Processing of Relative Clauses in Malayalam

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ABSTRACT

A study of the processing of relative clauses may offer insight into how a range of processes involving structural manipulation by way of movement might be realized in the mind. In this paper, I elucidate a self-paced reading experiment that investigates the processing of relative clauses in Malayalam. I use singly embedded relative clauses and counterbalance each item by varying the position of the RC in the sentence, and the gapping (subject or object) from the clause. I observe a slight preference for object relative clauses, and explain my results using an expectation based model.

1 Introduction

Models of processing account differently the manner of processing of relative clauses across languages. However, the general trend is that cross-linguistically subject extracted relative clauses are processed faster – due to the distance of extraction being lesser. Memory-based models and expectation-based models have different predictions for languages depending on how the head noun is placed in RCs. The two types of organization are noun-first and noun-last, depending on the position of the clausal modifier. English is a noun-first type of language:

(1) The man [whom I saw — in London] ...

On the other hand, languages such as Japanese and Chinese are noun-last:

(2) Japanese

[watashi-wa rondon-ni — mita] otoko ...
[I-TOP London-LOC — see.PST] man

'The man whom I saw in London...'

Memory-based models account for the ease of processing of subject extracted relative clauses in languages such as English, whereas their predictions with regards to noun-final languages such as Japanese go against the observations. Expectation-based models do account for a weak advantage for subject relative clauses in noun-final languages (O'Grady 2011, Levy 2008).

Malayalam is a Dravidian language that is spoken in the state of Kerala in India. With over 35 million native speakers, it is one among the 22 scheduled languages in the Indian constitution. It is a default head-final, agglutinative SOV language. It also allows for scrambling. It has a vocabulary heavily dependent on Sanskrit. The language lacks overt subject-verb agreement, a feature unique among the major Dravidian languages.

Malayalam relative clauses are of the noun-final type. It uses a modifier-like construction, known as a participial construction, in their formation, where a canonical relativizer is absent. Instead, they are formed by the suffixation of the participial morpheme *-a* to the verb which is inflected for time reference. This same participial morpheme is found in modifier structures such as adjectives in the language.

(3) Malayalam

a. e_i raavaNan-e konna raaman$_i$
EC raavaNan.ACC kill.PFV raaman.NOM
'Raaman who killed Raavanan'

b. raaman e_i konna raavaNan$_i$
raaman EC kill.PFV raavaNan.NOM
'Raavanan who Raman killed'

In the above examples, 3a is called the *subject (extracted)* RC, as the head noun is coindexed with the subject position empty category of the relative clause, and 3b is the *object (extracted)* RC, as the head noun coindexes with the empty category in the object position of the RC.

Mathew (2005) shows that participial morphemes in Malayalam precede the head noun, and leave a gap in the relative clause participial construction. Hima (2017) treats the participial as a determiner-like entity (cf. the Semitic relative clause analysis in Ouhalla 2004). Ishizuka (2005) proposes that in Japanese – where there is no relative pronoun, the RC structure does not involve movement but rather has a null pronoun in the position of where the gap should be, coindexed with the head noun. This follows the analysis in Pesetsky (2004), where the valuation of the interpretable unvalued feature of the participial is provided by the head noun. Ishizuka's account also provides a way to account for the processing of relative clauses in Japanese.

2 Accounts of Processing

I look at the processing of relative clauses using two processing models—one, a memory-based model, and the other, an expectation- or frequency-based model of processing.

2.1 Dependency Locality Theory

The Dependency Locality Theory (Gibson & Hickok 1993, Gibson 2000, and Gibson & Warren 2004), or DLT henceforth, which successfully explains the processing of pronominals in SVO languages, is a memory- or integration-based account of sentence processing. Comprehension is facilitated by the construction of a distance-based metric. The informational sources are integrated at each moment, and the interpretation is constrained by the available computational resources. DLT is explained using human computational resources that depend on the distance between the two elements that need to be integrated.

The computational resources required include the integration cost and the memory cost. The head and the constituents are connected, and the measure of the new discourse elements that intervene between them, is given by the energy units (EU) as the integration cost. The memory cost to keep the incomplete segments in memory, enabling the parser to keep track of the incomplete dependencies, is known as the memory units (MU). The sum of EU and MU is the total processing cost. Gibson's assumption (Gibson & Hickok 1993) is that the parser adopts an active filler strategy where the filler is assigned as soon as possible – at any plausible gap position.

