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A subject relative clause preference in a split-ergative language: ERP evidence from Georgian

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ABSTRACT

A fascinating descriptive property of human language processing whose explanation is still debated is that subject-gap relative clauses are easier to process than object-gap relative clauses, across a broad range of languages with different properties. However, recent work suggests that this generalization does not hold in Basque, an ergative language, and has motivated an alternative generalization in which the preference is for gaps in morphologically unmarked positions—subjects in nominative-accusative languages, and objects and intransitive subjects in ergative-absolutive languages. Here we examined whether this generalization extends to another ergative-absolutive language, Georgian. ERP and self-paced reading results show a large anterior negativity and slower reading times when a relative clause is disambiguated to an object relative vs a subject relative. These data thus suggest that in at least some ergative-absolutive languages, the classic descriptive generalization—that object relative clauses are more costly than subject relative clauses—still holds.

1. Introduction

It is a well-known observation that subject relative clauses are more common cross-linguistically than object relative clauses (Keenan and Comrie, 1977). One possible explanation put forth by Keenan and Comrie (1977) to account for this pattern is that subject relative clauses are easier to process in online comprehension. Since then, a large body of experimental work has emerged investigating the relative difficulty of processing subject and object relative clauses. Using a wide variety of psycholinguistic measures, a subject processing advantage in relative clauses has been clearly observed for English (self-paced reading time: King & Just, 1991; ERP: King & Kutas, 1995; PET: Stromswold et al., 1996, Caplan et al., 1998, 1999, Caplan et al., 2000; fMRI: Just et al., 1996, Caplan et al., 2002, Cooke et al., 2002, Constable et al., 2004, Chen et al., 2006, Caplan et al., 2008; eye-tracking: Traxler et al., 2002), as well as for other languages including Dutch (Frazier 1987), German (Mecklinger et al., 1995, Schriefers et al., 1995, Münte et al., 1997, Bader & Meng, 1999, Schwartz, 2007), French (Frauenfelder et al., 1980, Holmes & O'Regan, 1981, Cohen & Mehler, 1996), Hebrew (Friedmann & Novogrodsky, 2004, Arnon, 2005), Turkish (Kahraman et al., 2010), and Russian (Polinsky, 2011; Levy et al., 2013).

Theories of relative clause processing that have been put forth to explain these results have tended to focus either on the linear/temporal distance between the filler (in this case, the head noun) and the gap (inside the relative clause), or, alternatively, on the grammatical function of the relativized noun, whereby relativization on subjects is inherently easier to process. One obvious way to distinguish between these sets of theories is to look at languages that have prenominal relative clauses. In these languages, distance between the gap and filler will be shorter in object relative clauses, so if the subject processing advantage seen in languages with postnominal relative clauses, like English, is due to linear/temporal distance between the filler and gap, then we would expect object relative clauses to be easier. If, on the other hand, relativization on subjects is universally easier to process, then such languages should show the familiar preference for subject relative clauses.

The subject gap processing advantage has been consistently replicated in two languages with prenominal relative clauses: Japanese (self-paced reading time: Kanno & Nakamura, 2001, Miyamoto & Nakamura, 2003, Ishizuka et al., 2003; ERP: Ueno & Garnsey, 2008) and Korean

Abbreviations: LAN, Left anterior negativity; ORC, Object relative clause; SOA, stimulus onset asynchrony; SRC, Subject relative clause.

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(self-paced reading time: Kwon et al., 2006, Kwon, 2008b; eye-tracking: Kwon et al., 2010; ERP: Kwon et al., 2013), seeming to argue against a simple filler-gap distance account. For Chinese, however, mixed results have been reported: Hsiao and Gibson's initial (2003) report that Mandarin showed a preference for object relative clauses, supporting the linear distance account, has been followed up by a rich set of experimental studies, some of which replicate the object-relative clause preference (self-paced reading time: Lin & Garnsey, 2007, Chen et al., 2008, Lin, 2010, Gibson & Wu, 2013; maze-task: Qiao et al., 2012), some of which rather indicate a preference for subject relative clauses (self-paced reading time: Lin & Bever, 2006, Chen et al., 2010; Vasishth et al., 2013; Xu et al., 2019), and some of which argue that *both* SRCs and ORCs show distinct processing costs in different ERP measures (Bulut et al., 2018). For Cantonese, an object relative clause preference has been reported for child language, at least based on production (Yip & Matthews, 2007).

Although debate continues over how best to understand the variability observed across the Mandarin and Cantonese data, on the whole what seems clear from work on the processing of prenominal relative clauses is that (a) facilitated processing for subject gaps cannot be *wholly* attributed to the linear distance between the gap position and the filler (given the residual subject relative clause preference observed in the Japanese and Korean studies) and (b) other factors must also impact the ease of relative clause processing, given the differences in the processing profile for Mandarin/Cantonese (at the least, in the greater variability observed across studies). A recent set of careful picture-matching experiments in the verb-first language of Chamorro, which allows both prenominal and postnominal relative clauses, reinforces this picture (Wagers, Borja, & Chung, 2018). By examining interpretations of SRC/ORC ambiguous sentences in Chamorro, Wagers et al., found that the same participants that show a strong SRC interpretation bias for postnominal relative clauses, can flip to a slight ORC bias in prenominal relative clauses. This finding clearly demonstrates that SRC vs ORC preferences can shifted by other factors, such as linear order. However, Wagers et al., also found evidence that initiation times were faster overall for trials in which an SRC was chosen, and that in unambiguous postnominal relative clauses participants were more likely to make errors in which they interpreted an unambiguous ORC as an SRC. They argue that relative clause processing profiles are driven by *both* the desire to interpret the gap as rapidly as possible (linear distance) and a desire to link gaps to subjects (subject preference), and that these factors can interact differently depending on language-specific properties.

