same pattern of results in the grammaticality judgment task that immediately followed the on-line task shows that children may simply need more time to integrate lexicosemantic and contextual information.

Children's on-line RC processing has also been investigated within the scope of structural complexity processing. Booth et al. (2000) examined 8- to 11-year-old children's SRC and ORC processing in a self-paced reading and a self-paced listening task. Booth et al.'s (2000) materials included structures such as those in (5).

5.
  - a. The principal that tripped the janitor used the phone to call home. (SRC)
  - b. The man that the captain invited built the stage for the band. (ORC)

On the basis of the Perspective Shift hypothesis (e.g., MacWhinney and Pléh 1988), Booth et al. (2000) predict that children have more difficulty with ORCs, which require two perspective shifts (shifting from the subject of the main clause *the man* in (5b) to the

subject of the RC *the captain* and then back to the subject of the main clause), than with SRCs in which no perspective shift is required. Booth et al. (2000) also administered measures of working memory and short-term memory span. The self-paced reading and the self-paced listening tasks yielded similar results; children were significantly slower in the transition from main to relative clause in ORCs than in SRCs. Interestingly, the short-term memory digit span task showed that high-digit-span/older children slowed down more often than low-digit-span/younger children in the transition from the main to the relative clause. Booth et al. (2000) account for this result by claiming that high-digit-span children process cognitively demanding structures such as ORCs (5b) through storing each word in their short-term memory, allowing them to be more accurate than low-span children in answering comprehension questions. In contrast, low-digit-span/younger children do not (yet) have that option and this leads them to faster on-line RC processing but lower comprehension question accuracy compared to high-span children. Irrespective of the differences in processing speed between high- and low-span children, children's overall pattern of results (ORCs harder to process than SRCs) was similar to adults, and thus Booth et al. argue in favor of continuity in parsing.

In a recent study, Guasti et al. (2018) also provide evidence for continuity in sentence comprehension from a referent selection task and self-paced reading task including SRCs and ORCs in 5- to 7-year-old children and adults in French and Italian. Guasti et al. (2018) replicate the well-known SRC/ORC asymmetry and argue that structures that are first acquired by children (such as SRCs) are the easiest for adults to process (see Phillips and Ehrenhofer 2015). Interestingly, Guasti et al.'s (2018) materials in French and Italian also include a word order manipulation in the ORC condition, as shown in (6).

6. a. *Montre-moi [le lion qui mord les chameaux]* (SRC, SVO)  
'Show me the lion that bites the camels.'
- b. *Montre-moi [l'oie que les lapins poursuivent]* (ORC, OSV)  
'Show me the goose that the rabbits chase.'
- c. *Montre-moi [les lions que bat le cheval]* (ORC, OVS)  
show me the lions that hits the horse  
'Show me the lions that the horse hits.'

Schelstraete and Degand (1998) previously showed that OVS structures were easier to process than OSV structures in self-paced reading in French-speaking adults. Schelstraete and Degand (1998) interpret these results on the grounds of the Competition Model (e.g., MacWhinney and Pléh 1988), according to which grammatical role assignment of NPs in a sentence is based on the competition of cues such as frequency, case marking, and agreement, etc. The competition of NP cues, the weight of which may vary across different languages, starts as soon as the verb is encountered. Before encountering the verb, NPs are assumed to remain unbounded, thus causing working memory load. Thus, according to Schelstraete and Degand (1998), French OSV structures were read more slowly than OVS structures because OSV structures such as (6b) involve NP cue competition and working memory load, whereas OVS structures such as (6c) only involve competition<sup>2</sup>. In contrast, Guasti et al. (2018) provide evidence from French and Italian adults and children that pre-verbal subject OSV structures are actually easier to process than post-verbal subject OVS structures. Guasti et al. (2018) explain this result on the grounds of Fodor and Inoue's (2000) Diagnosis and Repair Model, according to which the parser resorts to a re-analysis of the initial structure. This process involves the revising or repairing of an existing analysis rather than building a new one. In OSV relatives, the parser receives information from two NPs that the preferred SRC interpretation is not correct and on the basis of these two NPs re-analyzes the structure and achieves the correct analysis upon reaching the verb. In OVS relatives, however, the parser sees the object NP and then the verb, and up to this point it still analyzes the structure as an SRC. Upon reaching the post-verbal subject, it has to reanalyze and repair on the basis of negative input, indicating that this is not an SRC, which in the end is a more costly procedure. Thus, the prediction and subsequent evidence of Guasti et al. (2018) is that pre-verbal NPs and RC verbs in OSV ORCs should be processed

faster than post-verbal NPs in OVS ORCs because in OSV structures the parser receives more evidence that the upcoming structure is an ORC and not an SRC. This prediction is similar to the prediction made by Surprisal (e.g., Levy 2008), according to which the occurrence of two NPs in OSV structures makes the probability of the verb very high. In contrast, the DLT (Gibson 1998, 2000) predicts, on the one hand, faster processing of pre-verbal NPs in comparison to post-verbal NPs in general (due to post-verbal NPs having to be immediately integrated to the preceding verb), but, on the other hand, the verb in OSV ORCs is expected to be processed very slowly because the parser has to simultaneously integrate the two preceding NPs.

Overall, it should be noted that both Schelstraete and Degand (1998) and Guasti et al. (2018) found an overall SRC preference, with SRCs being processed faster than both ORC configurations. In contrast to French and Italian which do not allow word order scrambling in SRCs, Greek allows different word order configurations both in SRCs and ORCs. Thus, the word order manipulation in our study allows us not only to shed more light on the previous conflicting evidence on the processing of different word order configurations in ORCs coming from French and Italian, but also to provide additional evidence on the processing of distinct word order configurations in SRCs. In terms of continuity, Guasti et al. (2018) found no main differences between adult and children's RC processing in Italian and French. In our study, we examine the extent to which children follow adult processing patterns by including data from 11- to 12-year-old children. We thus investigate the Continuity of Parsing Hypothesis (Clahsen and Felser 2006b). At the same time, we examine possible parsing effects that may stem from language-specific properties of Greek, such as free word order and morphological richness. In terms of linguistic knowledge, studies on languages with head-initial relative clauses show that SRCs are produced relatively early, and that children may struggle with the comprehension of ORCs in later stages of acquisition (see, e.g., Friedmann et al. 2009; Guasti et al. 2018; Guasti and Cardinaletti 2003). In Greek, it seems that children have fewer problems comprehending and producing relative clauses because case marking on NPs provides an extra cue for thematic role assignment and object relative clause comprehension (e.g., Guasti et al. 2012; Stathopoulou 2007; Stavrakaki 2001; Varlokosta 1997). In the absence of case as a disambiguating cue, Greek-speaking children perform similarly to Italian-speaking children, with higher scores in SRCs than ORCs (Guasti et al. 2012, 2008). More specifically, Guasti et al. (2012) investigated the role that number and case may play in the comprehension of relative clauses in 4.5- to 6.5-year-old Greek and Italian children. They conducted two picture selection tasks including Greek SRCs and ORCs, such as in (7) and (8).

7.
  - a. Dhikse mou to alogo pou kiniga ta liontaria. (SRC)  
'Show me the horse that chases the lions.'
  - b. Dhikse mou to alogo pou kinigoun ta liontaria. (ORC)  
show me the horse that chase the lions.  
'Show me the horse that the lions chase'
8.
  - a. Dhikse mou ti maimou pou pleni tin arkouda. (SRC)  
'Show me the monkey that is washing the<sub>ACC</sub> bear'
  - b. Dhikse mou ti maimou pou pleni i arkouda. (ORC)  
show me the monkey that is washing the<sub>NOM</sub> bear  
'Show me the monkey that the bear is washing'

In examples (7a) and (7b), the disambiguation towards an SRC or ORC interpretation takes place on the verb. When the verb is in the singular *kiniga* 'chases', then it is the horse that chases the lions, thus a SRC. When the verb is in the plural *kinigoun* 'chase', then it is the lions that chase the horse, thus an ORC. In examples (8a) and (8b), Guasti et al. (2012) use feminine (and masculine, in the experiment) NPs which inflect distinctly for nominative and accusative case. Thus, in this case, the RC verb is always in the singular and the disambiguation takes place after the verb on the determiner of the RC NP, which either has accusative case in SRCs or nominative case (post-verbal subject) in ORCs. The results show that the comprehension of ORCs significantly improved when

the disambiguation was achieved through case (8b), whereas there was no significant difference in the comprehension of SRCs between the number and case condition. Thus, Greek-speaking children performed similarly to Italian-speaking children in the number disambiguation condition. In the case disambiguation condition, which could only be applied to Greek, however, Greek-speaking children showed an improved performance. According to Guasti et al. (2012), the boost in Greek-speaking children's performance in the case disambiguation condition suggests that specific morphosyntactic characteristics of a language (such as overt case marking) affect children's acquisition of complex structures such as RCs.

In addition, Stavrakaki (2001) reports that overt case marking contributes to children's better performance in ORCs with the object NP head in the accusative and the RC subject in the nominative, in comparison to ORCs that are not marked for case. Additional evidence on the facilitatory role of overt case marking in the comprehension of ORCs is provided in Stavrakaki et al. (2015) and in Varlokosta et al. (2015), who investigated Greek-speaking 4- to 6.5-year-old children's comprehension of wh-questions, relative clauses, and free relatives.

Based on the results of previous real-time studies on RC processing in children, we hypothesized that the children would have a similar pattern of results as the adults. This means that locality effects that have been found in free word order languages in the relative pronoun condition (e.g., Levy et al. 2013) are also expected to be found in Greek-speaking children and adults in the current study. Levy et al. (2013) found an SRC preference in the syncretized pronoun condition, which was attributed to the SRC structure's high frequency of occurrence. Similarly, we expect frequency to play a role in both children's and adults' listening times. In terms of case marking, although previous results in French and Italian regarding the preference for pre-verbal vs. post-verbal subjects in ORCs are conflicting and do not allow us to form a robust prediction, we follow Guasti et al. (2018) in predicting that children and adults have an overall similar pattern of results.