In DLT, the number of discourse elements that need to be parsed is proportional to the integration cost. It also obeys the minimal attachment hypothesis – the incoming material is attached using the fewest nodes possible, as long as the parse is consistent with the wellformedness rules of the language.

According to DLT, the more the distance between the gap (marked as e, for empty category) and the filler, the integration costs are higher, and hence the processing time would be higher. The active filler strategy and minimal attachment hypothesis together imply that in a head-final language such as Malayalam, a filler-gap structure such as a relative clause would have an object advantage. That is, an object extracted RC would be processed faster compared to a subject extracted RC.

2.2 Surprisal Theory

Surprisal (Hale 2001, Levy 2008) quantifies the amount of new information conveyed by a word in context. The surprisal at word w_i is formalized as the negative log probability of observing word w_i given that words $w_1 ... w_{i-1}$ have already been processed. Processing difficulty is proportional to the amount of new information that needs to be processed, and it is not locality based, but rather is a parallel processing theory. Surprisal does not ascribe to any one grammar formalism that is used as a processing mechanism and instead uses frequency and expectation—it is a psycholinguistic analogue to mathematics and statistics.

It predicts a reversal of the locality-based difficulty patterns in syntactically constrained contexts. The integration of knowledge is incremental in resolving syntactic ambiguity. Expectation-based models account for a weak advantage in processing of subject relative clauses in noun-final languages.

3 Literature Survey

There is a plethora of existing work done on the processing of relative clauses in Germanic languages including English, and Romance languages. More recent work in processing has been done in Chinese, Japanese and Korean as well.

3.1 Noun-initial languages

A corpora-based experiment (Reali & Christiansen 2007) showed that *pronominal* object relative clauses took less time to be processed than *pronominal* subject relative clauses.

This was due to a difference in their frequency in speech. They also conducted a self-paced reading experiment to disconfirm a structure-based account that predicts a universal preference for subject relative clauses. Integration accounts cannot explain this preference since pronouns (overt or null) are not treated as new discourse elements – this is also the case with filler-gap pairs. Filler-gap pairs do not contribute to a processing difficulty as they are not new discourse elements. The experiment showed that pronominal object relative clauses are processed faster. This can be explained with theories such as similarity-based interference (Bever 1975, Gordon et al. 2001). Due to the dissimilarity of the head noun phrase with the personal pronouns, the interference in gap-filling is lesser. This accounts for a decreased interference during processing, as opposed to non-pronominal DPs. In addition, the preference of object position pronominal relative clauses can satisfactorily be explained with a frequency-based account.

In an ERP study in German by Mecklinger et al. (1995), the relative clauses were varied on syntactic and semantic dimensions, to examine the asymmetry in response to object and subject extracted relative clauses. There was a bias against the object, which was explained with the active-filler strategy—when gaps were encountered in the sentences, the main clause NP was assigned to the gap. Rohde & Horton (2014) observed that in English, implicit-causal constructions had a higher preference for relative clauses that attached to the lower argument. In Russian, Levy et al. (2013) proposed to integrate both the memory-based and expectation-based accounts to explain the differences in online sentence processing due to different sentential ordering, which is possible in Russian due to case marking.

3.2 Noun-final languages

Similar experiments have been conducted in noun-final Chinese, which has a processing advantage on subject relative clauses, whose analysis lean towards an expectation-based account of processing of relative clauses. Earlier studies accounted only for subject extracted subject relatives and object-extracted object relatives, wherein the object relative clauses were seen to be processed faster (Jäger 2015). Xu et al. (2019) reported online self-paced reading tasks in Chinese which show a marked preference for ORCs over SRCs, explained with the DLT model. They bring to question the claim that SRCs are processed faster cross-linguistically (assumed by the structural distance hypothesis), and highlight a need for crosslinguistic research. Wu et al. (2012) observed a facilitation with animate subjects and inanimate objects as heads, but a switch in animacy makes SRCs faster to process. Hsiao & Gibson (2003) found that for canonically ordered relative clauses, a memory-based account predicts that subject relative clauses would be processed slower, but they did observe the same for doubly-embedded relative clauses as well. Gibson & Wu (2013) observed statistically significant differences in the reduced processing speed of subject relative clauses, in Chinese relative clauses with a disambiguating context. Jäger et al. (2015) noted that a surprisal-based account for a sentence completion task does account for the faster processing of subject relative clauses over object relative clauses in

Chinese. In addition, Carreiras et al. (2010) also found an object RC advantage in Basque, and explained it using DLT.

