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Grammatical licensing and relative clause parsing in a flexible word-order language

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Abstract

Evidence from two experiments reveals that in Chamorro, a verb-first language, the comprehension of relative clauses (RCs) is sensitive to the order of the RC with respect to the head. Unlike most other languages, Chamorro allows both postnominal and prenominal RCs, so it is possible to compare how the two types are processed within the same language. Moreover, Chamorro is a small language whose speakers do not fit the typical profile of participants in cognitive science experiments. We found that RC comprehension is affected by the relative order of RC and head, and by other language-specific factors. However, we also found new support for a subject gap advantage in all RC types. This advantage emerged in early response measures and was reinforced in postnominal RCs, but often outcompeted in prenominal RCs by other pressures. We frame this competition in terms of a model in which grammatical licensing requirements play a key role in comprehension.

Keywords:

parsing; relative clauses; word order; Chamorro; Austronesian; subject preference

1. Introduction

Relative clauses comprise some of the most intensely investigated linguistic structures across practically all domains of inquiry, be it in formal syntax and semantics, neurolinguistics, language acquisition, etc. Why? In a relative clause (RC), a structurally complex form—an entire clause—is called upon to serve the core semantic function of modification. In (1), the noun phrase (NP) 'young coconuts' is modified by the RC that immediately follows it (delimited by brackets).

(1) The young coconuts [that the children brought __] came from Kiku's farm.

RCs provide an unlimited number of ways for the reference of an NP to be narrowed, because they permit the NP to be modified by any property expressible by a sentence containing a variable. To achieve this expressiveness, there must be a mechanism for linking the NP to a position inside the RC—the position corresponding to the variable. RCs are clauses themselves and so form their own grammatical microcosm. And this is the source of complexity that has preoccupied so many investigations: the link between the NP and its site of interpretation cannot be formed without interacting with the many processes that combine to 'build' a clause.

From a logical perspective, there's no reason to expect it should matter what syntactic position in the RC is linked to the modified NP. For example, compare (1) to (2), in which the RC is passive. Both RCs have the same meaning, that is, they denote the same property: the set of entities such that it is the case that the children brought them.

(2) The young coconuts [that __ were brought by the children] came from Kiku's farm.

Despite expressing identical meanings, the RCs in (1) and (2) are not on equal footing from a cognitive perspective. In sentences like (2), the modifier is a subject relative clause (SRC), but in (1) it is an object relative clause (ORC). The labels *subject* and *object* refer to which syntactic position inside the RC is linked to the modified NP, called the *head*. In (1) and (2) above, that

position is indicated by an underscore and referred to as the *gap*. SRCs are generally easier to comprehend than ORCs, an observation that has been extensively investigated (see Kwon, Lee, Gordon, Kluender, & Polinsky, 2010, for review).

Why should gaps in subject position be easier to link to the RC head than gaps in object position? According to an influential early hypothesis (Keenan & Comrie, 1977), there is a universal hierarchy of grammatical positions along which subjects outrank every other position – the Accessibility Hierarchy (AH). Typological generalizations about relativization patterns across languages were adduced to support this claim, and Keenan and Comrie conjectured that the AH might derive from the psychological complexity of recognizing different kinds of RCs. In particular, the ease of recognizing SRCs was thought to stem from the following fact: *every* clause projects a subject position, whereas other grammatical positions, such as objects, obliques, and so on, are dependent upon the identity of the clausal predicate. To put this another way, the mere existence of a clause is itself evidence of a subject position where a gap may be posited. A related construal of the hypothesis is that lower positions on the AH correspond to syntactic positions that are dominated by more nodes (O'Grady, 1997; Hawkins, 2004).

A second class of hypotheses links the difficulty of processing ORCs to the fact that other constituents tend to intervene in linear order between the head and the gap in such configurations, as (3) illustrates:

(3) a. *SRC (subject gap)* the **NP** [that __ V the NP]

|--------|

b. *ORC (object gap)* the **NP** [that the NP V __]

|------------x-------|

In Dependency Locality Theory (Gibson, 2000), the difficulty of forming a dependency is affected by the number of constituents instantiating discourse referents that intervene between the two members of the dependency. Likewise, in a theory of sentence processing embedded in ACT-R (Lewis & Vasishth, 2005), the difficulty of forming a dependency is modulated both by the activation history of dependents and potential similarity-based interference caused by intervening constituents. All things being equal, shorter dependencies are favored to longer dependencies. The cost of those intervening constituents can vary, and when the interveners are elements like local pronouns or quantified NPs, the asymmetry between SRCs and ORCs is leveled (Gordon, Henrick, & Johnson, 2004). In general, hypotheses in this class predict that linear order will exert its influence as a function of how constituents are maintained or retrieved from working memory. The direction and severity of subject-nonsubject asymmetries are predicted to vary across languages depending on the order of constituents inside the RC and the order of the RC with respect to the head.