Due to working memory limitations, we believe that children take longer to process RCs and this may result in significant effects and interactions in post-critical segments in the child group. According to Felser et al. (2003), 10- to 11-year-old English children-speaking do not process ambiguous RCs similarly to adults on-line, but they do so in the subsequent off-line grammaticality judgment task (see analysis of Felser et al.'s (2003) study above). The different processing pattern between children and adults in the on-line task was attributed by Felser et al. (2003) to 10- to 11-year-old children's still developing ability for automated use of lexicosemantic and textual cues. Our study includes a group of 11- to 12-year-old children. The main reason why we chose to include 11- to 12-year-old children in our study was to examine if children in that age group are actually able to successfully integrate all different types of cues (e.g., morphosyntactic, semantic, contextual) during on-line sentence complex RC processing.

## 2. The Present Study

### 2.1. Corpus Analysis

Prior to collecting experimental data, we extracted and analyzed a sample of 9074 relative clause structures from the Hellenic National Corpus (HNC) (<http://corpus.ilsp.gr>, accessed on 18 March 2014). The HNC analysis was conducted in order to have a clear picture of the frequency distributions of SRCs and ORCs in Greek. The corpus analysis is important because it allows us to examine the predictions of expectation-based theories, which largely assume that the most frequent structures in a given language are processed more easily than less frequent structures (see e.g., Levy 2008).

The results of the corpus analysis show that subject relative clauses (SRCs) are more frequent than object relative clauses (ORCs) in Greek (Table 1). More specifically, there was a 3:1 ratio of SRCs to ORCs (cf. 7.6:1 in English, 8.1:1 in Hungarian, 2.2:1 in Russian, see Levy et al. 2013; Kovács and Vasishth 2013). In terms of word order, SVO relatives are the most frequent ones in both relative pronoun and complementizer structures. The second

most frequent structure is the OVS, and, finally, the least frequent structures are the ones where the subject or object RC NPs are in pre-verbal positions.

**Table 1.** Hellenic National Corpus (HNC) sample analysis of SRC and ORC structural frequency.

Type of Relative	Type of Relativizer	Word Order	Frequency per 100 Tokens
Subject RC	relative pro. <sub>NOM</sub>	SVO	24.42
Subject RC	relative pro. <sub>NOM</sub>	SOV	1.66
Object RC	relative pro. <sub>ACC</sub>	OVS	16.56
Object RC	relative pro. <sub>ACC</sub>	OSV	2.01
Subject RC	complementizer	SVO	14.43
Subject RC	complementizer	SOV	0.18
Object RC	complementizer	OVS	5.43
Object RC	complementizer	OSV	0.05

## 2.2. Participants

A total of 146 adult native speakers of Greek (117 female; 29 male, age range 21–31, mean age: 21.5, *SD*: 1.6) participated in the study. All participants were students at the University of Ioannina in Greece, and declared no native or near-native knowledge in any language other than Greek. They all received course credit for their participation. In addition, we collected data from 61 11- to 12-year-old Greek-speaking children (25 female; 36 male, age range 10.9–12.2, mean age: 11.1, *SD*: 0.45). All children were students in the 3rd primary school of Evosmos in Thessaloniki. Written consent was provided prior to the collection of experimental data. All children were monolingual speakers of Greek, and none reported any developmental or language disorders. All participants were naïve to the experimental manipulation.

## 2.3. Materials and Design

The experiment originally consisted of eight lists of 24 items, each item having four versions, as in (9): RCs were either subject-modifying (SRC) or object-modifying (ORC), the RC word order was either canonical (VO in SRCs, SV in ORCs) or scrambled (OV in SRCs, VS in ORCs), and the relativizer was either the complementizer *pu* ‘that’ or the inflected relative pronoun *o opios / i opia / to opio* ‘whom<sub>MASC.FEM.NEU</sub>’ which agreed in case, number, and gender with the head noun phrase (NP) that it modified. We thus originally manipulated three factors: type of RC, relative clause-internal word order, and type of relativizer.

When we pilot tested the task with children, we realized that the full version of the task was too hard to cope with. We thus decided to separate the task into two versions, one including only critical items with the relative pronoun and one including critical items only with the complementizer. The filler sentences were the same in both sub-tasks. A total number of 39 children completed the pronoun-only task, and 22 children completed the complementizer-only task.

9.
  - a. SRC, SVO, complementizer  
[O dhaskalos.<sub>NOM</sub>]<sub>1</sub> [pu]<sub>2</sub> [heretise]<sub>3</sub> [ton mathiti.<sub>ACC</sub>]<sub>4</sub> [mpike]<sub>5</sub> [se ena leoforio]<sub>6</sub>  
[the teacher.<sub>NOM</sub>]<sub>1</sub> [that]<sub>2</sub> [waved at]<sub>3</sub> [the student.<sub>ACC</sub>]<sub>4</sub> [got]<sub>5</sub> [onto a bus]<sub>6</sub>  
‘The teacher that waved at the student got onto a bus’
  - b. SRC, SOV, complementizer  
[O dhaskalos.<sub>NOM</sub>]<sub>1</sub> [pu]<sub>2</sub> [ton mathiti.<sub>ACC</sub>]<sub>3</sub> [heretise]<sub>4</sub> [mpike]<sub>5</sub> [se ena leoforio]<sub>6</sub>  
[the teacher.<sub>NOM</sub>]<sub>1</sub> [that]<sub>2</sub> [the student.<sub>ACC</sub>]<sub>3</sub> [waved at]<sub>4</sub> [got]<sub>5</sub> [onto a bus]<sub>6</sub>  
‘The teacher that waved at the student got onto a bus’
  - c. ORC, OVS, complementizer  
[O dhaskalos.<sub>NOM</sub>]<sub>1</sub> [pu]<sub>2</sub> [heretise]<sub>3</sub> [o mathitis.<sub>NOM</sub>]<sub>4</sub> [mpike]<sub>5</sub> [se ena leoforio]<sub>6</sub>  
[the teacher.<sub>NOM</sub>]<sub>1</sub> [that]<sub>2</sub> [waved at]<sub>3</sub> [the student.<sub>NOM</sub>]<sub>4</sub> [got]<sub>5</sub> [onto a bus]<sub>6</sub>  
‘The teacher that the student waved at got onto a bus’
  - d. ORC, OSV, complementizer  
[O dhaskalos.<sub>NOM</sub>]<sub>1</sub> [pu]<sub>2</sub> [o mathitis.<sub>NOM</sub>]<sub>3</sub> [heretise]<sub>4</sub> [mpike]<sub>5</sub> [se ena leoforio]<sub>6</sub>  
[the teacher.<sub>NOM</sub>]<sub>1</sub> [that]<sub>2</sub> [the student.<sub>NOM</sub>]<sub>3</sub> [waved at]<sub>4</sub> [got]<sub>5</sub> [onto a bus]<sub>6</sub>  
‘The teacher that the student waved at got onto a bus’

- e. SRC, SVO, relative pronoun  
 [O dhaskalos.NOM]<sub>1</sub> [o opios.NOM]<sub>2</sub> [heretise]<sub>3</sub> [ton mathiti.ACC]<sub>4</sub> [mpike]<sub>5</sub> [se ena leoforio]<sub>6</sub>  
 [the teacher]<sub>1</sub> [who]<sub>2</sub> [waved at]<sub>3</sub> [the student]<sub>4</sub> [got]<sub>5</sub> [onto a bus]<sub>6</sub>  
 ‘The teacher who waved at the student got onto a bus’
- f. SRC, SOV, relative pronoun  
 [O dhaskalos.NOM]<sub>1</sub> [o opios.NOM]<sub>2</sub> [ton mathiti.ACC]<sub>3</sub> [heretise]<sub>4</sub> [mpike]<sub>5</sub> [se ena leoforio]<sub>6</sub>  
 [the teacher.NOM]<sub>1</sub> [who.NOM]<sub>2</sub> [the student.ACC]<sub>3</sub> [waved at]<sub>4</sub> [got]<sub>5</sub> [onto a bus]<sub>6</sub>  
 ‘The teacher who waved at the student got onto a bus’
- g. ORC, OVS, relative pronoun  
 [O dhaskalos.NOM]<sub>1</sub> [ton opio.ACC]<sub>2</sub> [heretise]<sub>3</sub> [o mathitis.NOM]<sub>4</sub> [mpike]<sub>5</sub> [se ena leoforio]<sub>6</sub>  
 [the teacher.NOM]<sub>1</sub> [who.ACC]<sub>2</sub> [waved at]<sub>3</sub> [the student.NOM]<sub>4</sub> [got]<sub>5</sub> [onto a bus]<sub>6</sub>  
 ‘The teacher who the student waved at got onto a bus’
- h. ORC, OSV, relative pronoun  
 [O dhaskalos.NOM]<sub>1</sub> [ton opio.ACC]<sub>2</sub> [o mathitis.NOM]<sub>3</sub> [heretise]<sub>4</sub> [mpike]<sub>5</sub> [se ena leoforio]<sub>6</sub>  
 [the teacher.NOM]<sub>1</sub> [who.ACC]<sub>2</sub> [the student.NOM]<sub>3</sub> [waved at]<sub>4</sub> [got]<sub>5</sub> [onto a bus]<sub>6</sub>  
 ‘The teacher who the student waved at got onto a bus’

Each experimental sentence was divided into six segments indicated in brackets in the examples in (9a–h). In the complementizer *pu* condition (examples 9a–d), the critical segment, which disambiguates the structure towards either an SRC or ORC interpretation was the RC NP, which occurred either post-verbally (segment 4 in 9a, 9c) or pre-verbally (segment 3 in 9b, 9d). Effects are then expected on the critical segment (either 3 or 4) and spillover effects are expected on the two segments following the critical segment. In the relative pronoun condition (examples 9e–h), the critical disambiguating segment was the relative pronoun, which was marked for nominative case in SRCs and accusative case in ORCs. The verbs in the experimental sentences were all transitive reversible, and all head NPs and RC NPs were masculine, definite, full, and animate. Each segment was initially acoustically recorded independently so that prosodic or co-articulatory cues were absent, and then reassembled to form the experimental sentences. All participants were exposed to all experimental conditions and none of the participants heard more than one version of each experimental item (Latin square design). The 24 experimental sentences were interleaved with 48 filler sentences, half of which were grammatical and half ungrammatical. The filler sentences were of various structures, including sentences from other experiments with completely unrelated hypotheses. Each of the filler sentences also comprised six segments which were also recorded on a segment-by-segment basis.