Kwon et al. (2006) show that there is a processing advantage for subject gaps over object gaps in relative clauses and adjunct clauses in Korean, extending the cross-linguistic advantage in subject processing, and casts doubts on the notion of syntactically determined structural distance; as well as on the nature of the gap in relative clauses (trace vs. null pronominal bounded by a null operator) – with existing data not resolving the dichotomy.

Prideaux (1982) studied the processing of Japanese relative clauses and used both the closure strategy, wherein the parser prefers to close the node, once the end of a particular unit is encountered; and the normal form strategy, where the form that is presented to the parser is assumed to be the canonical form of the material to be parsed. This account using the closure strategy showed that object position RCs are processed faster, in opposition to the standard assumptions that lean towards a faster processing of subject RCs, due to the extracted element closing the matrix clause. The normal form account however shows the difference in processing speed exists due to the word order, and object extracted relative clauses were hence easier to parse in Japanese. However, the theories were in contrast with later observations that showed trends similar to English.

MacDonald & Montag (2009) conducted elicitation tasks in English and Japanese with native speakers. They showed that in the presence of an inanimate noun, the relative clause structures in English were more often passivized than in Japanese. Animate nouns were equally passivized in both languages. They posited that passivization for inanimate nouns occur more in English due to a higher frequency of passive formation in the language. In addition, they report that it could be due to the differential amounts of priming by the experimental task itself.

Ishizuka (2005) work on the processing of relative clauses in Japanese speaks of the different processing models and how some account for Japanese relative clauses, whereas others do not. Firstly, the relative clause in Japanese is accounted for with a null pronoun in the position of the gap noun.

(4) Japanese

a. e_i uma-o ketta $roba_i$-ga shinda
EC horse-ACC kick.PST mule-NOM die.PST
'The mule that kicked the horse died (Subject RC)'

b. uma-ga e_i ketta $roba_i$-ga shinda
horse-NOM EC kick.PST mule-NOM die.PST
'The mule that the horse kicked died (Object RC)'

Following a DLT account, subject RCs should be harder to process. The integration cost is higher for subject extracted RCs as there were more intervening elements. However, the results were in contrast, and were explained by the depth of embedding model (O'Grady (1997)), where the number of nodes measure the distance traversed. The Object RC pronominal is more deeply embedded as compared to the subject RC pronominal,

making it harder to access. This explained the experimental results. In addition, a temporary reading of an object RC as the main clause and backtracking to reanalyze it as an RC causes an increase in reading time. The study also noted that case matching conditions were processed significantly faster than case clashing conditions of extraction and position of RCs. Mansbridge & Tamaoka (2019), redid the experiment, but with an eye-tracking task, to obtain similar results.

4 Experiment

Since the universality of subject advantage in RC processing has been contested, working it out from a crosslinguistic perspective is essential. Malayalam sets a good stage for this experimentation. According to DLT, when object position object RCs are considered in Malayalam, encountering a second noun (in a sentence like 5b below) would increase the processing time at that point due to the unexpectedness of a second nominal in the nominative case. In the case of a subject position ORC (5a below), the position of the relative verb still leaves information to be desired about the object of the RC, increasing processing time.

In the case of subject RCs, overall surprisal could be equal but individual levels after each word is encountered may be lesser. This may be explained by how subjects often are the topics of sentences, and one expects more information regarding the subject, thus decreasing the amount of new information, by virtue of expecting new information. However, I also want to look into whether a memory-based parsing model is able to explain this difference as well.

4.1 Hypothesis and Prediction

Hypothesis: Object relative clauses in Malayalam are processed faster than subject relative clauses, and an expectation-based model would align with, and thereby explain, the observed results. However, subject RCs, due to their universal trends of being processed faster, will also be looked into from an integration-based perspective.