Hsiao and Gibson (2003) investigated Mandarin, an SVO language in which RCs are *prenominal* (i.e. precede their heads). Consistent with an order-sensitive intervention hypothesis, they found evidence which they claimed showed that ORCs were easier to process than SRCs.[1] As (4) illustrates, SRCs in Mandarin create a dependency that linearly crosses an object NP, whereas in ORCs, no NP intervenes between the object position and the head.

[1] Hsiao and Gibson's evidence came from doubly-embedded RCs. Since this paper is concerned with singly-embedded RCs in Chamorro, we illustrate the idea with singly embedded RCs in (4).

(4) Dependency between Head and Gap in Mandarin RCs

a. *Subject Gap* [__ V NP de] **NP**

|------x----------|

b. *Object Gap* [NP V __ de] **NP**

|----------|

This finding has been controversial: while some investigators have found a similar ORC advantage in Mandarin (Hsu & Chen, 2007; Lin & Garnsey, 2011; Gibson & Wu, 2013; Vasishth, Chen, Li & Guo, 2013, Exp. 3), others found a SRC advantage (Lin & Bever, 2006, 2007, 2011; Lin, 2008; Wu, 2009; Vasishth et al., 2013, Exp. 1-2). In a meta-analysis of 15 studies, Vasishth et al. (2013) found that if any conclusion could be drawn from the data published to date, the balance of evidence was in favor of a SRC advantage in Mandarin. At least some of the variability in the findings stems from the fact that ORCs whose head serves as the subject of the main clause are temporarily ambiguous between a main clause parse and an RC parse. SRCs whose head serves as the subject of the main clause may also participate in a main clause ambiguity, because Mandarin has null pronominals (Lin & Bever, 2006). The debate about Mandarin seems headed toward the conclusion that SRCs are easier to process when all other circumstances are appropriately controlled (Jäger, Chen, Li, Lin, & Vasishth, 2015; Wu, Kaiser, & Vasishth, 2017), but other languages have at least appeared to show an ORC advantage when the RC precedes the head, notably, the ergative language Basque (Carreiras, Duñabeita, Vergara, de la Cruz-Pavía, & Laka, 2010).

A third class of hypotheses emphasizes the importance of linguistic experience. Whether SRCs are more difficult to parse than ORCs depends on the relative abundance of RC types in a given language (Mitchell, Cuetos, Corley, & Brysbaert, 1995) or the probabilities associated with the rules of grammar that derive RCs (Hale, 2003). The latter view was articulated most recently by

Yun, Chen, Hunter, Whitman, and Hale (2015) to explain RC processing in three languages with prenominal RCs: Chinese, Japanese, and Korean. Under their account, ORCs are more difficult to process than SRCs because they have "different amounts of sentence-medial ambiguity" (p. 114). That is, as a comprehender progresses through a sentence, the distribution of potential derivations changes more from word to word in the unfolding of an ORC as opposed to a SRC.

A different kind of experience-based explanation emphasizes the similarity or dissimilarity of the RC to canonical word order patterns in main clauses (Bever, 1970; MacDonald & Christiansen, 2002)—at least insofar as nouns and verbs are concerned. Thus in English SRCs, the head of the RC is in a substring-initial position, just like the subject of a main clause. In contrast, an ORC places two nouns in front of the verb of the RC.

Each of these accounts—a universalist account grounded in typological observations, a memory-based account that trades on the difficulty of forming dependencies between non-adjacent constituents, and an experienced-based account linked to the distributions of constructions, rules, or substrings—is deeply correlated with the others. And they may all simultaneously be correct descriptions of some linguistic process at some level of analysis. For example, the incremental re-ranking of derivations based on their probability may be the direct mechanism that causes difficulty to be manifested in the comprehension of ORCs. But one then immediately wants to know what aspect of language use and production causes the rules to have the weights they do, and why some languages prefer SRCs to ORCs (cf. Hawkins, 2004; MacDonald, 2013).

