PROCESSING SUBJECT AND OBJECT RELATIVE CLAUSES
IN A FLEXIBLE WORD ORDER LANGUAGE: EVIDENCE FROM GREEK
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Abstract

The present study investigates the on-line processing of subject and object relative clauses in Greek. Although asymmetries in processing difficulty between subject and object relatives clauses have been thoroughly investigated in fixed word order and head final languages, research in free word order languages is very scarce. This study aims to fill this gap by providing psycholinguistic data from Greek. We thus conducted an on-line self-paced listening task in which we manipulated word order, type of relative clause and relativizer. The results showed that processing difficulty derives primarily from differences in word order rather than from the type of relative clause.

Keywords: sentence comprehension, relative clauses, syntactic complexity, parsing, word order, Greek, self-paced listening, locality

1. Introduction

One of the core questions in the sentence processing literature involves whether or not parsing strategies which lead to the successful comprehension of incoming linguistic input are universal or language-specific. The investigation of relative clause processing, and more specifically the potential differences in processing difficulty between subject and object relatives clauses gives us the chance to explore this question.

1) a) Subject relative clause (SRC)
   The reporter that attacked the senator admitted the error.

   b) Object relative clause (ORC)
   The reporter that the senator attacked admitted the error.

In the examples from King and Just (1991) in (1), 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. Consequently, sentences like (1) have been used in the psycholinguistic literature to examine the role of WM in real-time sentence comprehension (e.g. Just & Carpenter 1992, King & Just 1991). In SRCs such as (1a), the extracted NP (the reporter) is the subject of both the main clause (e.g. the reporter admitted the error) and the relative clause (e.g. the reporter attacked the senator). In ORCs such as (1b), however, the extracted element (the reporter) is still the subject of the main clause (e.g. the reporter admitted the error) but the object of the relative clause (e.g. the senator attacked the reporter). A large amount of experimental
research has shown that ORCs (such as 1b) are processed more slowly and are thus harder to comprehend than SRCs (such as 1a) (e.g. Gibson 1998, Gordon, Hendrick & Johnson, 2001, King & Just 1991, MacWhinney 1982, Mak, Vonk & Schriefers 2006, Mak, Vonk & Schriefers 2002, Traxler, Morris & Seely 2002, Warren & 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 & Pléh 1988), syntactic and discourse factors (e.g. Clifton & Frazier 1989, Frazier & Clifton 1989, Frazier & Flores d'Arcais 1989), working memory limitations (e.g. Gibson 1998), and expectation based processing (e.g. Levy 2008). In what follows, we examine these factors in relation to their universality versus language specificity.

1.1 Universal complexity in RC processing

Universal complexity accounts basically claim that subject relative clauses should always be more difficult to comprehend than object relative clauses because subjects are inherently more salient than objects. Two prominent theories which can be characterized as universal complexity accounts are the Accessibility Hierarchy (e.g. Dowty 1991, Keenan & Hawkins 1987) and the Perspective Shift Hypothesis (e.g. Bever 1970, MacWhinney & 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 subject relative clauses should always be easier to process than object relative clauses. 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 main clause to object of relative clause) and this requires additional cognitive resources. Although the predictions of the universal complexity accounts are verified for SVO languages such as English and French, they stand falsified in head-final and ergative languages (e.g. Chinese: Hsiao & Gibson 2003 and Basque: Carreiras, Duñabeitia, Vergara, de la Cruz-Pavia & Laka 2010).

1.2 Cross-linguistic differences in RC processing

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.

1.2.1 Memory limitation theories

Theories that assume (to a greater or lesser extent) that WM limitations play an important role in the processing of relative clauses include the Active Filler Strategy (Clifton and Frazier 1989, Frazier & Flores d'Arcais 1989), the Minimal Chain Principle (De Vincenzi 1991), the Decay / Reactivation / Retrieval – Interference theory (Lewis & Vasishth
2005), the Similarity-based Interference (e.g. Gordon et al. 2001, Lewis & Vasishth 2005, McElree et al. 2003), and the Dependency Locality Theory (DLT: Gibson 1998, 2000). The most prominent most relevant theory for the present study is the DLT. The DLT accounts for the ORC processing difficulty on the grounds that ORCs in English involve a non-local structural dependency between the matrix clause NP (e.g. the reporter in (1b)) and the RC verb (e.g. attacked in (1b)). Non-local structural dependencies have been argued to add load to WM as the extracted element (the reporter) needs to be retrieved from memory as soon as the second element of the dependency (attacked) is encountered (e.g. Gibson 1998, 2000, Gordon et al. 2001, Just & Carpenter 1992, Lewis & Vasishth 2005). According to the DLT, the greater the linear distance between the two elements of the dependency, the slower the second element of the dependency (i.e. the verb) will be processed. Experimental support for the DLT comes from languages comes from languages such as English (e.g. Ford 1983, Grodner & Gibson 2005), French (e.g. Cohen & Mehler 1996), and Chinese (e.g. Hsiao & Gibson 2003). The main characteristic of these languages is that they have quite rigid word order, and poor morphological marking of grammatical roles.