Prediction: The reading time measure for object extracted relative clauses would be lower as compared to that of subject extracted relative clauses. Overall comprehension of the sentence will be ORC biased, with markedness of structure playing a pivotal role in determining surprisal. This means, in a default-SOV language such as Malayalam, an order OS or VO order would be marked, hence increase the level of surprisal. This however can also clarify what can occur in the next region. For example, with an Object extracted ORC, surprisal is initially high as two nominals follow one another, but this resolves the structure as an RC, hence the RT would show a decreasing trend after this juncture.

Figure 1: Sentence without the words is shown first

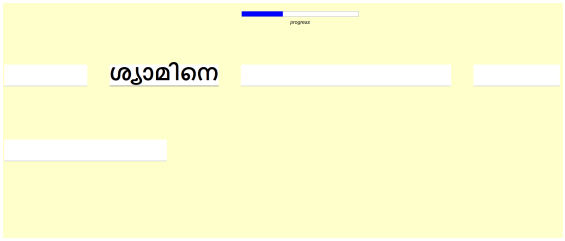

Figure 2: On pressing the SPACE BAR, the first word appears (not shown), and on pressing it again, it vanishes and the second word appears

4.2 Methodology

The task was a self-paced reading, moving window task. The stimuli were presented to the participants on PCIbex. Word(s) or phrases were shown on the screen on pressing the SPACE BAR. On a press, the reading time (the time taken from display of word to pressing the SPACE BAR, in milliseconds) would be recorded, and the word would disappear to show the next word in the sentence. Blank white rectangles indicating the whole sentence was provided for the participants at the start of each item. On the pressing SPACE BAR, the participant could move forward through the sentence regions. The masking was a modified dashed-sentence paradigm (Kush & Dillon 2021). The target sentences were presented in the Malayalam script.

Each experiment started with four unrelated practice trials for the participants to familiarize themselves with the procedure. Each item was followed by a comprehension question that asked for the correct answer, with two options given as full sentences. The participants could select the correct option by pressing the F- or the J- keys on their devices. The participants were given the choice of taking a short break every 16 items.

4.3 Task

16 sentences were shown to the participants, with 20 fillers and 40 sentences of other tasks (also acting as fillers), all counterbalanced. All experimental items were canonical SOV ordered sentences, with transitive verbs both in the RC and the matrix clause. The transitive verbs selected for a nominative and an accusative noun each, with the thematic roles nearly canonical Agent-Patient, for uniformity, and *the nouns used were all proper names*. All the sentences are hence appositive relative clauses. This was done because Malayalam does not allow for inanimate nouns to be morphologically accusative.

Two factors were controlled for the experiment viz:

1. Position of the RC in the sentences (subject vs. object) - to account for different configurations of RC occurrences.

2. Position of the gap of the noun from the RC (subject gap or subject extracted RC vs. object extracted RC)

A sample of the items with the forward slash indicating the breakdown of the regions of presentation is given below:

(5) a. RC in the Subject Position with an Object gap (SPOE)
darshana/ kaLi-ppi-cca/ Vanaja/ Ashaye protsaahippi-ccu
NPROP play-CAUS-PFV.PRT NPROP NPROP-ACC encourage-PFV
'Vanaja who Darshana played with encouraged Asha.'

b. RC in the Object Position with an Object gap (OPOE)
darshana/ Vanaja/ kaLi-ppi-cca/ Ashaye protsaahippi-ccu.
NPROP NPROP play-CAUS-PFV.PRT NPROP-ACC encourage-PFV
'Darshana encouraged Asha who Vanaja played with.'

c. RC in the Object Position with a Subject gap (OPSE)
darshana/ Vanaja-ye/ kaLi-ppi-cca/ Ashaye
NPROP NPROP-ACC play-CAUS-PFV.PRT NPROP-ACC
protsaahippi-ccu.
encourage-PFV
'Darshana encouraged Asha who played with Vanaja.'

d. RC in the Subject Position with a Subject gap (SPSE)
darshana-ye/ kaLi-ppi-cca/ Vanaja/ Ashaye
NPROP-ACC play-CAUS-PFV.PRT NPROP NPROP-ACC
protsaahippi-ccu.
encourage-PFV
'Vanaja who played with Darshana encouraged Asha.'

Counterbalancing was done as seen above. Only one type of each item was presented to each participant. The items were broken down into separate regions as can be seen in the example above, after each word, and the space bar had to be pressed to continue to the next region.