#### 2.4. Procedure

Sentences were presented segment by segment in a self-paced listening procedure on a personal computer (PC) running the E-Prime 2.0 software ([Psychology Software Tools, Inc. 2012](#)). Participants listened to stimuli through headphones connected to the PC. A set of instructions and a short list of six practice items were presented before the beginning of the main experiment, so as to familiarize participants with the task. Participants were instructed to listen carefully to each sentence segment and to move from one segment to the next by pressing the space bar. A question mark (?) appeared on the computer screen at the end of each sentence/segment sequence. At this point, participants were asked to indicate through the pressing of one of two keys whether they considered the sentence grammatical or not. No performance feedback was given at any point of the experimental procedure. The amount of time between key presses, as well as the time that each participant spent listening to each segment, was recorded. The whole task took about 20–25 min to complete.

### 3. Results

Three adult participants were excluded from further analyses because they were less than 70% accurate in judging the grammaticality of the filler sentences. All analyses thus include the data from the 143 remaining adults who were more than 80% accurate in judging the grammaticality of the filler sentences (mean accuracy: 87.6%, *SD*: 5.4%). Children were also more than 80% accurate in the filler sentences (mean accuracy: 81.4%, *SD*: 3.8%). We treated each of the six segments as a distinct region, and thus statistical analyses were conducted separately for each of the six segments. For reasons of better

understanding, and because distinct patterns were observed for the complementizer vs. relative pronoun, we plot these conditions separately in adults and children. Also note that the RC NP (which was either preceding or following the RC verb, depending on the word order condition) was statistically treated as a single region. This was done to statistically analyze and interpret the effect of word order and its interaction with RC type and relativizer. Extreme listening times in any segment above 4000 ms or below 100 ms were discarded (1.7% of data). All listening times that were 2SD above or below the mean per segment and per condition were deleted and replaced by the respective mean. This process resulted in the replacement of 3.2% of the data.

### 3.1. Listening Times (LTs)

All analyses were conducted in RStudio v. 2021.09.2 + 382 (R Studio Team 2021). For a statistical evaluation of the results, linear mixed-effect models were fitted using the package *lme4* v. 1.1-27.1 (Bates et al. 2015). For each group (adults; children), separate models were fitted per segment across relativizers. We modeled LT values (dependent variable; log-transformed) as a function of dummy-coded factors for RC (reference level “ORC”), word order (reference level “canonical”), and their interactions. As random effects, the models include random intercepts and slopes by subject and item for all fixed factors. The linear mixed-effect models were then fitted into an Omnibus Anova to test the significance of the factors, as well as their interactions. Specifically, for each segment, a likelihood ratio test compared a model that includes all factors as fixed effects and their interactions (full model), a model that includes all factors as fixed effects only (model), and a model with an absence of fixed effects (null model). All models converged. Lastly, to specify the exact effects, post hoc pairwise comparisons were conducted using the package *emmeans* v. 1.7.2 (Lenth et al. 2022). Tables of values and scripts for the analyses conducted on the basis of these values are available at <https://osf.io/5u78h/> (accessed on 22 June 2022). on the OSF platform. Results of the models are reported in the Appendices A and B.

In the complementizer condition, the segment in which the structure was disambiguated towards an SRC or ORC interpretation was the accusative pre-verbal RC NP in SOV and the nominative RC NP in OSV (segment 3), whereas it was the accusative post-verbal RC NP in SVO and the nominative RC NP in OVS (segment 4). In the relative pronoun condition, it was the case marking on the inflected relative pronoun *o opios / ton opio* which disambiguated the structure towards either an SRC or ORC interpretation. The relative pronoun was marked for nominative in SRCs and accusative in ORCs.

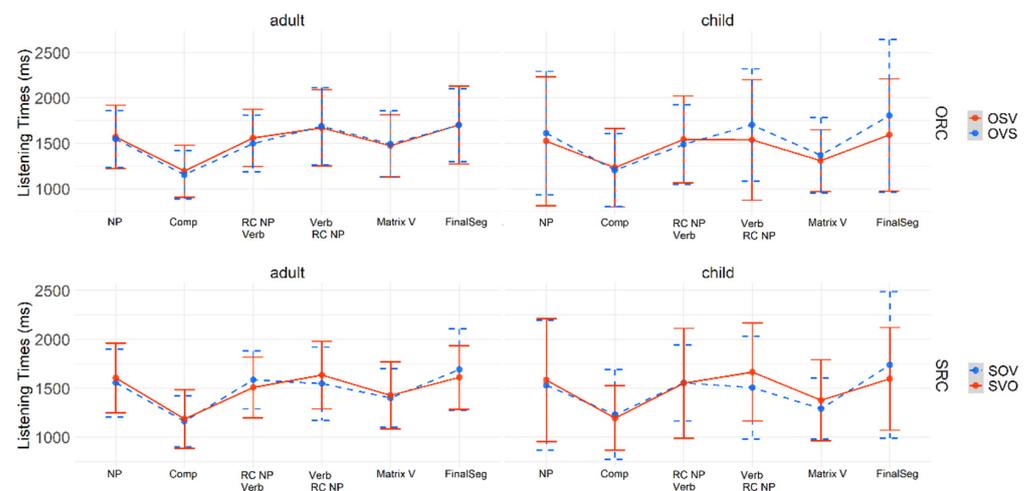
#### Complementizer Condition

Mean listening times in adults and children are presented in Figure 1 (as well as in Tables A1 and A2 in Appendix A). For both groups, no significant effects were found in segments 1 (NP) and 2 (complementizer).

For the adult group, on the verb segment, the likelihood ratio results indicate that all factors, as well as their interaction, were significant ( $\chi^2(3) = 33.79, p < 0.0001$ ). Specifically, the post hoc test showed that SVO structures were faster than OSV (estimate( $\mu_{OR}$ , OSV, adult –  $\mu_{SR}$ , SVO, adult) = 0.09,  $|t| = 3.221, p = 0.01$ ) and OVS structures (such as 9c) were processed faster than OSV structures (such as 9d) (estimate( $\mu_{OR}$ , OSV, adult –  $\mu_{OR}$ , OVS, adult) = 0.10,  $|t| = 3.524, p = 0.002$ ). This means that the occurrence of the pre-verbal subject inflates the processing time of the verb in ORCs. A similar pattern was not found in SRCs (no time difference between SVO and SOV structures).

No significant differences were found on the verb segment in children’s LTs.

On the RC NP, the likelihood ratio results for the adult group indicate that all factors, as well as the interaction between RC and word order, were significant ( $\chi^2(3) = 21.91, p = 0$ ). Specifically, we see that pre-verbal RC NPs are processed significantly faster than post-verbal RC NPs in ORCs. Thus, OSV structures are parsed faster than OVS structures (estimate( $\mu_{OR}$ , OSV, adult –  $\mu_{OR}$ , OVS, adult) =  $-0.07, |t| = 3.468, p = 0.003$ ). Similar to the verb segment, SVO structures were not processed faster than SOV structures.



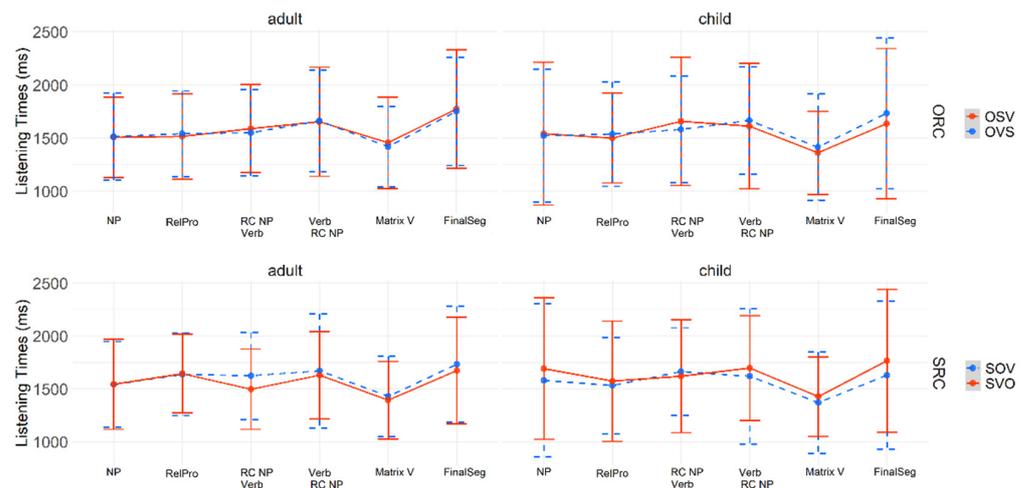
**Figure 1.** Mean listening times (in ms) per segment in the complementizer condition as a function of relative clause type (ORCs in upper panels, SRCs in bottom panels) in adults (left panels) and children (right panels).

For the child group, the likelihood ratio results show a significant interaction between RC and word order on the RC NP ( $\chi^2(3) = 10.02, p = 0.02$ ). Specifically, children processed OSV structures faster than OVS (estimate( $\mu_{OR, OSV, child} - \mu_{OR, OVS, child}$ ) =  $-0.09, |t| = 2.708, p = 0.03$ ). No further effects were found.