Yet another dimension of cross-linguistic variation has to do with the encoding of subjects. Except for Mandarin and Cantonese (which do not have overt morphological case), the languages listed above all have nominative-accusative alignment, which means that their subjects, regardless of transitivity, are in the nominative case (alternative subject encoding, for example, as with dative experiencer subjects, is possible but such subjects are not included in the standard experimental stimuli). However, a large number of languages throughout the world have ergative-absolutive alignment, where the case of subject varies depending on transitivity (intransitive subjects appear in the absolutive case, transitive in the ergative case) and the same case—absolutive—can encode a subject and object.

Whereas nominative-accusative languages do not allow one to distinguish between the effects of a subject gap advantage versus an advantage of extracting from a position with unmarked (nominative) case, ergative-absolute languages have the potential to distinguish between the two possibilities. Since ergative-absolutive languages separate case and grammatical function, these languages allow us to compare the processing of ergative and absolutive subjects. If it is the case that subjects are universally easier to process, then both ergative and absolutive subjects should be easier to process than absolutive objects; on the other hand, if case is the relevant factor, then ergative subjects should be more difficult to process than absolutive subjects and should instead behave more like objects when it comes to subextraction.

Carreiras and colleagues (Carreiras, Duñabeitia, Vergara, de la Cruz-Pavía, & Laka, 2010) investigated subject vs object relative clause preferences in Basque, which, like Japanese, Korean, and Chinese, has head-final relative clauses, but which also has an ergative-absolutive case system. In two separate experiments they measured self-paced reading reaction times and ERPs, in a disambiguation design where they looked for differential processing difficulty for disambiguation to an object relative clause vs a subject relative clause.

Because Basque is heavily inflected, Carreiras et al. (2010) relied on an accident of form overlap in order to create a temporarily ambiguous structure. In particular, the first noun of the relative clause could be a plural absolutive, where the plural marker on the noun is *–ak*, or a singular ergative, where the singular determiner is *–a-* and the ergative marker is *–k*, yielding the same ending *–ak*. This form ambiguity in the context allowed the researchers to create sentences that were ambiguous between subject- and object-relative-clause analyses until the main clause auxiliary. The disambiguating cue is the singular vs plural-marking on the auxiliary, viz., the singular *ditu* 'has' in the SRC condition and the plural-marked *dira* 'are' in the ORC, as illustrated in the example below.

(1) Subject relative clause (SRC)

[___$_1$ irakasle-ak aipatu ditu-en] ikasle-a-k$_1$
teacher-ABS.PL mentioned has-ADNOMINAL student-DET-ERG$_1$
lakun-ak ditu.
friend-ABS.PL has
"The student that mentioned the teachers has friends."

(2) Object relative clause (ORC)

[irakasle-a-k _$_1$ aipatu ditu-en] ikasle-ak$_1$
[teacher-DET-ERG mentioned has-ADNOMINAL student-ABS.PL
lakun-ak dira.
friend-ABS.PL are
"The students that the teacher mentioned are friends."

In their self-paced reading experiment, Carreiras et al. (2010) found a slowdown at the singular-marked verb that disambiguated to the SRC analysis relative to the plural-marked verb that disambiguated to the ORC analysis. In their ERP experiment, they found that ERPs to the singular-marked verb were more positive than ERPs to the plural-marked verb, over left-hemisphere sites, which they interpreted as a late positivity to SRCs of the type that is often reported for syntactic violations or garden paths. Together, they interpreted these results as evidence that ORCs are preferred to SRCs in Basque, in contrast to the typical SRC > ORC pattern observed in the previous literature. They suggested that the correct cross-linguistic generalization may not be that subject relative clauses are preferred, but that comprehenders prefer relative clauses headed by an unmarked case. As ergative is a marked case, this predicts that languages with ergative subjects will prefer object relative clauses that are headed by the unmarked absolutive case. Somewhat relatedly, subsequent ERP work by the same group in Basque argues that ergative and absolutive subjects are subject to qualitatively different agreement computations with the verb (Chow et al., 2018). A study by Gutierrez-Mangado (2011), which found better picture-matching performance for object relatives than subject relatives in 4- and 6- year olds, converges with this view.

Although these results are intriguing, further work is needed to determine whether they generalize to other constructions and

languages. Studies of relative-clause processing in Avar (Polinsky et al., 2012) and Niuean (Longenbaugh and Polinsky, 2016; 2017) did not replicate the Basque results. Notably, the results of a recent self-paced reading study of relative clause processing in Georgian by Foley and Wagers (2017) appear to conflict with Carreiras et al.'s (2010) proposed generalization. Foley and Wagers used structures in which disambiguation to subject vs object relative clauses occurred early in the relative clause. They did this either by using clause-initial relative pronouns whose case marking reflected the case of the relativized argument, or by positioning the co-argument early in the relative clause so that its case would disambiguate the structure (i.e. if the co-argument is an ergative-marked subject, the gap cannot also be a subject, indicating an ORC). In general, Foley and Wagers found faster reading times for cues that indicated subject relatives than cues that indicated object relatives, mirroring the traditional findings for nominative-accusative languages in which SRCs are preferred.

Here we aimed to extend the initial findings of Foley and Wagers (2017) with data from ERPs, which provide greater temporal sensitivity and where different scalp distributions can allow some degree of qualitative discrimination between different response types.

Before we discuss our study, some comments on the grammatical structure of Georgian are in order. Georgian is a split-ergative language—that is, subjects only appear with ergative case in certain constructions.[1] In Georgian, the split appears to relate to verbal aspect: ergative case shows up when the verb is in the aorist series, which has strong perfective connotations.[2] In Georgian, the ergative case is always overtly marked with the suffix *-m(a)* (*-m* after a vowel, *-ma* after a consonant), which makes it quite visible and distinct. The accompanying object appears in the nominative case (it is conventional for Georgian to use the term 'nominative' for the absolutive). Another important property that played a critical role in our design has to do with a relatively free word order found in Georgian. In affirmative declarative sentences, all orders are possible, although there is a tendency to avoid verb-initial orders if the verb is followed by the main arguments.[3] In order to provide a closer point of comparison with the prior Basque study, we took advantage of this relatively free word order, to create structures in which the disambiguation point between subject vs object relative clause (the case-marked co-argument) occurred closer to the end of the clause. Finally, the reader should keep in mind that in Georgian the head noun may precede a relative clause modifying it, which is the case for the stimuli tested here. Relative clauses can include a relative pronoun *romeli* 'which' that matches the case of the extracted constituent, or the invariable complementizer *rom* 'that'. We used the latter, to make the materials more ambiguous and challenging.