Comprehension questions for all the above sentences was to choose the more correct option (randomized in presentation) from below:

a. darshana aasha-ye protsaahippi-ccu
Darshana aasha-ACC encourage-PFV
'Darshana encouraged Asha.'

b. vanaja aasha-ye protsaahippi-ccu
Vanaja aasha-ACC encourage-PFV
'Vanaja encouraged Asha.'

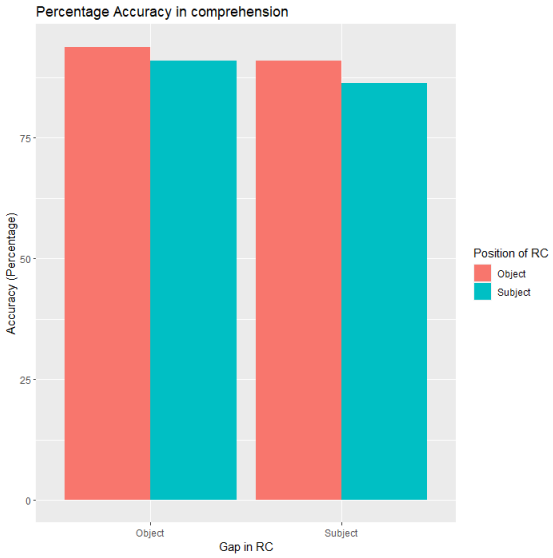

Figure 3: Graph with the mean accuracy in the Comprehension Task for each type of sentence

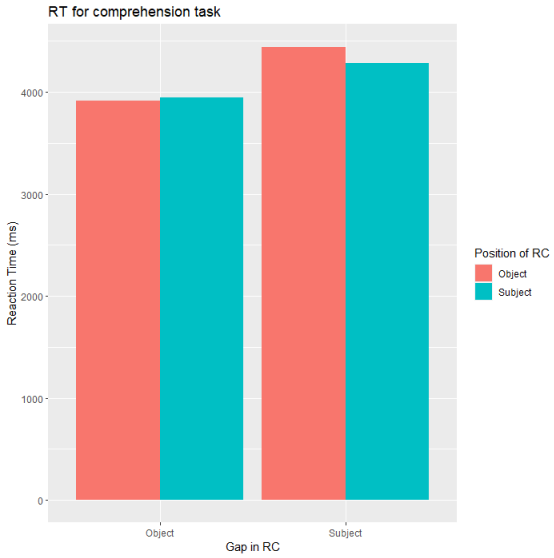

Figure 4: Graph showing the mean RT in the Comprehension Task for each type of RC sentence

One of the experimental design elements chosen was to present the accusative noun of the main clause with its corresponding verb. This design choice, in retrospect, shall be modified in future work.

4.4 Participants

Participants (n=53, male =18, $\geq$ 75% responses between 200-2500ms, and $\geq$ 67% accuracy for all items including fillers) read 4 sentences of each crossed factors (subject and object position vs. subject and object extraction), and the conditions were counterbalanced across the participants.

The participants fell within an age range of 18-53 years with mean age: 27.3 $\pm$ 8.5 years were recruited online. They were provided with a compensation of 25INR for their participation.

5 Results and Discussion

The data obtained was sorted first. The accuracy percentages were calculated, and the average RT for both the comprehension task, as well as of each region, was plotted against the corresponding region. Following this, I also performed a statistical analysis on R (2 factor repeated measures ANOVA), to account for statistically significant data.

These graphs (Figures 3 and 4) point to a higher accuracy in the comprehension tasks where the gap is in the object position, despite the time to complete the comprehension task being lower for these items. In addition, the lowest accuracy is obtained for subject RC,

with a gap in the subject position. This observation indicates a possibility that object RCs are easier to process due to the noun-final structure of Malayalam RCs.