No significant effects were found for children and adults on the matrix clause verb segment, and on the final segment. All effects and interactions appear in tables in Appendix B.

### 3.2. Relative Pronoun Condition

Mean listening times for adults and children per segment are presented in Figure 2. There were no significant effects or interactions in the NP (segment 1) and in the relative pronoun segment (segment 2).



**Figure 2.** Mean listening times (in ms) per segment in the relative pronoun condition as a function of relative clause type (ORCs in upper panels, SRCs in bottom panels) in adults (left panels) and children (right panels). Word order within relative clause type is colour-coded (canonical word order in solid red, scrambled word order in dashed blue).

For the adult group, the likelihood ratio results indicate that, for the verb segment, all factors and their interaction were significant ( $\chi^2(3) = 68.83, p < 0.0001$ ). In this segment, we find a preference for canonical word order in SRCs, with SVO structures being parsed

faster than SOV structures in adults (estimate( $\mu$ SR, SVO, adult –  $\mu$ SR, SOV, adult) = –0.09,  $|t| = 6.459$ ,  $p < 0.0001$ ). In addition, structures in which the verb was adjacent to the relative pronoun (SVO and OVS) were processed faster than OSV structures which included pre-verbal subject NPs (estimate( $\mu$ OR, OSV, adult –  $\mu$ SR, SVO, adult) = 0.09,  $|t| = 4.794$ ,  $p < 0.0001$ ), (estimate( $\mu$ OR, OSV, adult –  $\mu$ OR, OVS, adult) = 0.06,  $|t| = 3.847$ ,  $p = 0.0007$ ). Similarly, OVS structures were parsed faster than SOV structures (estimate( $\mu$ OR, OVS, adult –  $\mu$ SR, SOV, adult) = –0.06,  $|t| = 3.427$ ,  $p = 0.003$ ). The difference between SOV and OSV structures was not significant. All in all, in the verb segment, there was no significant difference between SRCs and ORCs either.

No effects were found in the verb segment for the children.

For the adult group, the likelihood ratio results indicate that, for the RC NP segment, all factors were significant as well as the interaction between RC and word order ( $\chi^2(3) = 10.43$ ,  $p = 0.02$ ). Here, ORCs with preverbal subject NPs (OSV) were processed faster than OVS (estimate( $\mu$ OR, OSV, adult –  $\mu$ OR, OVS, adult) = –0.04,  $|t| = 3.210$ ,  $p = 0.007$ ) and SVO structures (estimate( $\mu$ OR, OSV, adult –  $\mu$ SR, SVO, adult) = –0.03,  $|t| = 2.023$ ,  $p = 0.05$ ).

No effects were found in the RC NP segment for the children.

In the matrix verb region, for the adult group, the likelihood ratio test showed is a significant interaction between RC and word order ( $\chi^2(3) = 7.79$ ,  $p = 0.05$ ). In this region, OSV structures were parsed slower than SVO (estimate( $\mu$ OR, OSV, adult –  $\mu$ SR, SVO, adult) = 0.04,  $|t| = 2.247$ ,  $p = 0.05$ ).

In children, the likelihood ratio test showed that there is a significant interaction between RC and WO in the matrix verb region ( $\chi^2(3) = 12.04$ ,  $p = 0.01$ ). Specifically, SVO structures were parsed slower than SOV (estimate( $\mu$ SR, SVO, child –  $\mu$ SR, SOV, child) = 0.09,  $|t| = 2.629$ ,  $p = 0.04$ ) and OSV structures (estimate( $\mu$ SR, OSV, child –  $\mu$ OR, SVO, child) = –0.07,  $|t| = 2.015$ ,  $p = 0.05$ ).

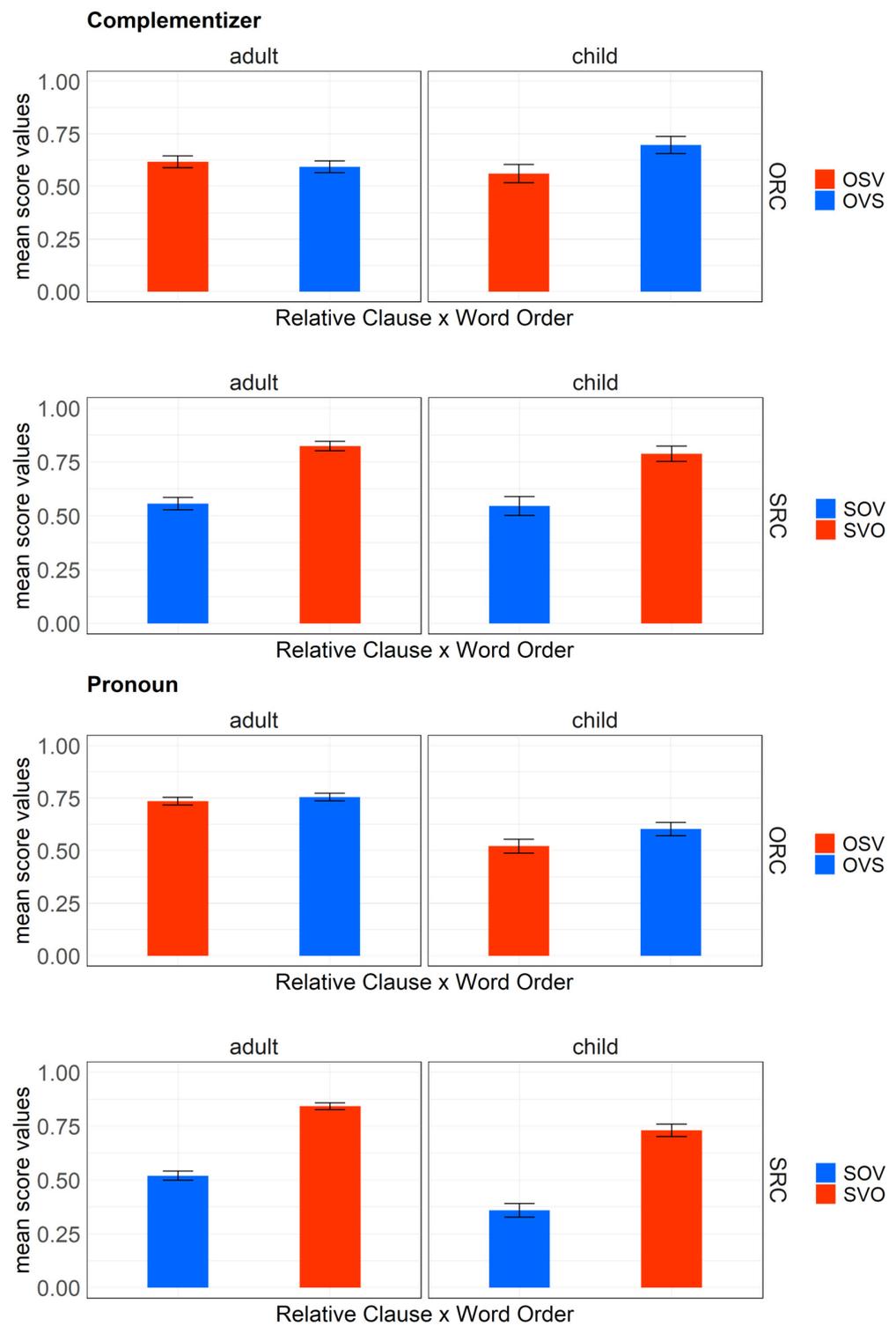
Finally, in adults, the RC has a significant main effect in the final segment ( $\chi^2(3) = 8.10$ ,  $p = 0.04$ ). Specifically, there is a clear SVO preference, as SVO structures are faster than OSV (estimate( $\mu$ OR, OSV, adult –  $\mu$ SR, SVO, adult) = 0.05,  $|t| = 3.315$ ,  $p = 0.005$ ) and OVS structures (estimate( $\mu$ OR, SVO, adult –  $\mu$ SR, OVS, adult) = –0.05,  $|t| = 2.848$ ,  $p = 0.02$ ).

Children’s LTs in the final segment show the same pattern as in the previous segment (significant interaction between RC and word order in the matrix verb region ( $\chi^2(3) = 16.52$ ,  $p = 0$ )); SVO structures are parsed slower than SOV (estimate( $\mu$ SR, SVO, child –  $\mu$ SR, SOV, child) = 0.12,  $|t| = 2.806$ ,  $p = 0.03$ ) and OSV structures (estimate( $\mu$ SR, SVO, child –  $\mu$ OR, OSV, child) = –0.10,  $|t| = 2.467$ ,  $p = 0.05$ ). OVS are also parsed slower than SOV structures, although the difference only reaches significance in SOV structures (estimate( $\mu$ OR, OVS, child –  $\mu$ SR, SOV, child) = 0.10,  $|t| = 2.281$ ,  $p = 0.05$ ).

### 3.3. Grammaticality Judgments

Aside from listening times, we also recorded Greek-speaking children’s and adults’ grammaticality decisions for each sentence that they listened to. These off-line data are presented in Figure 3. All analyses were conducted in Rstudio v. 2021.09.2 + 382 (R Studio Team 2021). For a statistical evaluation of the results, generalized linear mixed-effect models were fitted using the function *glmer* from the package *lme4* v. 1.1-27.1 (Bates et al. 2021). To select the best model for our data, we compared the ratios of the likelihoods of the models of interest (by subject and by item: varying intercepts; varying intercepts and slopes; varying intercepts and slopes with correlation). In case the ratio was greater than the critical chi-square value, for a given degree of freedom, the indication was that the compared models did not have the same log-likelihoods, meaning that the maximal model was better. Conversely, if there was no difference among the compared models, we chose the simpler model (Bates et al. 2018). Based on the model comparison results, we modeled score values (dependent variable) as a function of dummy-coded factors for RC (reference level “ORC”), word order (reference level “canonical”), and their interactions for each group separately. As random effects, the models include random intercepts by subject

and item. We followed the same procedure for model selection and significance testing of fixed factors, as well as their interactions, as reported in Section 3.1.