1.2.2 Expectation-based theories

Expectation-based theories include word-order frequency theories (e.g. Bever 1970, MacDonald & Christiansen 2002) which assume that the surface word orders with higher frequency in a language will be easier to process than lower frequency ones, and syntactic surprisal accounts (e.g. Gennari & MacDonald 2008, Hale 2001, Levy 2008) which predict difficulty in processing for less frequent structures on the assumption the parser has more takes longer to integrate less expected input in an incremental structure. For instance, based on the fact that ORCs are less frequent than SRCs in English (Roland, Dick & Elman 2007), surprisal predicts that ORCs will be harder to process after the parser encounters the relativizer that because at this point an SRC is more expected than an ORC. Thus, contrary to memory limitation theories which expect processing difficulty on the RC verb, surprisal predicts processing difficulty on the RC NP (the senator in (1b)). In fact, a facilitation effect is expected on the RC verb on the grounds that it is more expected (than an SRC verb) after the parser has encountered two NPs (the matrix NP and the RC NP). Evidence for expectation-based theories mostly comes from languages such as Hindi (Vasishth & Lewis 2006), German (Konieczny 2000, Konieczny & Doering 2003), and Japanese (e.g. Miyamoto & Nakamura 2003, Nakatani & Gibson 2010). These languages are predominantly verb-final, have a relatively high flexibility in scrambling nominal constituents, and have rich morphological systems which allow them to explicitly mark grammatical roles of verbal arguments.
1.3 RC processing in languages with flexible word order

The main goal of the present study is to investigate the on-line processing of SRCS and ORCS in Greek, a language with rich morphology and flexible word order. Although, as we saw above, there is an abundance of research in languages with relatively rigid constituent orders, real-time processing of SRCS and ORCS in free word order languages is scarce and only very recent. To date, there are only two previous studies; one in Russian (Levy, Fedorenko & Gibson 2013) and one in Hungarian (Kovács & Vasishth 2013). These studies examined the on-line processing of SRCS and ORCS introduced by a relative pronoun, and found evidence in support of the DLT (e.g. Gibson 1998). In addition, Levy et al.'s (2013) study partly confirmed the predictions of surprisal (e.g. Levy 2008) as there was evidence for inflated reading times on the RC NP for ORCS in the syncretized relative pronoun condition. The results of these two studies thus seem to be inconclusive concerning the exact parsing mechanisms of RC processing in free word order languages.

2. The present study

The present study aims to fill this gap in the research by providing data from a free word order language, Greek. Greek largely seems similar to Russian and Hungarian in that it has a rich inflectional system and free word order. In addition, and apparently contrary to Russian and Hungarian, Greek has two types of relativizers: the relative pronoun o opios ‘who’ which is fully inflected and agrees in number, case and gender with the head NP, and the complementizer pu ‘that’. This is very important because it allows us to investigate RC which are disambiguated (in terms of being an SRC or and ORC) at different points in the structure. In this way, we can examine possible effects of early vs. late disambiguation of RC structures. The two types of relativizers along with two different manipulations of word order were thus included in the experimental SRC and ORC structures of the on-line self-paced listening task that was conducted for the present study.

3. Method

3.1 Participants

A total of 103 native speakers of Greek (82 female, age range 20-32, mean age: 21.8, SD: 3.7) 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. All participants were naïve to the experimental manipulation. They all received course credit for their participation.
3.2 Materials and design

Eight lists of 24 items were constructed following the pattern in (2). Three factors were manipulated: type of relative clause, relative clause internal word order, and type of relativizer. Relative clauses were thus either subject (SRC) or object (ORC) extracted, their internal word order was either canonical (VO in SRCs, SV in ORCs) or scrambled (OV in SRCs, VS in ORCs) with respect to the default Greek main clause word order, and their relativizer was either the complementizer ποι (ποι, ‘that’) or the relative pronoun ὁ ὁποῖος (ὁ ὁποῖος, ‘who’) which agreed in case, number and gender with the head noun phrase (NP) that it modified. The head NPs and the relative clause NPs (RC NP) were always definite, full and animate.