To illustrate the key properties of Georgian that govern our design, we provide an example item set below. In both conditions, sentences began with an adverbial clause and a leading ergative-marked noun phrase. At this point in the sentence, a reader would likely presume that a simple matrix clause lies ahead, and this analysis could still be maintained at the subsequent locative phrase ('outside the post office' in (2–3)). However, the complementizer *rom* indicates the presence of an embedded clause.[4] Through the complementizer and the verb, it is ambiguous whether the extraction is from the subject or object position of the embedded clause. This ambiguity is resolved by the case-marking on the subsequent noun inside the relative clause. If that noun is marked nominative, then the gap must correspond to an (ergative) subject of a transitive clause; if that noun is marked ergative then the gap must correspond to an (nominative) object of a transitive clause. In the examples below, the matrix clause has a transitive verb ('buy') in the aorist, so the subject is ergative and the object is nominative ('the baker bought a new house'). The ergative matrix subject is modified by a relative clause in which this argument is either in the subject, (2) or object, (3) position. The gap position is indicated by an underscore; we treat it as uniformly preverbal, although given the relatively free word order of Georgian, this is only an approximation (see more discussion under "Materials"). The critical word at which we evaluated ERP responses was the disambiguating nominative or ergative case-marked noun.

(3) Subject relative clause (SRC) condition

წინა კვირაში ხაბაზმა, ფოსტის გარეთ რომ წააქცია

ფოსტალიონი, იყიდა მშვენიერი სახლი.

cina	kvira-s	xabaz-ma	[p'ost'-is	garet	rom	__ c'aakcia
last	week-DAT	baker-ERG	post.office-GEN	outside	COMP	trip.3SG.AOR
p'ost'alion-i]	iq'ida	mšvenieri	saxl-i.			
mailman-NOM	buy.3SG.AOR	new	house-NOM			

'Last week the baker [that ___ tripped the mailman outside the post office] bought a new house.'

(4) Object relative clause (ORC) condition

წინა კვირაში ხაბაზმა, ფოსტის გარეთ რომ წააქცია

ფოსტალიონმა, იყიდა მშვენიერი სახლი.

cina	kvira-s	xabaz-ma	[p'ost'-is	garet	rom	__ c'aakcia
last	week-DAT	baker-ERG	post.office-GEN	outside	COMP	trip.3SG.AOR
p'ost'alion-ma]	iq'ida	mšvenieri	saxl-i.			
mailman-ERG	buy.3SG.AOR	new	house-NOM			

'Last week the baker [that the mailman tripped ___ outside the post office] bought a new house.'

To recapitulate, our goal was to investigate the hypothesis that the traditional SRC > ORC preference is flipped in ergative languages, as claimed for Basque by Carreiras et al. (2010). As in the prior work, we conducted both an ERP experiment and a self-paced reading experiment, in order to take advantage of the strengths of both. ERPs provides an extremely time-sensitive index of processing differences. However, because there is no straightforward correspondence between the direction of ERP voltage changes and the overall amount of neural activity, in some cases in which differences are observed it can be difficult to disambiguate which condition is inducing more processing cost, as discussed above. Based on prior ERP studies using an SRC/ORC disambiguation manipulation in Japanese (Ueno & Garnsey, 2008) and Korean (Kwon et al., 2013), we predicted that increased relative clause processing cost would be associated with an increased anterior negativity between approximately 300–500 ms after the noun with the disambiguating case-marker. Anterior negativities in sentential dependency processing have classically been attributed to working

[1] Some researchers characterize Georgian alignment as active-inactive (split-intransitive) rather than ergative. On this approach, the main distinction is between agentive and non-agentive subjects (e.g. Harris 1981). The former are always in the agentive form (the form in *-m(a)* described below), the latter are themes, and grouped together with nominative-marked objects which are also themes. Georgian does have a number of verbs which are semantically intransitive ('yawn', 'dance') but take the ergative subject in the aorist series, which is the main reason for classifying it as active. However, it remains to be seen if such verbs are genuinely intransitive or have a covert object. (They were not included in our study.) In this work, we proceed with characterizing the language as split-ergative.

[2] In Georgian the ergative case is limited to the aorist series and does not occur with perfectives in the present series.

[3] Verb-initial orders are common in yes–no questions, and of course given the extensive pro-drop of Georgian, sentences with the verb appearing alone are possible.

[4] A reviewer points out that this means that the locative phrase 'in the post office' may be initially attached at the matrix clause level, and only *optionally* reanalyzed to attach to the embedded clause. Although this is worth noting, it seems unlikely that this interacts with the current question of interest, as the attachment options are the same for the SRC and ORC cases, and more generally this reanalysis requires minimal change to the partial interpretation (either way an event involving the baker took place at the post office) and is therefore likely to be low in processing cost.

memory computations (Kluender & Kutas 1993; King & Kutas, 1995). Increased relative clause processing cost might also be associated with a late positivity (Ueno & Garnsey, 2008), although this latter effect seems more variable across studies (see Kwon et al., 2013 for discussion). Late positivities in sentence processing are often attributed to late processes such as reanalysis and retrieval interference (e.g. Tanner, Grey, & Van Hell, 2017).