**Figure 3.** Mean grammaticality scores per relativizer (complementizer: upper panels, pronoun: bottom panels) in adults (left panels) and children (right panels) as a function of Relative Clause and Word Order (SOV and OVS illustrated in blue, SVO and OSV in solid red).

### 3.3.1. Complementizer Condition

In the adult group, the likelihood ratio results indicate a significant main effect of relative clause type, as well as a significant interaction between relative clause type and word order ( $\chi^2(3) = 67.54, p = 0$ ). The post hoc test showed a clear SVO precedence. More specifically, adults assigned significantly higher scores to SVO than to SOV (estimate( $\mu$ SR, SVO, adult) –  $\mu$ SR, SOV, adult) = 1.46,  $p < 0.0001$ ), OSV (estimate( $\mu$ OR, OSV, adult) –  $\mu$ SR, SVO, adult) = –1.18,  $p < 0.0001$ ), and OVS structures (estimate( $\mu$ SR, SVO, adult) –  $\mu$ OR, OVS, adult) = 1.29,  $p < 0.0001$ ).

In the child group, the likelihood ratio results indicate a significant main effect of both relative clause type and word order, as well as a significant interaction between the two factors ( $\chi^2(3) = 27.7, p < 0.0001$ ). The post hoc test revealed that children judged SVO structures as grammatical significantly more often than SOV (estimate( $\mu$ SR, SVO, child) –  $\mu$ SR, SOV, child) = 1.32,  $p = 0.0001$ ) and OSV structures (estimate( $\mu$ OR, OSV, child) –  $\mu$ SR, SVO, child) = –1.24,  $p = 0.0002$ ). Furthermore, children assigned significantly higher scores to OVS than to OSV structures (estimate( $\mu$ OR, OVS, child) –  $\mu$ OR, OSV, child) = 0.69,  $p = 0.06$ ) and SOV structures (estimate( $\mu$ OR, OVS, child) –  $\mu$ SR, SOV, child) = 0.77,  $p = 0.03$ ).

### 3.3.2. Pronoun Condition

In the adult group, the likelihood ratio results indicate a significant main effect of relative clause type, as well as a significant interaction between relative clause type and word order ( $\chi^2(3) = 162.24, p = 0$ ). As in the complementizer condition, in the pronoun condition, SVO structures received the highest scores and SOV the lowest. The differences here were even more pronounced than in the complementizer condition. Thus, SVO received significantly higher scores than SOV (estimate( $\mu$ SR, SVO, adult) –  $\mu$ SR, SOV, adult) = 1.74,  $p < 0.0001$ ), OSV structures (estimate( $\mu$ SR, SVO, adult) –  $\mu$ OR, OSV, adult) = 0.70,  $p < 0.0001$ ), and OVS structures (estimate( $\mu$ SR, SVO, adult) –  $\mu$ OR, OVS, adult) = 0.59,  $p = 0.0009$ ). In contrast, SOV structures received significantly lower scores than OSV (estimate( $\mu$ SR, SOV, adult) –  $\mu$ OR, OSV, adult) = –1.03,  $p < 0.0001$ ) and OVS structures (estimate( $\mu$ SR, SOV, adult) –  $\mu$ OR, OVS, adult) = –1.15,  $p < 0.0001$ ).

In the child group, the likelihood ratio results indicate a significant main effect of both relative clause type and word order, as well as a significant interaction between the two factors ( $\chi^2(3) = 76.83, p < 0.0001$ ). The post hoc test revealed that children also judged SVO structures as grammatical significantly more often than SOV (estimate( $\mu$ SR, SVO, child) –  $\mu$ SR, SOV, child) = 1.74,  $p < 0.0001$ ), OSV (estimate( $\mu$ SR, SVO, child) –  $\mu$ OR, OSV, child) = 1.00,  $p < 0.0001$ ), and OVS structures (estimate( $\mu$ SR, SVO, child) –  $\mu$ OR, OVS, child) = 0.64,  $p = 0.01$ ). Furthermore, OSV structures were judged as grammatical significantly more often than SOV (estimate( $\mu$ OR, OSV, child) –  $\mu$ SR, SOV, child) = 0.73,  $p = 0.001$ ). Finally, as in adults, OVS structures received higher scores than SOV (estimate( $\mu$ OR, OVS, child) –  $\mu$ SR, SOV, child) = 1.10,  $p < 0.0001$ ).

## 4. Discussion

We carried out an on-line self-paced listening task manipulating word order and relativizer to investigate possible effects of word order, type of relativizer, and language-specific morphosyntactic cues, such as morphological case, in Greek-speaking adults and 11- to 12-year-old children. This manipulation was conducted in order to investigate how these factors affect Greek speakers' parsing strategies, and how they interact with each other in real-time processing. Importantly, due to its rich morphology and word order flexibility, Greek gives us the chance to examine these three factors simultaneously.

Our main motivation has been to examine the type of strategies that adult and child speakers of Greek apply in the moment-to-moment processing of relative clause structures in relation to the well-known asymmetry between subject and object relative clauses. According to universal complexity accounts such as the Accessibility Hierarchy (e.g., Keenan and Comrie 1977) and the Perspective Shift Hypothesis (e.g., MacWhinney and Pléh 1988), SRCs should always be easier to process than ORCs. In the present study, we

did indeed find that canonical structure (SOV) SRCs were easier to process than ORCs, but this difference only clearly manifested itself in the participants' off-line grammaticality judgments. In the on-line processing of the experimental sentences, the different factors that we manipulated contributed to such an extent that no clear SRC preference surfaced in the statistical analyses. In the following sections, we discuss the role of different cues (word order, morphological case) in RC processing in adults. Next, we relate the discussion of adults' RC processing strategies to the child data in order to explore the continuity of parsing hypothesis.

#### 4.1. The Role of Word Order

The primary goal of the present study is to examine if the well-known SRC versus ORC asymmetry would still hold if the word order of SRCs and ORCs were kept constant. The results of the on-line self-paced listening task show that this was not the case, as SVO structures were processed as equally fast as OVS structures, and SOV structures were as equally fast as OSV structures across critical and post-critical segments in both adult and child groups. This means that in Greek there is no difference in the processing of SRCs and ORCs when the SRC and ORC have the same word order. There was thus no statistically significant difference between the SVO structures such as *O majiras pu esprokse [ton servitoro.ACC]* 'the cook that pushed the waiter' and OVS structures such as *O majiras pu esprokse [o servitoros.NOM]* (the cook that pushed the waiter.NOM), 'the cook that the waiter pushed'. This is to a large extent expected because up to the point of the RC verb, the SVO and OVS conditions are identical. In contrast, a very robust time difference was found between SVO and OSV structures in the complementizer *pu* condition (SVO: 1510 ms vs. OSV: 1671 ms; see Table A1 in the Appendix A for the full set of Listening Times). This means that structures such as *O majiras pu esprokse [ton servitoro]* 'the cook that pushed [the waiter]' were processed faster than structures such as *O majiras pu o servitoros esprokse* 'the cook that the waiter pushed' in the RC verb region. This result for structures that reflect the English word order configuration replicates the widely attested SRC preference found in the literature (e.g., King and Just 1991; Gordon et al. 2001).

A similar pattern was found in the relative pronoun condition. In the verb region, in structures introduced with the relative pronoun, we found inflated listening times in structures that included pre-verbal NPs (SOV, OSV) and a robust statistically significant advantage of structures in which the verb was adjacent to the relativizer (SVO and OVS). This result is compatible with the DLT (e.g., Gibson 1998), which predicts inflated times on the RC verb in structures in which the verb is not adjacent to the relativizer. According to Levy et al. (2013), the locality preference is so strong that it ends up neutralizing the asymmetry between SRCs and ORCs. Similar results were obtained for the pronoun condition in Russian (Levy et al. 2013) and Hungarian (Kovács and Vasishth 2013). It is then not at all surprising that OSV structures are more time-costly than SVO (and OVS) structures, because substantially more computation is needed at the point of the RC verb in OSV structures, as thematic roles have to be assigned to both the preceding subject NP and the NP head of the RC, so as to be simultaneously integrated in the structure (see, e.g., Gibson 1998). All in all, our data from adult Greek speakers' RC processing are compatible with the results of previous studies in free word order languages, in that we find evidence for the DLT (Gibson 1998), given that the RC verb in OSV and SOV structures was the segment that was processed the slowest in RCs introduced with the relative pronoun. In the complementizer *pu* condition, a time penalty was only found on the RC verb of OSV structures, but not in SOV structures. We take this as an indication that accusative pre-verbal NPs facilitated the processing of SOV structures. We discuss the contribution of morphological case marking in the processing of Greek RCs in the following section.

#### 4.2. The Role of Morphological Case Marking

As discussed in the previous section, the verb segment in OSV structures was the segment with the most inflated listening times in the complementizer *pu* condition. This

slowdown on the verb for OSV structures, in which both the object and the subject of the RC are marked with nominative case, is well attested in the literature. More specifically, previous studies in adult and child RC processing have shown that featural similarity of pre-verbal NPs causes processing difficulty. This processing difficulty in RCs stems from the fact that two pre-verbal NPs with identical features (full, masculine, singular, nominative) compete for the subject role of the RC verb (e.g., [Friedmann et al. 2009](#); [Gordon et al. 2001](#); [Lewis and Vasishth 2005](#); [Tabor and Hutchins 2004](#)). We should note, however, that, although featural similarity between the pre-verbal subject NP and the NP head of the RC resulted in inflated listening times on the RC verb in OSV structures, the overall processing of pre-verbal NPs was faster than that of post-verbal NPs. In addition, and somewhat surprisingly, accusative post-verbal NPs yielded almost similar listening times to post-verbal nominative NPs (1636 ms in adults, 1667 ms in children vs. 1690 ms in adults, 1704 ms in children). This indicates that, no matter if the structure is the canonical, most frequent, and most expected structure (SVO), speakers still take a similar amount of time to compute the post-verbal accusative NP as the time that they take to compute the nominative post-verbal NP in the less frequent OVS structure. The fact that pre-verbal NPs are processed faster than post-verbal NPs has also been found in other on-line studies that have manipulated word order in RCs (e.g., [Levy et al. 2013](#); [Guasti et al. 2018](#)). More specifically, [Guasti et al. \(2018\)](#) found that French and Italian-speaking adults and children processed OSV structures more easily than OVS structures. They interpreted this asymmetry using [Fodor and Inoue's \(2000\)](#) Diagnosis and Repair Model, which posits that it should be easier for the parser to process OSV than OVS structures because OSV structures contain more positive information regarding the reanalysis of the initial default SVO interpretation.