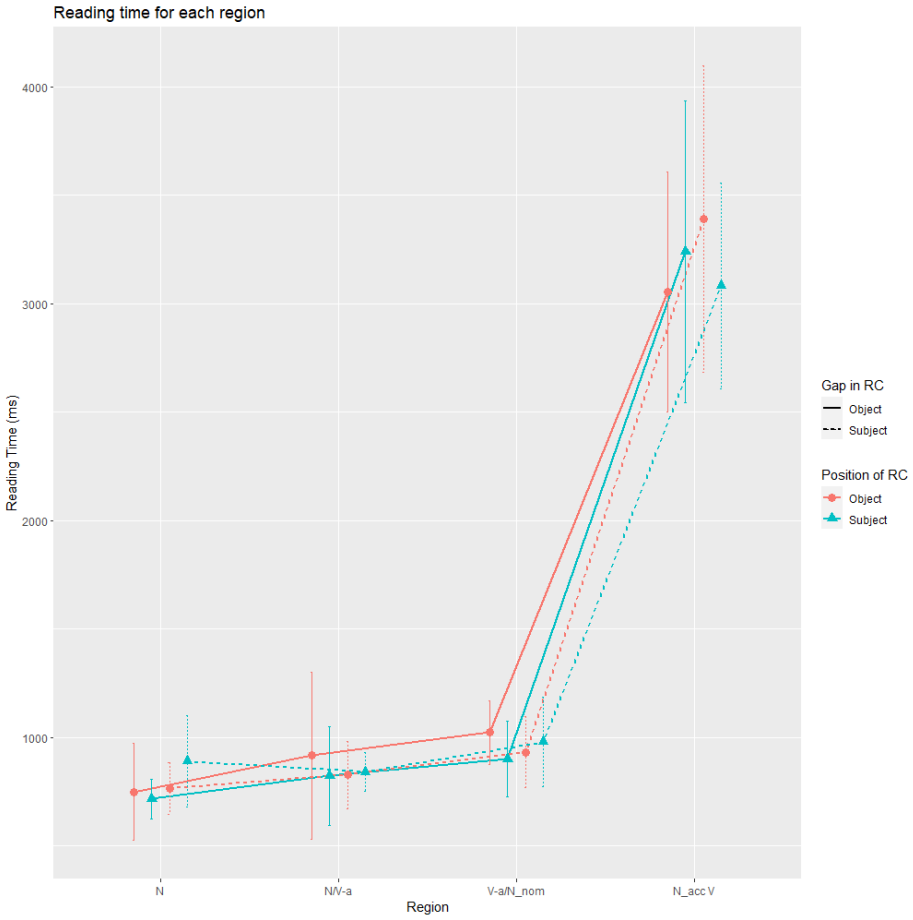

Figure 5: Reading time for each region: for sentences with the RC in the object position, the second region is the noun, and the third region is the verb (*V-a*), and for sentences with the RC in the subject position, the second region is the verb *V-a*

The graph (Figure 5) of the reading time for each region in milliseconds indicates a lot of interesting observations:

In the first region, the average reading time for the noun is the highest in the case of a Subject RC in the subject position. This can be attributed to the noun being accusative. The canonical order of sentences in Malayalam is SOV, hence encountering an accusative is an unexpected occurrence.

In the second region, it can be noticed that the highest RT is for sentences with an object gap RC in the object position (cf. 5b). It is not usual for sentences to have two nouns in the nominative to follow one another, without any intervening particle that shows conjunction or disjunction. This can be the reason for this observation.

In the third region, the RT for sentences with an object gap RC in the object position is still the highest. This can be explained by how the sentence has so far had two nouns in the nominative case. The verb is required, but the sentence remains unresolved.

In the final region, where all elements are put together, and the dependencies are exhausted, the trend is quite interesting. The highest RT is for sentences with a subject gap RC in the object position of the sentence. Sentences with the gap in the RC in a position congruent to the position of the RC modified noun take the least time (RC gap is in the object, and the RC modifies the object noun - or subject gap RC modifying the subject).

Figures 6 and 7 are the plots of the RTs for each element (noun or verb) in the relative clause, classified according to the type of relative clause (Gap) and the position of the RC, i.e., whether the RC modifies the noun or the verb of the matrix clause.