Self-paced reading is a less time-sensitive measure, but as a reaction-time measure, the directionality of differences can be more straightforwardly interpreted with the assumption that larger RTs indicate greater processing difficulty. We predicted that increased relative clause processing cost would be associated with longer response times after the disambiguating noun.

2. Experiment 1 - EEG

2.1. Participants

EEG data were collected in Tbilisi, Georgia, from a total of 46 participants, for which they received monetary compensation. All the participants were right-handed native speakers of Georgian. Written informed consent was obtained from all participants. Datasets from 15 participants had to be excluded from further ERP analysis due to excessive artifact during the epoch (artifact identification procedures detailed below). This number is slightly larger than typical for EEG studies, primarily because imperfect climate control during the hot Georgian summer resulted in large sweat artifacts in a significant number of participants. Data from the remaining 31 participants (9 male, mean age 23.6y) were carried forward for subsequent analysis.

2.2. Materials

We constructed 60 item sets in which sentences were initially ambiguous as to whether the relative clause contained a subject or object gap, and where relative clause structure was disambiguated by the case-marking on the embedded noun, as illustrated above in (3)-(4). In each sentence both the subject and the object were animate (either both animals or both humans). The stimuli capitalized on the aforementioned free word order of Georgian; the most common orders are verb-final and verb-medial (Skopeteas et al., 2009), with both subject and object equally possible in the postverbal domain.

Because in this experiment the participant's task was to judge the sentences for acceptability, half of the experimental items included grammatical errors at some later point in the sentence after the critical relative clause region. These subsequent errors were always fully independent from the relative clause structure itself and were distributed equally across ORC and SRC conditions so that the clause structure did not predict the likelihood that the sentence would be judged acceptable. These errors occurred in the morphology on a verb late in the sentence, generally consisting of incorrect person/number agreement or incompatible combinations of preverbs and version(izer) vowels, i.e., vowels that correspond to applicative forms.

In addition to the experimental items, there were 120 fillers and 180 items from another experiment. The 180 items from the other experiment, as well as half of the fillers, began with either a locative adverbial or a temporal adverbial, followed by a noun, just like the relative clause stimuli. The remaining 60 fillers were sentences that began in other ways, usually with a sentence initial noun or a subordination marker.

The 60 item sets were distributed across two lists in a Latin Square design, such that each item could appear in the ORC and SRC condition, but only one of these versions would occur on any given list. The 60 RC items from each list were combined and randomized with the 300 additional items, such that each participant saw a total of 360 items in the experimental session, where half of the items were designed to be judged acceptable and half were designed to be judged unacceptable.

2.3. Procedure

During the experiment, participants were seated in a chair in a quiet room. Stimuli were visually presented on a computer monitor in white 18-point text on a black background. Each trial began with a 1000 ms fixation cross. After a 200 ms blank screen, the words of the sentence were presented with a constant 600 ms stimulus onset asynchrony (SOA), where each word appeared for 500 ms separated by a 100 ms blank screen. The final word stayed on the screen for a duration 600 ms, followed by a blank screen of 200 ms. Then the probe screen appeared, asking whether the sentence was acceptable or not. Participants responded using the 'F' and 'J' keys on the keyboard, where 'F' indicated acceptable and 'J' indicated unacceptable. The experiment was preceded by a brief practice session with filler sentences to ensure that participants understood the task and were comfortable with the presentation format. Five breaks were evenly spaced across the experiment to allow participants to rest.

2.4. Electrophysiological recording

Sixteen Ag/AgCl electrodes were held in place on the scalp by an elastic cap (BrainVision): AFz, F7, F3, Fz, F4, F8, FC5, FC6, Cz, CP5, CP6, P7, *P*3, Pz, *P*4, P8. Bipolar electrodes were placed above and below the left eye and at the outer canthus of the right and left eyes to monitor vertical and horizontal eye movements. Responses were referenced to the left mastoid. The ground electrode was positioned on the scalp between Fz and Cz. Impedances were maintained at less than 10 kΩ for all scalp and ocular electrode sites and less than 2 kΩ for the mastoid site. The EEG signal was amplified by a portable BrainVision V-Amp system and continuously sampled at 512 Hz by an analog-to-digital converter.

2.5. Analysis

As our recordings were conducted in an environment without electrical shielding, two notch filters were applied offline to the continuous data (50 Hz and 100 Hz) to minimize line noise. We also applied offline a more standard bandpass filter (Butterworth, order 2) of 0.1–20 Hz. We then extracted epochs time-locked to the onset of the critical word from −100:1000 ms. Averaged ERPs were formed from these epochs, after rejecting trials containing ocular and muscular artifact, using preprocessing routines from the EEGLAB (Delorme & Makeig, 2004) and ERPLAB (Lopez-Calderon & Luck, 2014) toolboxes. Muscle potential, sweat, and alpha wave artifacts were identified using the peak-to-peak artifact rejection routine provided by ERPLAB (specifically, the *pop_artmwppth()* function), and eye-blink and eye-movement artifacts were identified using the step function artifact rejection routine provided by ERPLAB (specifically, the *pop_artstep()* function), followed by visual confirmation of the identified artifacts by the experimenters, and exclusion of these trials from further analysis. Participants for whom more than 50 % of trials contained artifacts were excluded from further analysis. In three datasets, one electrode (different for each dataset) contained a disproportionate number of epochs containing peak-to-peak fluctuations of 100 μV or more and was therefore replaced with an interpolated value from surrounding electrodes, using the *eeg_interp()* function provided by EEGLAB with the default method of spherical interpolation. A 100-ms pre-stimulus baseline was subtracted from all waveforms, and a 40-Hz low-pass filter was applied to the ERPs offline. ERP data are made publicly available for further analyses on the first author's website (https://neurolinglab.files.wordpress.com/2022/12/georgia.zip).