#### 4.3. RC Processing in Children

The statistical analysis of the child data revealed an SRC default word order (SVO) advantage only in the grammaticality judgments that immediately followed the on-line self-paced listening task. The pattern of grammaticality scores that adults and children provided for the experimental structures in the relative pronoun condition is exactly the same (see [Table A7](#) in [Appendix B](#)). SVO structures received the highest scores, with the rest of the structures receiving more or less similar scores. In the complementizer condition, the pattern of grammaticality judgment scores looks, again, very similar, except for the fact that OVS structures received a significantly higher grammaticality score than OSV structures for children, whereas there was no significant difference in grammaticality scores for adults. This difference between adults and children in the two versions of ORCs reflects children's real-time processing of OSV and OVS structures. We discuss this difference in more detail in the next paragraph. First, though, we emphasize the general picture of our child data: although there are differences in the segment-to-segment on-line RC processing between children and adults, there is remarkable similarity between child and adult processing in the grammaticality judgment task which immediately followed the processing of each sentence. In congruence with previous on-line sentence processing studies in children (e.g., [Clahsen and Felser 2006a](#); [Booth et al. 2000](#)), we thus conclude that our study provides evidence for continuity of parsing in children.

Let us now have a closer look at the children's listening times. The analysis of the LTs in the child group did not reveal any statistically significant differences among the experimental conditions in the verb region. This is to a certain extent expected, as children possibly need more time than adults to integrate the constituents in the structure, due to lower cognitive capacity than adults (e.g., [Felser et al. 2003](#); [Traxler et al. 2005](#)). On the RC NP in the complementizer condition, there was a statistically significant time penalty for post-verbal nominative NPs in OVS structures such as *O majiras.NOM pu esprokse o servitoros.NOM* (the cook that pushed the waiter.NOM) 'the cook that the waiter pushed', indicating that the child parser was garden-pathed upon encountering a nominative post-verbal NP instead of the "expected" accusative NP. This time penalty, which also occurred

in adults, is compatible with expectation-based models (such as Surprisal, e.g., [Levy 2008](#)), which predict longer processing times in segments which are the least expected and thus have a low probability of occurrence. Note, however, that despite the fact that post-verbal nominative NPs induced a high processing cost, OVS structures received the second highest acceptability score in the child group (SVO structures received the highest grammaticality scores). This means that the child parser eventually recovered from the garden path and managed to successfully process the structure and assign the correct thematic roles.

In the relative pronoun condition, the statistical analysis of children's listening times did not show a post-verbal nominative NP time penalty in OVS structures. We take this to mean that early RC disambiguation through the insertion of an inflected relativizer, such as the relative pronoun in Greek or the relative pronoun in French (see [Schelstraete and Degand 1998](#)), makes the expectation of a nominative post-verbal NP higher in comparison to when the nominative post-verbal NP is actually the point of structural disambiguation towards an SRC or ORC analysis. In an OVS structure such as *O majiras ton opio.ACC esprokse o servitoros.NOM* (the cook who.ACC pushed the waiter.NOM) 'the cook whom the waiter pushed', the parser receives very early (on the relative pronoun/second segment) the crucial piece of information that the preceding NP *o majiras* is actually the object of the RC. This information is provided through accusative case marking on the relative pronoun. When the parser reaches the RC verb segment, it has already assigned an object to the RC and is now looking for a subject NP, and this subject NP is precisely the post-verbal nominative NP.

In addition, OVS and SVO structures were parsed slower than OSV and SOV structures in the child group in the two post-critical segments (matrix verb and final segment) in the relative pronoun condition. We interpret this slowdown in listening times as the time that the child parser needed to successfully integrate and process the RC structures, and not as difficulty in processing. The fact that SVO and OVS structures received the highest scores in the subsequent grammaticality judgment task provides evidence for the validity of this claim. This claim is also supported by the fact that SOV structures such as *O majiras.NOM o opios ton servitoro.ACC esprokse ekapse to fajito* (the cook who the waiter.ACC pushed.burnt the food) 'the cook who pushed the waiter burnt the food' were processed the fastest in the two post-critical segments. These structures begin with a nominative NP which is then modified by a nominative relative pronoun and then followed by an accusative NP and then two verbs (RC verb and matrix-clause verb). We believe that, at the point of the second verb (matrix-clause verb), the child parser rendered the structure ungrammatical and thus processed the final two segments very quickly. The grammaticality judgment scores verify this claim, as SOV structures in the relative pronoun condition received a score of 0.359, which means that 65% of the responses deemed the structures ungrammatical. Note that SOV structures in the relative pronoun condition also received the lowest grammaticality score in the adult group (0.520). In the LT pattern, however, this corresponds to adult speakers' slow processing of SOV structures. What these results point to is that the well-known correspondence between processing difficulty and inflated listening or reading times, which is well-established in adults, does not always hold for children. Our study provides strong evidence that 11- to 12-year-old children process challenging and structurally complex sentences faster than sentences with which the child parser can cope. Structures that the child parser can cope with have default word order, and are very frequent and computationally simple structures such as SRCs.

Another crucial aspect to be considered here is that, if one follows Fodor and Inoue's Diagnosis and Repair Model, which [Guasti et al. \(2018\)](#) adopted for their analysis, then one would expect OSV, as well as SOV, structures to be easy to process, on the assumption that the NPs that occur before the RC verb can provide the parser with positive information regarding the reanalysis of the structure. This is indeed the case for SOV structures in the complementizer condition. The analysis of the LTs shows that SOV structures were processed similarly to the default word order SVO structures in the verb segment. Thus, no time penalty on the RC verb is found in structures such as *O majiras pu ton servitoro.ACC*

*esprokse* (the cook that the waiter<sub>ACC</sub> pushed) ‘the cook that pushed the waiter’ in either the adult or child group. In contrast, the RC verb in the relative pronoun condition in SOV structures was processed significantly more slowly than the verb in SVO structures in the adult group. This result is, as already mentioned, compatible with the DLT, though incompatible with the diagnosis and repair model.

Our data are also partly compatible with Guasti et al.’s claim that structures that are harder for children to comprehend are processed slower by adults. The evidence that we found from the processing of SOV structures in children verifies Guasti et al.’s claim. SOV structures were the hardest for children to comprehend, and it is exactly these structures which were the slowest for adults to process in the relative pronoun condition. In contrast, the difference in the processing of the two ORC word order configurations in children is not reflected in adults’ listening times in the two post-critical segments.

Overall, the child data in our study seem to be compatible with the Competition Model (Bates and MacWhinney 1987), which predicts that SVO structures should be the easiest to process, followed by OVS structures, and then by OSV structures, which should be the hardest to process for both children and adults. Moreover, the Competition Model hypothesizes a developmental change in sentence-processing strategies, which constitutes a change in ranking of cues. Children commit to the default SVO word order, and they also process OVS word orders relatively easily, but the cognitively demanding SOV and OSV word orders are very hard for the children to process and are often considered ungrammatical. This commitment to an initial/default structural interpretation in children’s processing is well attested in the literature (e.g., Felser et al. 2003). In addition, although studies in acquisition report that morphological case marking on NPs has a positive effect on children’s comprehension of Greek RCs (e.g., Guasti et al. 2012; Varlokosta et al. 2015), early disambiguation of the RC structure through accusative case marking on the relative pronoun did not seem to make real-time processing easier for 11- to 12-year-old Greek-speaking children. On the grounds of the Competition model, we thus conclude that, for 11- to 12-year-old Greek-speaking children, the word order cue is more prominent than the case cue in on-line RC processing.

## 5. Conclusions

Greek speakers’ on-line listening times and grammaticality scores in the complementizer condition showed a clear SVO advantage compatible with the SRC advantage that has been found cross-linguistically (e.g., MacWhinney and Pléh 1988; King and Just 1991; Arnon 2010). In the on-line data, however, we did not find a clear SRC advantage in the critical RC verb and RC NP segments.

Our data on the verb and RC NP regions in the relative pronoun condition provide support for locality in parsing, as structures in which the verb occurs immediately after the relative pronoun are processed faster than structures in which the verb is linearly in non-local position (see Gibson 1998). We also find evidence for faster processing in structures in which the RC disambiguation takes place through the accusative case in adults. We conclude that our data are to a large extent compatible with the data from other free word order languages such as Russian and Hungarian (Levy et al. 2013; Kovács and Vasishth 2013).

Children seem to struggle with heavy cognitive load structures that include pre-verbal NPs and show heavy reliance on word order. The fact that children’s LTs were the same for nominative and accusative pre-verbal NPs, and the surprisal effect in ORCs with post-verbal nominal NPs, lead us to conclude that, for Greek children, word order is a more prominent cue than morphological case. Overall, however, our study provides evidence (complementizer condition, grammaticality scores) that children parse complex structures similarly to adults, thus allowing us to argue in favor of continuity in children’s parsing (see Clahsen and Felser 2006a; Guasti et al. 2018).

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**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki, and approved by the Faculty of Social Sciences Ethics Committee of TECHNISCHE UNIVERSITÄT KAISERSLAUTERN (Ethikantrag Nr.2, 25.04.2018).