2) a) Subject relative clause (SRC), Canonical word order (VO), Complementizer
Ο γιατρός / που / επισκέφθηκε / τον ασθενή / έγραψε / μια νέα συνταγή.
The-NOM doctor-NOM that visit-PERF.3S the-ACC patient-ACC write-PERF.3S a new prescription

b) Subject relative clause (SRC), Scrambled word order (OV), Complementizer
Ο γιατρός / που / τον ασθενή / επισκέφθηκε / έγραψε / μια νέα συνταγή.
The-NOM doctor-NOM that the-ACC patient-ACC visit-PERF.3S write-PERF.3S a new prescription

‘The doctor that visited the patient wrote a new prescription’

c) Object relative clause (ORC), Canonical word order (SV), Complementizer
Ο γιατρός / πο / ο ασθενής / επισκέφθηκε / έγραψε / μια νέα συνταγή.
The-NOM doctor-NOM that the-NOM patient-NOM visit-PERF.3S write-PERF.3S a new prescription

d) Object relative clause (ORC), Scrambled word order (VS), Complementizer
Ο γιατρός / πο / επισκέφθηκε / ο ασθενής / έγραψε / μια νέα συνταγή.
The-NOM doctor-NOM that visit-PERF.3S the-NOM patient-NOM write-PERF.3S a new prescription

‘The doctor that the patient visited wrote a new prescription’

e) Subject relative clause (SRC), Canonical word order (VO), Relative pronoun
Ο γιατρός / ο οποίος / επισκέφθηκε / τον ασθενή / έγραψε / μια νέα συνταγή.
The-NOM doctor-NOM who-NOM visit-PERF.3S the-ACC patient-ACC write-PERF.3S a new prescription

f) Subject relative clause (SRC), Scrambled word order (OV), Relative pronoun
Ο γιατρός / ο οποίος / τον ασθενή / επισκέφθηκε / έγραψε / μια νέα συνταγή.
The-NOM doctor-NOM who-NOM the-ACC patient-ACC visit-PERF.3S write-PERF.3S a new prescription

‘The doctor who visited the patient wrote a new prescription’

g) Object relative clause (ORC), Canonical word order (SV), Relative pronoun
Ο γιατρός / τον οποίο / ο ασθενής / επισκέφθηκε / έγραψε / μια νέα συνταγή.
The NOM doctor-ACC the-NOM patient-NOM visit-PERF.3S write-PERF.3S a new prescription

h) Object relative clause (ORC), Scrambled word order (VS), Relative pronoun

Ο γιατρός / τον οποίο / επισκέφθηκε / ο ασθενής / έγραψε / μια νέα συνταγή.

The NOM doctor-ACC visit-PERF.3S the-NOM patient-NOM write-PERF.3S a new prescription

'The doctor whom the patient visited wrote a new prescription'

Each item was divided into six segments which were presented serially in the self-paced listening task (see (2)). Each segment was acoustically recorded independently so that prosodic or co-articulatory cues were absent, and then reassembled.

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 in a segment-by-segment basis.

3.3 Procedure

Sentences were presented segment by segment in a self-paced listening procedure on a personal computer running the E-Prime 2.0 software (Schneider et al., 2002a, b). Participants listened to stimuli through headphones connected to the PC. A set of instructions and a short list of 6 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 to participants. 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 minutes to complete.

4. Results

4.1 Data treatment and analysis

The on-line data were analyzed using a 2 (RC Type: SRC vs. ORC) x 2 (Relativizer Type: pronoun vs. complementizer) x 2 (Word Order: canonical vs. scrambled) by-subjects and by-items ANOVA. Two separate analyses were conducted; one for mean listening times and one for the offline grammaticality decisions for each experimental sentence.
4.2 Accuracy

Three 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 100 remaining participants who were more than 80% accurate in judging the grammaticality of the filler sentences (mean accuracy: 87.6%, SD: 5.4%).

4.3 Listening Times

We also analyzed participants’ listening times for the critical sentences. 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 relative pronoun vs. the complementizer conditions, we plot these conditions separately (Figures 1 and 2). 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 4000ms or below 100ms were discarded (2.07% of data). All listening times which 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 5.4% of the data.