We conducted Type III SS repeated-measures ANOVAs on mean ERP amplitudes in two time-windows: 300–500 ms for the LAN and 800–1000 ms for the late positivity. For the latter, we focused on the later end of the traditional time-window in which late positivities are observed (~600–1000 ms) because the complexity of Georgian morphology would be likely to increase the processing time associated

with basic morphological decomposition, and because a syntactic violation manipulation in the other sub-experiment elicited a late positivity in this later time-window (Lau, Polinsky, Clarke, & Socolof, 2022); however, we note that the use of a less standard time-window means that the conclusions that can be drawn from the late positivity results are more tentative. In order to quantify the topography of the effects, we included the factor of anteriority in all analyses (anterior electrodes: AFz, F7, F3, Fz, F4, F8, FC5, FC6; posterior electrodes: Cz, CP5, CP6, P7, P3, Pz, P4, P8).

2.6. Results

Behavioral accuracy on acceptability judgements across the relative clause conditions was 63 % and was similar for subject relative clauses (61 %) and object relative clauses (64 %). We note that these accuracies were somewhat low. We speculate that this can be attributed to the fact that our stimuli were quite complex, and the overall length and syntactic complexity may have led to lower ratings (see Alexopoulou & Keller 2007, Sprouse & Almeida 2017 on the effect of the length of dependencies on ratings).

In ERPs to the critical noun, an increased negativity over anterior electrodes was observed for the object relative clause compared to the subject relative clause (Figs. 1 and 2). This resulted in a main effect of condition ($F(1,30) = 14.7$, $p < .05$) and a significant interaction between condition and anteriority in the 300–500 ms time-window ($F(1,30) = 6.0$, $p < .05$); the difference between conditions was larger in anterior electrodes (1.6 μV) than in posterior electrodes (.3μV).

In the 800–1000 ms time-window we observed a marginal interaction between condition and anteriority ($F(1,30) = 4.05$, $p = .053$). This interaction appeared to be driven by the combination of a residual anterior negativity and a small late posterior positivity in the object relative clause condition. As the anterior negativity extended to some of the electrodes in the posterior region, while others showed a small positivity, the result overall was a mean difference between conditions over anterior electrodes (.7μV) but essentially no difference in posterior electrodes (0.01 μV).

Given potential concerns about the overall low accuracy in the behavioral judgments, we also conducted a supplementary analysis in which we excluded the 13 participants whose accuracy was lower than 60%. We analyzed the remaining 18 participants, whose mean judgment accuracy was 69%. Results were similar in this smaller sample. We observed a significant main effect of RC type in the 300–500 ms time-window ($F(1,17) = 5.95$, $p < .05$), the interaction between RC type and anteriority trended towards significance ($F(1,17) = 2.56$, $p = .12$), and the effect of RC type was again numerically larger in anterior electrodes (1.4 μV) than posterior electrodes (.6μV).

2.7. Discussion

The primary finding from the ERP experiment was that ambiguous relative clauses elicit an increased anterior negativity when disambiguated to the ORC analysis compared to the SRC analysis. As prior ERP work has associated anterior negativities with increased processing cost, these results indicate that Georgian does not fit the generalization proposed by Carreiras et al. (2010) in which SRCs should be dispreferred in an ergative language.

Although logically possible, we believe it is unlikely that these differences are due to inherent differences in processing the ergative and nominative case. A separate manipulation in the same session (reported in Lau et al., 2022), required us to vary the case of the matrix subject between ergative and nominative (*Tomorrow doctor-ERG…* or *Tomorrow doctor-NOM…*). In this manipulation, we observed no hint of differences between the two conditions at the matrix subject position.

At the same time, it remains a logical possibility that our interpretation of the ERP difference as an increased anterior negativity for the ORC could be incorrect, and that instead the ERPs reflect an increased anterior *positivity* for a more costly SRC analysis. This possibility is particularly pertinent because Carreiras et al. (2010) observed a left-lateralized difference spanning anterior and posterior electrodes in which SRCs were more positive than ORCs and interpreted this as a P600 associated with processing cost in SRCs.[5] We believe that such an interpretation is less possible in the current case, because the strongly frontal distribution of the effect is so different from the posteriorly distributed P600 standardly observed for syntactic manipulations in the ERP literature. It is also worth noting that we did observe a trend towards a more standardly distributed P600 effect for ORCs in the later time-window (800–1000 ms), although this trend must be interpreted cautiously as the interaction in this time-window was only marginally significant and was driven by residual anterior negativity as well.

However, in Experiment 2, we directly evaluated the alternative 'anterior positivity' interpretation of the ERP results by investigating reaction time measures to the same SRC and ORC materials, in which increased processing cost can be more unambiguously related to increased RTs. Converging results from a second experiment also address the potential concern that the relatively low performance on acceptability judgments in the ERP experiment impacted the contrast of interest in some way.

3. Experiment 2 – Self-paced reading

3.1. Participants

Self-paced reading data was collected online from a total of 33 participants (mean age = 22.1 years), for which they received monetary compensation. All the participants were monolingual native speakers of Georgian. Written informed consent was obtained from all participants. The majority of participants were current or former undergraduate students living in Tbilisi.

3.2. Materials

Materials were a subset of 30 of the relative clause items used in the EEG experiment, along with 136 fillers and 20 items from another experiment. The other sentences were mostly simple clauses (i.e. did not include relative clauses), though they began similarly to the relative clause items, with an adverbial phrase followed by the subject noun. As in the EEG experiment, experimental items were distributed across lists in a Latin Square design such that each participant saw 15 items from each of the two conditions and no participant saw more than one version of each item.