The plot of the reading times of RC nouns show a higher RT for the object RC mod-

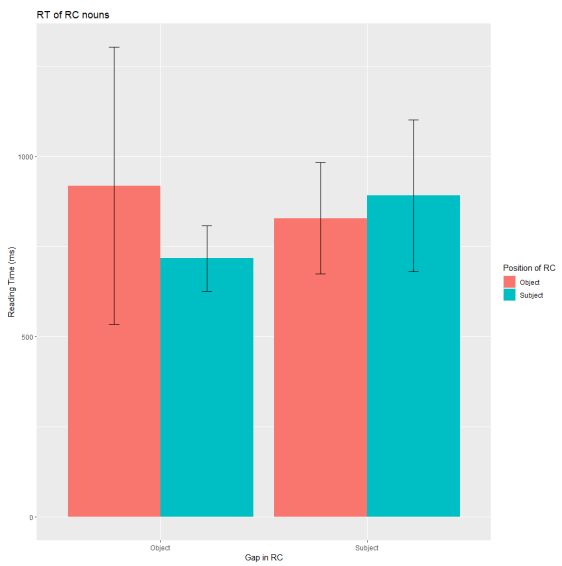

Figure 6: Mean Reading times of the nouns within the RC

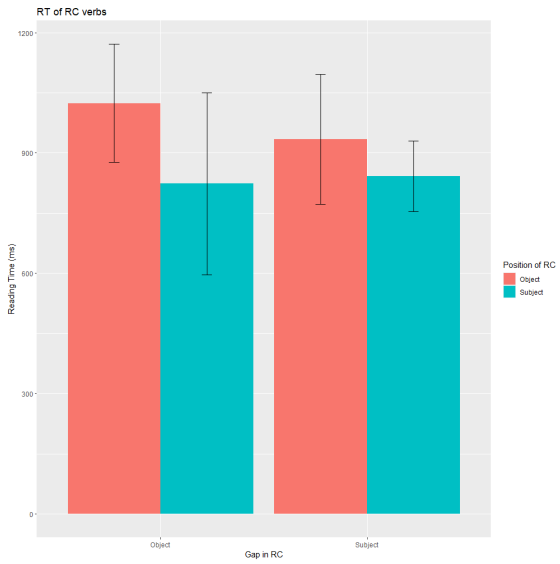

Figure 7: Mean Reading times of the RC participial verbs

ifying the object. This is attributable to the sentence being of the form (5b), as the RC nominative noun follows another nominative noun. It is also high for the subject gap RC modifying a subject, as the noun is accusative, and occurs as the first element of the sentence.

The plot of the reading times of the RC verbs also has an increase for the structure in (5b). The verb follows two nouns in the nominative case; hence it resolves one of the nouns' relations. This increases the RT as the other noun is still unresolved. As for the sentences with a subject gap in the RC with an object position, the time is higher as the structure expects

In addition to plotting the reading times, a two-factor repeated measures ANOVA was performed for RC nouns and RC verbs. The reading times are statistically significant in the following contexts:

1. on RC nouns across the type of gapping in the RC: $p = 0.048$
2. on RC verbs, across the position of the RC modifier (modifying the subject vs. the object): $p = 0.03$
3. on RC verbs, across the interaction of the gap as well as the position of the modifier: $p = 0.036$

In addition to the experimental data, the sentential items were also analyzed for the surprisal of each region. This has been plotted in Figure 8.