**Informed Consent Statement:** Informed consent was obtained from all participants involved in the study.

**Data Availability Statement:** Data tables and scripts for the statistical analyses that were conducted for the current study are freely available on the OSF platform at <https://osf.io/5u78h/> (accessed on 22 June 2022).

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## Appendix A

**Table A1.** Listening Times (LTs) per condition and segment in the adult group.

Type of Relative/Word Order	Type of Relativizer	Segment 1 (NP)	Segment 2 (Relativizer)	Segment 3/4 (Verb)	Segment 3/4 (RC NP)	Segment 5 (Main Verb)	Segment 6 (Final)
Subject RC_SVO	complementizer	1605	1187	1510	1636	1427	1612
Subject RC_SOV	complementizer	1556	1163	1548	1586	1403	1692
Object RC_OVS	complementizer	1548	1155	1498	1690	1493	1701
Object RC_OSV	complementizer	1572	1195	1671	1561	1473	1703
Subject RC_SVO	relative pro.NOM	1544	1645	1498	1629	1393	1674
Subject RC_SOV	relative pro.NOM	1543	1638	1672	1623	1430	1733
Object RC_OVS	relative pro.ACC	1514	1541	1550	1662	1420	1752
Object RC_OSV	relative pro.ACC	1508	1515	1654	1589	1457	1775

**Table A2.** Listening Times (LTs) per condition and segment in the child group.

Type of Relative/Word Order	Type of Relativizer	Segment 1 (NP)	Segment 2 (Relativizer)	Segment 3/4 (Verb)	Segment 3/4 (RC NP)	Segment 5 (Main Verb)	Segment 6 (Final)
Subject RC_SVO	complementizer	1585	1196	1553	1667	1379	1597
Subject RC_SOV	complementizer	1531	1233	1507	1556	1293	1739
Object RC_OVS	complementizer	1613	1206	1488	1704	1370	1805
Object RC_OSV	complementizer	1525	1232	1539	1544	1309	1594
Subject RC_SVO	relative pro.NOM	1592	1574	1621	1697	1428	1766
Subject RC_SOV	relative pro.NOM	1581	1533	1620	1664	1370	1630
Object RC_OVS	relative pro.ACC	1522	1537	1581	1667	1415	1734
Object RC_OSV	relative pro.ACC	1543	1500	1613	1659	1362	1636

**Table A3.** Grammaticality judgment scores per condition and segment in the adult group (Standard Deviation in parenthesis).

Type of Relative/Word Order	Type of Relativizer	Grammaticality Score
Subject RC_SVO	complementizer	0.823 (0.382)
Subject RC_SOV	complementizer	0.557 (0.498)
Object RC_OVS	complementizer	0.593 (0.492)
Object RC_OSV	complementizer	0.617 (0.487)
Subject RC_SVO	relative pro.NOM	0.842 (0.365)
Subject RC_SOV	relative pro.NOM	0.520 (0.500)
Object RC_OVS	relative pro.ACC	0.754 (0.431)
Object RC_OSV	relative pro.ACC	0.735 (0.442)

**Table A4.** Grammaticality judgment scores per condition and segment in the child group (Standard Deviation in parenthesis).

Type of Relative/Word Order	Type of Relativizer	Grammaticality Score
Subject RC_SVO	complementizer	0.788 (0.410)
Subject RC_SOV	complementizer	0.545 (0.500)
Object RC_OVS	complementizer	0.697 (0.461)
Object RC_OSV	complementizer	0.561 (0.498)
Subject RC_SVO	relative pro. <sub>NOM</sub>	0.731 (0.445)
Subject RC_SOV	relative pro. <sub>NOM</sub>	0.359 (0.481)
Object RC_OVS	relative pro. <sub>ACC</sub>	0.603 (0.490)
Object RC_OSV	relative pro. <sub>ACC</sub>	0.521 (0.501)

**Appendix B**

**Table A5.** Summary of the Likelihood Ratio Tests testing the significance of the fixed factors and their interactions as opposed to a null model. Asterisks denote levels of significance (“\*\*\*” 0; “\*\*” 0.001; “\*” 0.05).

	npar	AIC	BIC	LogLik	Deviance	Chisq	Df	Pr(>Chisq)
<b>Comp_adult_LT</b>								
segment 1	WORD1NULL	16	−343.10	−261.66	187.55	−375.10		
	WORD1FULL	19	−340.60	−243.89	189.30	−378.60	3	0.32
segment 2	WORD2NULL	16	−457.08	−375.64	244.54	−489.08		
	WORD2FULL	19	−456.16	−359.45	247.08	−494.16	3	0.17
segment VERB	WORD_VERB_NULL	16	−389.44	−308.00	210.72	−421.44		
	WORD_VERB_FULL	19	−417.24	−320.52	227.62	−455.24	3	0.00 ***
segment NOUN	WORD_NOUN_NULL	16	−454.51	−373.06	243.25	−486.51		
	WORD_NOUN_FULL	19	−470.42	−373.70	254.21	−508.42	3	0.00 ***
segment 5	WORD5NULL	16	−346.63	−265.19	189.31	−378.63		
	WORD5FULL	19	−345.16	−248.44	191.58	−383.16	3	0.21
segment 6	WORD6NULL	16	−220.34	−138.90	126.17	−252.34		
	WORD6FULL	19	−220.46	−123.75	129.23	−258.46	3	0.11
<b>Comp_child_LT</b>								
segment 1	WORD1NULL	16	859.12	927.42	−413.56	827.12		
	WORD1FULL	19	861.06	942.17	−411.53	823.06	3	0.25
segment 2	WORD2NULL	16	126.98	195.28	−47.49	94.98		
	WORD2FULL	19	132.42	213.53	−47.21	94.42	3	0.91
segment VERB	WORD_VERB_NULL	16	368.80	437.11	−168.40	336.80		
	WORD_VERB_FULL	19	373.95	455.06	−167.98	335.95	3	0.84
segment NOUN	WORD_NOUN_NULL	16	145.80	188.49	−62.90	125.80		
	WORD_NOUN_FULL	19	141.77	197.27	−57.89	115.77	3	0.02 **
segment 5	WORD5NULL	16	75.31	143.61	−21.65	43.31		
	WORD5FULL	19	75.84	156.95	−18.92	37.84	3	0.14
segment 6	WORD6NULL	16	393.84	462.14	−180.92	361.84		
	WORD6FULL	19	395.38	476.49	−178.69	357.38	3	0.22

**Table A5.** *Cont.*

		npar	AIC	BIC	LogLik	Deviance	Chisq	Df	Pr(>Chisq)
<b>Pro_adults_LT</b>									
<i>segment 1</i>	WORD1NULLPRO	23	1287.16	1418.51	−620.58	1241.16			
	WORD1FULLPRO	26	1291.32	1439.79	−619.66	1239.32	1.84	3	0.61
<i>segment 2</i>	WORD2NULLPRO	23	−1182.54	−1051.20	614.27	−1228.54			
	WORD2FULLPRO	26	−1180.85	−1032.37	616.43	−1232.85	4.31	3	0.23
<i>segment VERB</i>	modelNULLPRO	23	−136.38	−5.04	91.19	−182.38			
	modelFULLPRO	26	−199.21	−50.73	125.60	−251.21	68.83	3	0.00 ***
<i>segment NOUN</i>	mdlNULLPRO	23	−549.28	−417.93	297.64	−595.28			
	mdlFULLPRO	26	−553.70	−405.23	302.85	−605.70	10.42	3	0.02 **
<i>segment 5</i>	WORD5NULL	23	−328.34	−197.00	187.17	−374.34			
	WORD5FULL	26	−330.13	−181.66	191.07	−382.13	7.79	3	0.05 *
<i>segment 6</i>	WORD6NULL	23	701.86	833.21	−327.93	655.86			
	WORD6FULL	26	699.76	848.24	−323.88	647.76	8.10	3	0.04 *
<b>Pro_child_LT</b>									
<i>segment 1</i>	WORD1NULLPRO	16	1561.46	1638.93	−764.73	1529.46			
	WORD1FULLPRO	19	1558.85	1650.84	−760.42	1520.85	8.61	3	0.1
<i>segment 2</i>	WORD2NULLPRO	16	129.46	206.93	−48.73	97.46			
	WORD2FULLPRO	19	134.43	226.42	−48.21	96.43	1.03	3	0.79
<i>segment VERB</i>	modelNULLPRO	16	593.86	671.32	−280.93	561.86			
	modelFULLPRO	19	598.30	690.29	−280.15	560.30	1.56	3	0.67
<i>segment NOUN</i>	mdlNULLPRO	16	209.41	286.87	−88.70	177.41			
	mdlFULLPRO	19	211.96	303.95	−86.98	173.96	3.44	3	0.33
<i>segment 5</i>	WORD5NULL	16	580.23	657.70	−274.12	548.23			
	WORD5FULL	19	574.20	666.19	−268.10	536.20	12.04	3	0.01 **
<i>segment 6</i>	WORD6NULL	16	997.98	1075.45	−482.99	965.98			
	WORD6FULL	19	987.47	1079.46	−474.73	949.47	16.52	3	0.00 ***
<b>Comp_adults_GJT</b>									
	mdlNULL	3	1526.36	1541.63	−760.18	1520.36			
	mdlFULL	6	1464.82	1495.36	−726.41	1452.82	67.54	3	0.00 **
<b>Comp_child_GJT</b>									
	mdlNULL	3	650.16	662.97	−322.08	644.16			
	mdlFULL	6	628.44	654.05	−308.22	616.44	27.72	3	0.00 **
<b>Pro_adults_GJT</b>									
	mdlNULL	3	2635.20	2652.33	−1314.60	2629.20			
	mdlFULL	6	2478.96	2513.22	−1233.48	2466.96	162.24	3	0.00 **
<b>Pro_child_GJT</b>									
	mdlNULL	3	1260.44	1274.97	−627.22	1254.44			
	mdlFULL	6	1189.61	1218.66	−588.81	1177.61	76.83	3	0.00 **

**Table A6.** Summary of the statistical models which showed a significant effect or interaction of the factors in the Likelihood Ratio Tests.