3.3. Procedure

Items were presented word-by-word in a self-paced moving window paradigm (Just, Carpenter & Woolley, 1982) using the IBEX software (Drummond, 2017). Each trial began with a screen in which a row of dashes masked the words in the sentence. Participants revealed the first word and each subsequent word by pressing the space bar. When a new

[5] We note that Carreiras et al. (2010) tested a time-window (450-700ms) that falls in between the standard LAN and late positivity time-windows. When we conducted a supplementary analysis in the same intermediate time-window, we observed a significant main effect of condition in the same direction as in our LAN time-window (more negative for ORCs), but with a slightly less anterior distribution. Therefore, our data are not inconsistent with those of Carreiras et al., What varies is rather the interpretation of the data; where Carreiras et al. (2010) interpret the effects in this intermediate time-window as SRCs eliciting a P600 with an unusually early onset and anterior distribution, we interpret these effects as the continuation of the anterior negativity elicited by the ORC (see also Longenbaugh & Polinsky, 2017, for a similar interpretation of the Basque data).

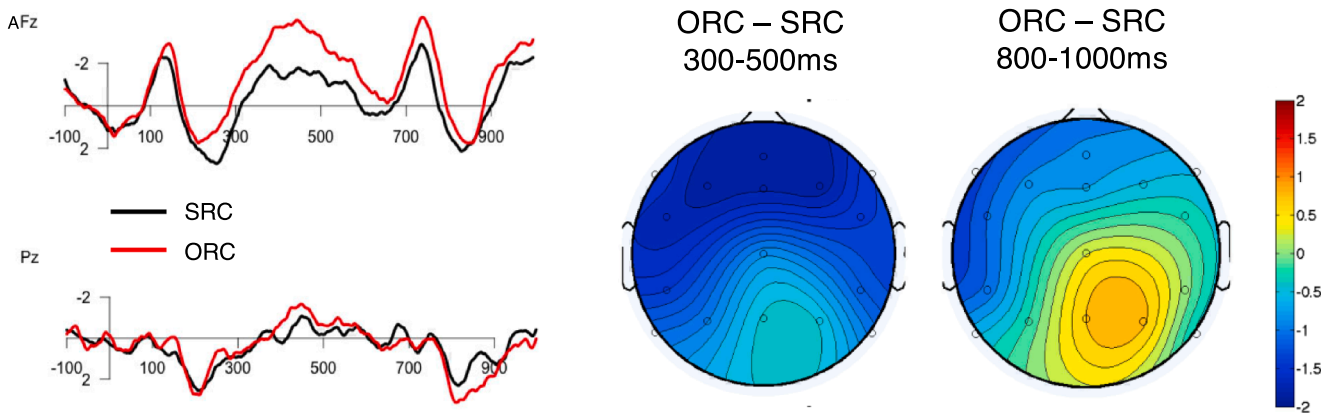

Fig. 1. ERP responses at the point of disambiguation to object relative clause vs subject relative clause analysis at representative frontal and posterior electrode sites. Scalp maps illustrate the distribution of the difference between the two conditions (ORC – SRC) in the LAN time-window and the late positivity time-window.

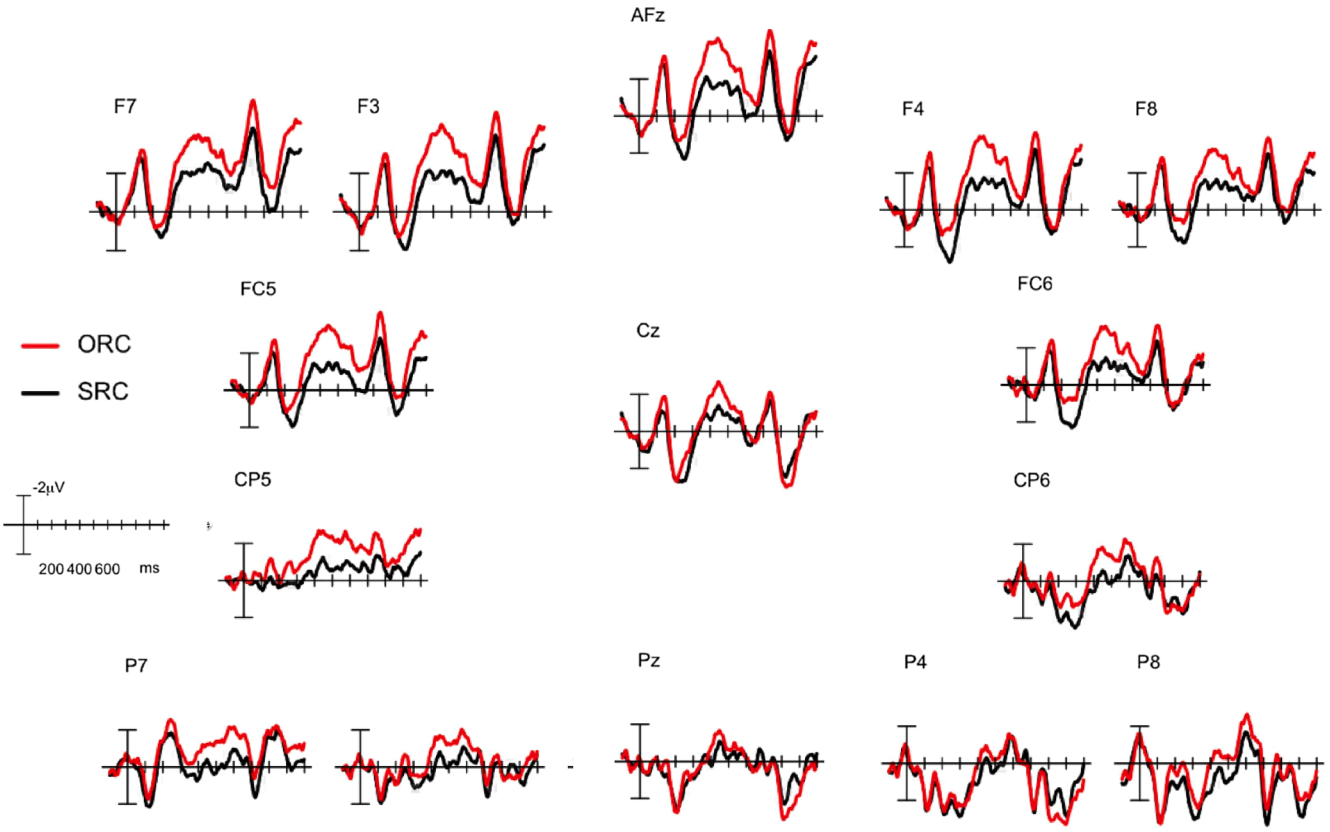

Fig. 2. ERP responses at the point of disambiguation to object relative clause vs subject relative clause analysis at all scalp electrode sites.

word was revealed, the previous word was re-masked, so that only one word was ever visible at a time. Participants were instructed to read as naturally as possible at their normal reading speed and to make sure that they understood the sentences they were reading. 25 % of items were followed by a two-choice comprehension question to encourage participants to attend to the stimuli.