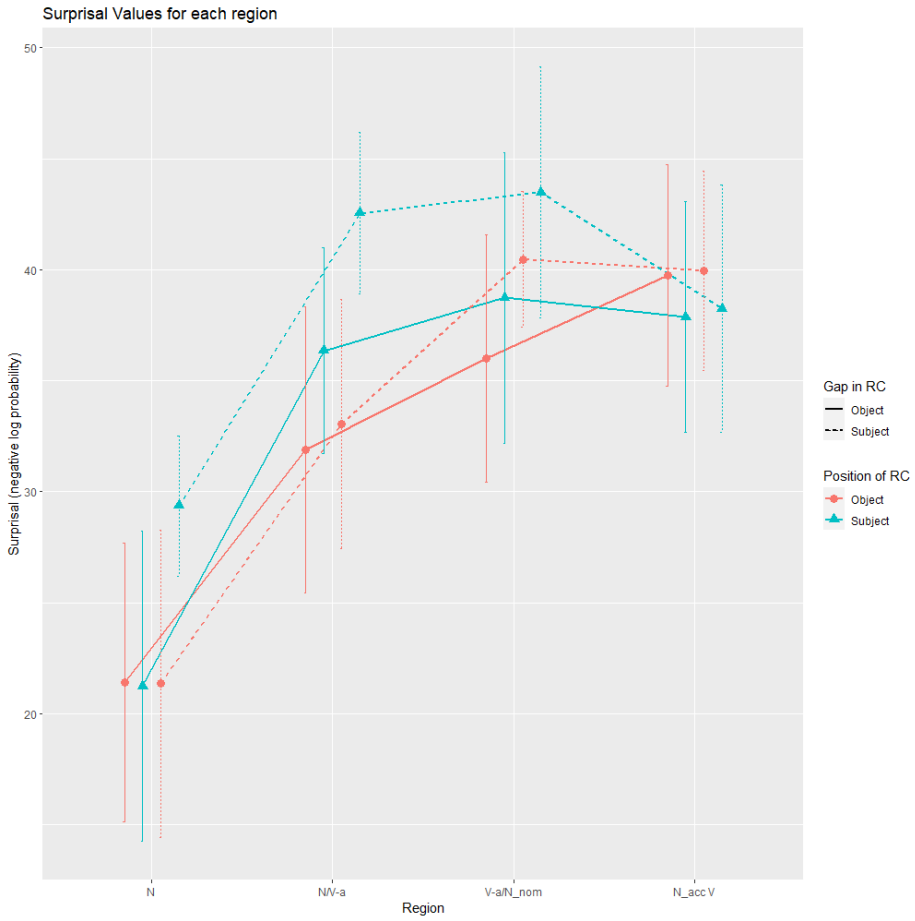

Figure 8: Surprisal at each region: for sentences with the RC in the object position, the second region is the noun, and the third region is the verb (*V-a*), and for sentences with the RC in the subject position, the second region is the verb *V-a*

The surprisal was calculated for the dataset using the *L3Cube Pune Malayalam Bert LLM*, with an incremental LM scorer. The surprisal analysis was performed with the minicons library in Python (Misra 2022). The surprisal analysis suggests that object gapped RCs (solid blue and red lines) are more oriented to expectations than subject gapped RCs (dashed blue and red lines). With regards to the position of the RCs, subject modifying RCs (both blue lines) tend to take more time initially, but it balances out in the end. This could be due to the relativized verb being encountered in the second region instead of later.

The surprisal data however shows an increase in the middle region instead of at the end of the sentence. The opposite observation is true for the experimental data. This discrepancy could be due to how in the case of absolute expectation values are more primed by the canonical structures, and non-canonical observations tend to increase the surprisal; whereas sentence termination comes with a decreased surprisal. In the case of experiments, however, there is an increase at the end due to the resolution of all dependencies, that occurs only when the matrix verb is read.

Gapping in RC	Position of Modifier	RT (ms)	Surprisal
Subject	Subject	5797.618	401.62
	Object	5919.849	383.09
Object	Subject	5683.16	354.8
	Object	5747.632	351.05

Table 1: Total RT and the total surprisal for each type of sentence

An analysis of the total RT and the total surprisal of each type of sentences have values as tabulated in Table 1, which shows a reduction in RT and surprisal in object gapped RCs over subject gapped RCs.

Analysing the memory load on each sentence type, it may be observed that the memory load is directly proportional to the number of unintegrated (with respect to integration with verbs) elements, at any point. From the items 5a, 5b, 5c and 5d, the memory load is highest in the RCverb for 5b, with two nominative nouns, followed by 5c. And with respect to the matrix verbs, all appear to have equal memory load (an RC modified proper noun and another noun) - with possible difference on where the modification occurs (on the subject or the object). This however does not translate directly, as the object modifier RCs have similar RTs at the matrix verb.

5.1 Summary of results

The analyses above show that the processing of Malayalam relative clauses seem to have a preference to Object RCs over Subject RCs during comprehension, and this can be explained with an expectation-based model, over a memory-based model. However, the relative clauses themselves seem to have a very slight subject preference, when the noun and the verb are being read. The work needs to be further refined, and more accurate methods employed, for more conclusive evidence.

6 Future Directions

This experiment offers evidence that supports an object RC preference in processing of Malayalam relative clauses. A theoretical analysis of RCs must follow to understand this observation, in addition to supplementing this with other behavioural tasks such as eye-tracking experiments and elicited production experiments. More importantly, tasks where a relative clause may be expected even before encounter, can provide much better evidence to the observations outlined above.

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