	Coefficient	$\beta$	SE	<i>t</i>
<b>Comp_adults_LT</b>				
<i>segment VERB</i>	(Intercept)	7.39	0.02	316.09
	RC (SR)	−0.09	0.03	−3.221
	WO (scrambled)	−0.10	0.03	−3.524
	RC (SR):WO(scrambled)	0.12	0.02	5.554
<i>segment RC NP</i>	(Intercept)	7.33	0.02	486.34
	RC (SR)	0.05	0.02	2.739
	WO (scrambled)	0.07	0.02	3.468
	RC (SR):WO(scrambled)	−0.10	0.02	−4.532
<b>Comp_child_LT</b>				
<i>segment RC NP</i>	(Intercept)	7.30	0.04	173.05
	RC (SR)	0.07	0.04	1.931
	WO (scrambled)	0.08	0.03	2.708
	RC (SR):WO(scrambled)	−0.13	0.04	−3.092
<b>Pro_adults_LT</b>				
<i>segment VERB</i>	(Intercept)	7.37	0.02	410.25
	RC (SR)	−0.09	0.02	−4.794
	WO (scrambled)	−0.06	0.01	−3.847
	RC (SR):WO(scrambled)	0.15	0.02	8.192
<i>segment RC NP</i>	(Intercept)	7.34	0.02	467.99
	RC (SR)	0.03	0.01	2.023
	WO (scrambled)	0.04	0.01	3.210
	RC (SR):WO(scrambled)	−0.04	0.02	−2.597
<i>segment 5</i>	(Intercept)	7.25	0.01	499.228
	RC (SR)	−0.04	0.02	−2.247
	WO (scrambled)	−0.02	0.01	−1.515
	RC (SR):WO(scrambled)	0.05	0.02	2.603
<i>segment 6</i>	(Intercept)	7.44	0.01	518.97
	RC (SR)	−0.05	0.02	−3.315
	WO (scrambled)	−0.007	0.02	−0.452
	RC (SR):WO(scrambled)	0.03	0.02	1.360
<b>Pro_child_LT</b>				
<i>segment 5</i>	(Intercept)	7.16	0.04	197.93
	RC (SR)	0.07	0.04	2.015
	WO (scrambled)	0.04	0.03	1.213
	RC (SR):WO(scrambled)	−0.13	0.04	−3.368
<i>segment 6</i>	(Intercept)	7.31	0.04	175.11
	RC (SR)	0.10	0.04	2.467
	WO (scrambled)	0.07	0.04	1.665
	RC (SR):WO(scrambled)	−0.20	0.05	−4.024

**Table A6.** *Cont.*

	<b>Coefficient</b>	<b><math>\beta</math></b>	<b>SE</b>	<b>z</b>
<b>Comp_adults_GJT</b>				
	(Intercept)	0.53	0.15	3.626
	RC (SR)	1.18	0.20	5.820
	WO (scrambled)	−0.11	0.18	−0.623
	RC (SR):WO(scrambled)	−1.35	0.27	−5.028
<b>Comp_child_GJT</b>				
	(Intercept)	0.32	0.29	1.112
	RC (SR)	1.24	0.30	4.174
	WO (scrambled)	0.69	0.28	2.483
	RC (SR):WO(scrambled)	−2.01	0.41	−4.892
<b>Pro_adults_GJT</b>				
	(Intercept)	1.10	0.12	9.494
	RC (SR)	0.70	0.16	4.537
	WO (scrambled)	0.11	0.14	0.790
	RC (SR):WO(scrambled)	−1.85	0.20	−8.913
<b>Pro_child_GJT</b>				
	(Intercept)	0.09	0.18	0.505
	RC (SR)	1.00	0.20	4.845
	WO (scrambled)	0.37	0.20	1.859
	RC (SR):WO(scrambled)	−2.10	0.29	−7.230

**Table A7.** Summary of the pairwise comparisons of the models which showed a significant effect or interaction of the factors in the Likelihood Ratio Tests. Values are rounded at 2 decimal places.

	<b>Coefficient</b>	<b><math>\beta</math></b>	<b>SE</b>	<b>p</b>
<b>Comp_adults_LT</b>				
<i>segment VERB</i>	OSV – SVO	0.09	0.03	0.01
	OSV – OVS	0.10	0.03	0.00
	OSV – SOV	0.07	0.04	0.21
	SVO – OVS	0.01	0.04	0.99
	SVO – SOV	−0.02	0.03	0.93
	OVS – SOV	−0.03	0.03	0.70
<i>segment RC NP</i>	OSV – SVO	−0.05	0.02	0.03
	OSV – OVS	−0.07	0.02	0.00
	OSV – SOV	−0.02	0.02	0.79
	SVO – OVS	−0.02	0.02	0.66
	SVO – SOV	0.03	0.02	0.59
	OVS – SOV	0.05	0.02	0.01

Table A7. Cont.

	Coefficient	$\beta$	SE	$p$
<b>Comp_child_LT</b>				
<i>segment RC NP</i>	SVO – OSV	0.07	0.04	0.22
	SVO – SOV	0.05	0.03	0.35
	SVO – OVS	−0.01	0.04	0.99
	OSV – SOV	−0.02	0.04	0.95
	OSV – OVS	−0.09	0.03	0.03
	SOV – OVS	−0.06	0.04	0.32
<b>Pro_adults_LT</b>				
<i>segment VERB</i>	OSV – SVO	0.09	0.02	0.00
	OSV – OVS	0.06	0.01	0.00
	OSV – SOV	−0.01	0.02	0.99
	SVO – OVS	−0.03	0.02	0.37
	SVO – SOV	−0.09	0.01	0.00
	OVS – SOV	−0.06	0.02	0.00
<i>segment RC NP</i>	OSV – SVO	−0.03	0.01	0.05
	OSV – OVS	−0.04	0.01	0.01
	OSV – SOV	−0.02	0.01	0.33
	SVO – OVS	−0.01	0.01	0.82
	SVO – SOV	0.00	0.01	0.99
	OVS – SOV	0.02	0.01	0.65
<i>segment 5</i>	OSV – SVO	0.04	0.02	0.05
	OSV – OVS	0.02	0.01	0.43
	OSV – SOV	0.01	0.02	0.88
	SVO – OVS	−0.02	0.02	0.76
	SVO – SOV	−0.03	0.01	0.27
	OVS – SOV	−0.01	0.02	0.97
<i>segment 6</i>	OSV – SVO	0.05	0.02	0.01
	OSV – OVS	0.01	0.02	0.97
	OSV – SOV	0.03	0.02	0.24
	SVO – OVS	−0.05	0.02	0.02
	SVO – SOV	−0.02	0.02	0.46
	OVS – SOV	0.02	0.02	0.47
<b>Pro_child_LT</b>				
<i>segment 5</i>	OSV – SVO	−0.07	0.04	0.05
	OSV – OVS	−0.04	0.03	0.62
	OSV – SOV	0.02	0.04	0.98
	SVO – OVS	0.03	0.04	0.87
	SVO – SOV	0.09	0.03	0.04

**Table A7.** *Cont.*

	<b>Coefficient</b>	$\beta$	<b>SE</b>	<i>p</i>
	OVS – SOV	0.06	0.04	0.37
<i>segment 6</i>	OSV – SVO	−0.10	0.04	0.05
	OSV – OVS	−0.07	0.04	0.34
	OSV – SOV	0.02	0.05	0.97
	SVO – OVS	0.03	0.05	0.94
	SVO – SOV	0.12	0.04	0.03
	OVS – SOV	0.10	0.04	0.05
	<b>Coefficient</b>	$\beta$	<b>SE</b>	<i>p</i>
<b>Comp_adults_GJT</b>				
	OSV – SVO	−1.18	0.20	0.0
	OSV – OVS	0.11	0.18	0.92
	OSV – SOV	0.28	0.18	0.38
	SVO – OVS	1.29	0.20	0.00
	SVO – SOV	1.46	0.20	0.00
	OVS – SOV	0.17	0.18	0.77
<b>Comp_child_GJT</b>				
	OSV – SVO	−1.24	0.30	0.00
	OSV – OVS	−0.69	0.28	0.06
	OSV – SOV	0.07	0.27	0.99
	SVO – OVS	0.55	0.30	0.27
	SVO – SOV	1.32	0.30	0.00
	OVS – SOV	0.77	0.28	0.03
<b>Pro_adults_GJT</b>				
	OSV – SVO	−0.70	0.16	0.00
	OSV – OVS	−0.11	0.14	0.86
	OSV – SOV	1.03	0.13	0.00
	SVO – OVS	0.59	0.16	0.00
	SVO – SOV	1.74	0.15	0.00
	OVS – SOV	1.15	0.14	0.00
<b>Pro_child_GJT</b>				
	OSV – SVO	−1.00	0.21	0.00
	OSV – OVS	−0.37	0.20	0.25
	OSV – SOV	0.73	0.20	0.00
	SVO – OVS	0.64	0.21	0.01
	SVO – SOV	1.74	0.21	0.00
	OVS – SOV	1.10	0.20	0.00

## Notes

- <sup>1</sup> According to Tzanidaki (1995), an analysis of Greek corpus data shows that all possible word order combinations occur frequently enough to be considered grammatical. Moreover, Tzanidaki (1995) notes that structures with full NPs (as in our study) are rather infrequent in morphologically rich free word order languages such as Greek, because rich verbal morphology often renders them redundant. Further analysis shows that full NPs are mostly omitted in informal discourse settings, but they occur quite frequently in formal discourse settings. In addition, full subject NPs are more often omitted than full object NPs. Finally, different word order placement of full subject and object NPs depends on the focal status of the NPs.
- <sup>2</sup> It should be noted here that, similar to Levy et al. (2013) and Kovács and Vasishth (2013), Schelstraete and Degand (1998) also found inflated reading times on the RC verb of ORCs with OSV word order.

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