3.4. Analysis

Reaction times exceeding a threshold of 2.5 s were excluded as outliers from further analysis; this impacted 2.1 % of all reading times. The regions of analysis were the disambiguating case-marked noun and the subsequent verb (the spillover region). As we had only two conditions, we conducted pairwise comparisons between SRC and ORC conditions in those two regions. We report results both by-subjects and by-items. Following a reviewer suggestion, we also evaluated the results in a single mixed effects model including both by-subject and by-item random intercepts using the lmerTest package in R (Bates et al., 2015).

3.5. Results

Mean accuracy on comprehension questions was 97.5 % (s.d. 3.8 %). Reading times for the disambiguating noun and the three words before and after are presented in Fig. 3. At the disambiguating noun, we observed significantly slower reading times for the ORC condition relative to the SRC condition (by subjects: $t(32) = 3.07$, $p < .05$; by items: $t(29) = 2.31$, $p < .05$; mean difference = 85 ms). This was also the case in the following spillover region (by subjects: $t(32) = 2.78$, $p < .05$; by

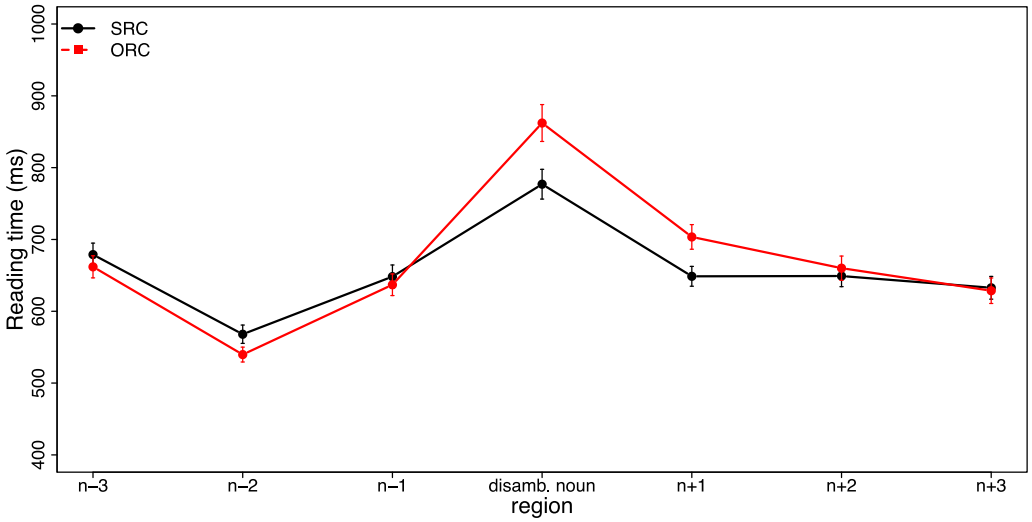

Fig. 3. Self-paced reading reaction times at the disambiguating noun and three positions preceding and following. Error bars indicate standard error of the mean.

items: t(29) = 2.82, p <.05; mean difference = 55 ms). The mixed effects analyses also showed a significant effect of condition in the disambiguating region (t = 3.8, p <.05) and in the spillover region (t = 2.8, p <.05).

3.6. Discussion

The goal of Experiment 2 was to provide converging reaction time evidence on Georgian speakers' preference for disambiguation to subject vs object relative clauses. The results of the self-paced reading experiment showed a clear reaction time cost for disambiguation to ORCs. This supports our interpretation of the ERP results of Experiment 1 in which the cost of ORC disambiguation was reflected by an increased anterior negativity (AN). Experiment 2 also provides further support for the ORC cost observed in Experiment 1 by replicating that cost under circumstances in which all participants performed very accurately on the behavioral judgment task.

4. General discussion

The current study evaluated processing cost differences for subject vs object relative clauses in Georgian, in the context of recent proposals that ergative-absolutive languages do not show the ORC processing cost observed in most other languages (Carreiras et al., 2010; Chow et al., 2018). In two experiments using ERPs and self-paced reading respectively, we presented native speakers of Georgian with sentences which were initially ambiguous between subject and object relative clause analyses and looked for signs of differential processing cost at the point of disambiguation. Both experiments indicated that Georgian speakers preferred disambiguation to the subject relative as opposed to object relatives. In particular, we observed an increased anterior negativity for disambiguation to the ORC structure in ERPs, and increased reaction times for disambiguation to the ORC structure in self-paced reading. Together, these results suggest that the generalization about SRC vs ORC preference in ergative-absolutive languages cannot be stated as simply as an overall preference for ORCs due to the morphologically unmarked form of their objects.

As reviewed in the introduction, some theories propose that object relative clauses bear an extra processing cost that holds across languages; for example, that the extra cost for ORCs lies in the complexity of the message or scenario that they convey, relative to SRCs (e.g. Keenan & Comrie, 1977; MacWhinney, 1977). These classic theories naturally account for the current results, as they demonstrate that yet another language, with its own idiosyncratic morphosyntactic properties, fits the predominant ORC-more-costly-than-SRC pattern observed for most other languages.