Our goal here is not to provide decisive evidence for any of these broad, overlapping classes of explanation to the exclusion of the others. However, we argue that none of them alone is a sufficient account. Our investigation of the processing of RCs in Chamorro, an Austronesian

language of the Mariana Islands,[2] provides evidence that subject gaps enjoy a particular advantage in parsing *in addition to* other processes that may sometimes cumulatively favor non-subject gaps. In a sense, this will not be a radical conclusion: linguistic objects are complex, and interpreting them incrementally involves the engagement of many different processes overlapping in time and priority. The SRC/ORC asymmetry, when it is observed, is consequently to be viewed as a derived phenomenon and not the result of one monolithic factor.

Chamorro is a language unusually well-suited to making this argument. Until relatively recently, the languages investigated in studies of RC processing have been drawn from an uneven sample: they have been predominantly languages in which RCs are postnominal (i.e. follow the head). Languages with postnominal RCs are statistically more prevalent among the world's languages; for example, the WALS typological survey (Dryer, 2013) identifies 579 out of 824 languages (~70%) as having postnominal RCs, but only 141 languages as having prenominal RCs (~17%).

What makes Chamorro special is that it has *both* postnominal *and* prenominal RCs. This typologically rare pattern makes it an ideal language for tracing the influence of word order on real-time language processing.[3] Over and above this, Chamorro differs in two further ways from other languages in which RC processing has been investigated. Firstly, the default word order of

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[2] The Mariana Islands are divided politically into U.S. Commonwealth of the Northern Mariana Islands (CNMI) and the unincorporated U.S. territory of Guam. Our research was conducted in the three inhabited islands of the CNMI (Saipan, Rota, and Tinian).

[3] Just 31 of the 751 languages whose dominant RC order is reported in WALS (Dryer & Haspelmath, 2013) to be prenominal and/or postnominal allow both of these orders.

Chamorro clauses is verb-first, so comprehenders are confronted with the verb before they have a chance to encounter any of its arguments. Secondly, Chamorro RCs are immediately preceded by morphological material that signals that they form part of a complex NP; namely, the head (in postnominal RCs) or the determiner of the complex NP (in prenominal RCs). Thus, comprehenders who encounter the verb of an RC have already encountered the main-clause verb, as well as material that identifies the current verb as part of a complex NP. There is no opportunity for even temporary ambiguity between an RC parse and a main-clause parse, as occurs in Mandarin or Basque (Yun et al., 2015; Carreiras et al., 2010).

Another characteristic that makes Chamorro special is that its speakers do not fit the typical profile of participants in cognitive science experiments (Henrich, Heine, & Norenzayan, 2010), including experiments on language processing. Most such experiments are done on major world languages, like English and Chinese (Anand, Chung, & Wagers, 2011; but see Clemens et al., 2015, and Polinsky, Gallo, Graff, & Kravtchenko, 2012 for some exceptions). Chamorro is a small language, with some 38,000 speakers in the Mariana Islands. Like many small languages, it is widely believed to be on the cusp of language endangerment. Our experiments were conducted in the U.S. Commonwealth of the Northern Mariana Islands (CNMI), a multilingual, multicultural society. Most Chamorros there are not college-educated—fewer than 10% have a bachelor's degree. Almost every Chamorro speaker is bilingual. The very oldest speakers are typically bilingual in Japanese, while almost all other speakers are bilingual in English. According to the 2010 US Census, less than 0.2% of 11,671 ethnic Chamorros reported speaking Chamorro only, and almost no one under the age of 18 speaks the language fluently. For this reason among others, the average participant in our experiments was in their 40s and our experiments were conducted entirely in the Chamorro language, because we wanted to minimize possible effects of bilingualism.

We probed the comprehension of RCs in Chamorro in two picture-matching, touch-tracking experiments conducted in the CNMI in September 2013 and June-July 2014. In brief, we found that subject gaps were preferred in postnominal RCs, but object gaps were preferred in prenominal RCs. We also found that subject gap responses were initiated earlier than object gap responses, even when the environment ultimately promoted an object gap response. We propose that comprehenders must resolve two issues as they incrementally progress through an RC: (i) the syntactic position of the gap must be identified and (ii) the subject of the RC must be identified. Differences in the timing of these requirements and the strength of the evidence that allows the comprehender to resolve them are responsible for the interaction of the subject gap preference with word order. In addition, we propose that the early initiation of subject gap responses implicates the existence of a subject gap preference, which cannot be derived from (i) and (ii) alone.