A three-way analysis of variance (ANOVA) (see section 4.1) was conducted in each of the six segments. We only report here significant effects and interactions for the regions for which the three-way interaction was significant. These regions are the relativizer \( F_1(1,99) = 5.392, p = .022, \) partial \( \eta^2 = .052, \) \( F_2(1,23) = 3.342, p = .081, \) and the RC verb region \( F(1,99) = 11.528, p = .001, \) partial \( \eta^2 = .105, \) \( F(1,23) = 8.073, p = .009, \) partial \( \eta^2 = .260. \) The significant interaction in the region of the relativizer stems from significantly slower listening times for the nominative relative pronoun (in SRCs) in relation to the accusative relative pronoun (in ORCs).

There was a significant main effect of RC Type at the verb \( F(1,99) = 4.740, p = .032, \) partial \( \eta^2 = .046, \) \( F(1,23) = 5.326, p = .030, \) partial \( \eta^2 = .188 \) which resulted from slightly faster overall listening times (-32.9 ms) for SRCs over ORCs. The effect of Word Order was also significant \( F(1,99) = 49.435, p < .001, \) partial \( \eta^2 = .335, \) \( F(1,23) = 37.789, p < .001, \) partial \( \eta^2 = .622 \) as canonical word orders were generally processed faster than scrambled ones. Finally, there was a significant main effect of Relativizer Type \( F(1,99) = 3.961, p = .049, \) partial \( \eta^2 = .039, \) \( F(1,23) = 7.099, p = .014, \) partial \( \eta^2 = .236 \) which was due to the fact that complementizer structures were processed faster than relative pronoun structures.

The three-way interaction at the verb is due to the difference in word order in SRCs between the complementizer and the relative pronoun condition. More specifically, planned comparisons showed that structures with scrambled word order were processed faster than the ones with canonical word order in ORCs both in the relative pronoun \( (t(99) = 4.395, p < .001, t(23) = 4.005, p = .001) \) and in the complementizer condition \( (t(99) = 5.438, p < .001, t(23) = 4.286, p < .001). \) Canonical word order SRCs, on the
other hand, were processed significantly faster than scrambled ones in the relative pronoun condition ($t_1(99) = 5.561, p < .001$, $t_2(23) = 5.123, p < .001$) (see Fig.2), but there was no such difference in the complementizer condition. This pattern of results can be seen as a main effect of locality which is more robust in ORC than SRC structures.

In order to further investigate this distinct pattern of results, we conducted separate two-way ANOVAs with RC Type (SRC vs. ORC) and Word Order (canonical vs. scrambled) as the main variables for the complementizer and relative pronoun conditions. In the complementizer condition, significant two-way interactions were found both in the RC verb ($F_1(1,99) = 18.754, p < .001$, partial $\eta^2 = .161$, $F_2(1,23) = 12.114, p = .002$, partial $\eta^2 = .345$) and in the RCNP ($F_1(1,99) = 19.672, p < .001$, partial $\eta^2 = .166$, $F_2(1,23) = 12.953, p = .002$, partial $\eta^2 = .360$). These interactions stem from the fact that participants were faster when either the verb or the NP immediately followed the complementizer than when they did not (see Fig.1). In addition, a significant main effect of RC Type ($F_1(1,99) = 7.449, p = .008$, partial $\eta^2 = .071$, $F_2(1,23) = 7.530, p = .012$, partial $\eta^2 = .247$) was found at the verb. This effect was due to the fact that SRCs were processed faster than ORCs. There was also a robust main effect of word order ($F_1(1,99) = 14.232, p < .001$, partial $\eta^2 = .127$, $F_2(1,23) = 8.373, p = .008$, partial $\eta^2 = .267$) which was also partly found in the RCNP ($F_1(1,99) = 4.966, p = .028$, partial $\eta^2 = .048$, $F_2(1,23) = 2.146, p = .156$) and was – interestingly – due to the fact that scrambled word orders were processed faster than canonical ones (see figure 1).

Pairwise comparisons at the RCNP revealed that both nominative and accusative RCNPs were processed significantly faster preverbally than postverbally (nominative: $t_1(99) = 4.340, p < .001$, $t_2(23) = 3.160, p = .004$; accusative: $t_1(99) = 2.069, p = .041$, $t_2(23) = 1.685, p = .106$). Pairwise comparisons for the RCNPs in the two locality conditions showed that, postverbally, nominative NPs in ORCs were processed significantly slower than accusative NPs in SRCs by subjects ($t_1(99) = 2.932, p = .019$) whereas there was no significant difference between nominative and accusative NPs preverbally.