As discussed in the introduction, one case that does not seem to fit this classic pattern is that of another ergative-absolutive language Basque, where self-paced reading shows longer reading times for SRCs than for ORCs (Carreiras et al., 2010).[6] The current data suggest that the preference pattern in Basque may not reflect a simple cut between nominative-accusative and ergative-absolutive languages, as Georgian patterned with the preferences typically reported for nominative-accusative languages. However, there are several possible explanations for the dissociation.

One possibility is that there really is an ORC cost in Basque, but that this cost was masked by additional factors in the prior study. For example, the temporary ORC/SRC ambiguity was introduced by using a morphological ambiguity between the ergative singular ending and the absolutive plural ending, such that baseline differences in frequency between these *morphemes* could have driven parsing commitments that would have downstream consequences before comprehenders were aware that they were in a relative clause. The critical disambiguation region was also a main clause verb whose transitivity differed across the two conditions, potentially introducing variability that would be independent of relative clause processing itself (see Longenbaugh & Polinsky, 2017, for further discussion).

However, another possibility is that Basque relative clause processing cost really is governed by a different factor like morphological markedness, and that languages simply differ in the factors that govern their relative clause processing. The case of Chinese, reviewed in the Introduction, is worth noting here: although the facts about SRC/ORC preferences in Chinese are hotly debated, it is at least clear that the experimental data on those preferences for Chinese is much more mixed than is the case in English. This may similarly reflect language-specific processing factors at work. One potentially relevant difference between Basque and Georgian is that Basque is an ergative language, while Georgian is a split-ergative language, with ergativity found only with certain tense-aspect forms of the predicate. A reviewer suggests that perhaps the ORC preference emerges only in languages like Basque in

[6] It is less clear whether the Basque ERP results conflict with the current ERP results. Carreiras et al., also observed a difference over anterior electrodes in the same direction for ORCs than SRCs as the current data, but their effect was more left lateralized, and they interpreted it as an increased positivity for SRCs. Although this might also seem consistent with the interpretation of a SAN for ORCs, the self-paced reading times went in the opposite direction and so we remain agnostic about this here.

which the ergative alignment is more pervasive throughout the grammar. We think this is an interesting hypothesis for future investigation. More generally, the work reviewed in the introduction by Wagers et al. (2018) on Chamorro suggests that even if a preference for interpreting gaps as subject gaps were always present, it might well be overwhelmed by other parsing preferences (such as the desire to minimize filler-gap distance, or preferences about morphological markedness) in particular languages.

The Georgian data alone obviously cannot speak directly to the generality of ORC processing cost across languages. We think progress on this question will require more specific mechanistic proposals about exactly what level of representation the subject gap preference is stated at and exactly how it translates into extra computing time in those languages that do demonstrate the classic ORC cost.

4.1. Potential caveats

One question is the extent to which the differences in ORC/SRC processing cost observed here are proximally driven by differences in the simple frequency of the constructions. If this were the case, another possible explanation for the differences between Basque and Georgian might lie in differences in construction frequency within the language. As a first step towards exploring this possibility, we conducted some basic corpus counts of intransitive subject RCs, transitive subject RCs, and object RCs in Georgian. In the Corpus of New and Modern Georgian (https://corpora.iliauni.edu.ge), we examined 785 relative clauses with *rom*.[7] Out of those, 32 percent were relative clauses with the intransitive subject gap, 26 percent had transitive subject gap, and 28 percent had the object gap (the remaining 14 % were other gaps). These results are comparable to the relative frequencies of relative clauses in other ergative languages, where the most common relative clause structures are intransitive subject RCs, while transitive subject and object RCs are fairly comparable in frequency (Carreiras et al., 2010; Polinsky et al., 2012; Longenbaugh & Polinsky, 2017). They are also comparable to the distribution of relative-clause types in English (Gordon & Hendrick, 2005). Crucially, the frequency of transitive-subject relative clauses and that of object relative clauses were comparable, such that the conditional likelihood of a SRC vs an ORC given a noun and a transitive verb would appear to be relatively well-matched in Georgian. However, although we don't see evidence in these counts of an asymmetry in SRC/ORC likelihood, it is always possible that some other contextual features that we haven't yet counted provide additional biasing information; for example, given the free word order of Georgian, it might be that particular word orders also impact the likelihood of SRCs vs ORCs (e.g., Levy et al., 2013). Another possibility is that frequencies may be different when limited to clauses with animate arguments, as in the current materials (and in most ERP experiments on relative clauses, because of the use of reversible predicates). While we cannot evaluate these possibilities adequately in our current corpus given its limited size, we think this is an important and valuable direction to be pursued in future work.

Another potential caveat is the relatively low behavioral accuracy observed in the acceptability ratings task in Experiment 1. Although it is not clear that this points to an alternative explanation for the robust anterior negativity observed in the ERPs to the ORCs vs SRCs, and the same ORC cost was shown in Experiment 2 with high behavioral accuracy performance, future ERP replications would be more compelling if the behavioral accuracy were higher. We suggest that this could be achieved by conducting behavioral pre-tests and debriefing on experimental materials with participants from the same population to determine what systematic factors govern 'incorrect' responses, such that they can be modulated accordingly for the ERP sessions.

[7] This corpus is the largest currently available for Georgian and it is more annotated than some other corpora, for example, the Georgian National Corpus (available at https://gnc.gov.ge/gnc/page), which is still under development and is smaller than the corpus we used.

5. Conclusion

Here we have reported some of the first ERP work on online comprehension of Georgian. Our results make an important contribution to ongoing debates about language processing differences across languages, suggesting that in contrast to a recent proposal, the classic preference for subject relative clauses over object relative clauses is mirrored in at least some ergative-absolutive languages. More broadly, we note that with continued improvements in the portability and usability of the EEG technology, it is now much more feasible for psycholinguists to bring their equipment to new populations of speakers and languages who can most effectively resolve core questions about language processing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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