Figure 1: Mean listening times (in ms) per segment in the complementizer condition
Figure 2: Mean listening times (in ms) per segment in the relative pronoun condition

We also conducted a separate analysis of the four relative pronoun conditions; a 2x2 ANOVA crossing RC Type and Word Order revealed a significant two-way interaction between RC Type and Word Order ($F_1(1,99) = 41.050, p < .001$, partial $\eta^2 = .293$, $F_2(1,23) = 35.371, p < .001$, partial $\eta^2 = .606$) at the verb only. As in the complementizer condition, this interaction stems from the fact that verbs were processed faster when they immediately followed the relative pronoun (canonical SRCs, scrambled ORCs) than when they did not. No other effect was significant at the verb.

At the RCNP, we found a significant main effect of Word Order ($F_1(1,99) = 4.971, p = .028$, partial $\eta^2 = .048$, $F_2(1,23) = 7.420, p = .012$, partial $\eta^2 = .244$) which stems from faster listening times for the canonical word order conditions. Pairwise comparisons indicated that nominative RCNPs were processed faster preverbally than postverbally ($t_1(99) = 2.072, p = .041$, $t_2(23) = 1.797, p = .085$) while accusative RCNPs were slower preverbally (though this difference was only numerical). In addition, pairwise comparisons of the RCNPs in the two locality conditions showed that, preverbally, accusative NPs in SRCs were significantly slower than nominative NPs in ORCs ($t(99) = 2.932, p = .019$, $t(23) = 1.647, p = .113$).

5. Discussion

The present study investigated the on-line processing of SRCs and ORCs in Greek in a self-paced listening task in which RC type, word order and type of relativizer were manipulated. 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 – along with Russian and Hungarian – gives us the chance to examine these three factors simultaneously. Thus the main goal of the present study was to contribute to the RC processing literature by investigated a language from a group of languages that has
only recently started to be examined (namely, languages with rich morphology and flexible word order).

The most striking result of the present study was the statistically significant interaction between RC type (SRC vs. ORC) and word order (canonical vs. scrambled) at the RC verb. This interaction, which stems from faster listening times for canonical SRCs and scrambled ORCs, provides robust evidence for a preference for local processing. In line with the predictions of the DLT (Gibson 1998, 2000), local structures (i.e. the ones in which the verb immediately followed the relativizer) were processed significantly faster than non-local ones. This difference was primarily found at the verb of the relative clause, which — according to DLT — is the most integration-intensive region. This pattern of result is in line with the results in Russian (Levy et al. 2013) and Hungarian (Kovács & Vasishth 2013).

At the same time, although our results constitute very strong evidence for locality parsing, we still found a significant overall advantage for SRCs at the RC verb. This result, which was not found in any of two previous studies in flexible word order languages, seems to be rendering support to universal complexity accounts such as the Accessibility Hierarchy (e.g. Dowty 1991, Keenan & Hawkins 1987) and the Perspective Shift Hypothesis (e.g. Bever 1970, MacWhinney & Pléh 1988). After the separate analysis of the two types of relativizer, however, it was very evident that this SRC advantage was only significant in complementizer structures. Relative pronoun structures, similarly to Russian and Hungarian, exhibit no preference for SRCs over ORCs.

Finally, a very interesting pattern of results was found in ORCs in the complementizer condition. In this condition, in which disambiguation (whether the RC is SRC or ORC) depends on the RC NP, we found slow listening times at the RC NP and at the verb when the RC NP occurred preverbally, and at the RC NP when the RC NP occurred postverbally. This pattern of results, which is consistent with the results for the Russian case syncretized pronoun chto, indicates that participants were strongly garden-pathed upon realizing that they were listening to an ORC and not an SRC, and thus meets the predictions of expectation-based theories (e.g. Levy 2008) as in this case the constituent which causes processing difficulty is not the verb but the RCNP.

6. Conclusions

The analysis of native Greek speakers' listening times for the processing of SRCs and ORCs with varying word orders and with their introduction of either an inflected relative pronoun or a relative complementizer indicates that although there is evidence for expectation-based processing, locality is the primary parsing strategy for morphologically rich languages with free word order.

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