2. Background: Chamorro Relative Clauses

Chamorro is a verb-first language that allows null pronouns as arguments. The word order of arguments after the verb is not fixed, so clauses can be Verb Subject Object (VSO) or Verb Object Subject (VOS), although VSO is the default. The verb expresses agreement with the subject via a prefix that also indicates mood and transitivity.[4]

(5) Word order and subject-verb agreement

[4] The following abbreviations are used in the Chamorro examples: AGR 'agreement', C 'complementizer', L 'linker', LOC 'local case', OBJ 'object', PROG 'progressive', SUBJ 'subject', wh 'wh-agreement'. While the AGR morpheme is sometimes written as if it were separate from the verb, it is not a prosodically independent word.

a. Matåta'chung i taotao.

AGR.sit.PROG the person

'The man is sitting down.'

b. Ha åkka' i ga'lågu i patgun låhi.

AGR bite the dog the child male

'The dog bit the boy / The boy bit the dog.'

c. Un gigimin i hanum.

AGR drink.PROG the water

'You are drinking the water.'

The word order of NPs is Determiner Noun. Importantly, relative clauses can precede or follow the noun they modify (Chung, 1998; Chung & Ladusaw, 2006). When the RC is prenominal, it follows the determiner and precedes the head. The RC and the head are 'joined' by the linker, which here is realized as *na* (glossed L below). The prenominal RCs in (6) are in brackets.

(6) Prenominal RCs

a. Kao siña un li'i' atyu i [matåta'chung] na tåotao?

Q can AGR see that the AGR.sit.PROG L person

'Can you see the man who is sitting down?'

b. Estagui' i risuttan i CCR … put i [un gigimin] na hånum.

here.is the result.L the CCR about the AGR drink.PROG L water

'Here are the results of the CCR...about the water that you drink.'

(Commonwealth Utility News, July 2014, p. 8)

A postnominal RC begins with a complementizer that simultaneously spells out the linker. This complementizer is *i* when the head is preceded by a demonstrative plus the linker, as in (7a), and *ni* otherwise, as in (7b). (The complementizer in these examples is bolded.)

(7) Postnominal RCs

a. Kao siña un li'i' atyu na tåotao [**i** matåta'chung]?
Q can AGR see that L person C AGR.sit.PROG

'Can you see the man who is sitting down?'

b. Impottånti esti na infotmasion put i hanum [**ni** un gigimin].
important this L information about the water C AGR drink.PROG

'This information about the water that you drink is important.'

(Commonwealth Utility News, July 2014, p. 8)

The RC must contain a gap, which is always an NP. When the gap is an argument, the verb of the RC registers its grammatical relation with wh-agreement, a special agreement that replaces the normal subject-verb agreement. Wh-agreement is not realized when the gap is the subject of an intransitive verb; see (6a) and (7a). It is realized optionally when the gap is an object (Chung, 1998; Wagers, Borja, & Chung, 2015); compare (8a) with (8b), (6b), and (7b).

(8) RCs with and without object wh-agreement

a. un guma' [ni finahån-ña si Juan]
a house C WH[OBJ].buy-AGR Juan

'a house that Juan bought'

b. un guma' [ni ha fåhan si Juan]
a house C AGR buy Juan

'a house that Juan bought'

When the gap is the subject of a transitive verb in the realis mood, wh-agreement is usually realized as the infix *-um-*, as (9) shows.

(9) RCs with subject wh-agreement

a. i [k**um**uentutusi yu' nigap] na palåo'an
the WH[SUBJ].speak.to.PROG me yesterday L woman

'the woman who was speaking to me yesterday'

b. i lalåhi [ni k**um**akassi i ma'estra]
the men C WH[SUBJ].tease.PROG the teacher

'the men who were teasing the teacher'

But here too, wh-agreement is not obligatory; it is possible for the verb of the RC to have normal subject-verb agreement instead. Compare (9) with (10).

(10) RCs with a subject gap and no wh-agreement

a. i lalåhi [ni ma kakassi i ma'estra]
the men C AGR tease.PROG the teacher

'the men who were teasing the teacher'

b. i Lattin Taga' [ni ha reprisesenta i kustumbrin manChamorro]
the latte.L Taga' C AGR represent.PROG the custom.L Chamorros

'the Taga' latte stones that represent the culture of the Chamorros' (from the mission statement of a local organization)

The idea that wh-agreement is optional in SRCs as well as ORCs is supported by data from fieldwork and naturally-occurring discourse. Our electronic Chamorro database includes some 269 examples of SRCs whose gap is the subject of a transitive verb in the realis mood—254 elicited

during fieldwork and 15 collected unsystematically from narrative texts, web blogs, and so on. Of these SRCs, 231 (86%) show wh-agreement (pattern (9)), and 38 (14%) have normal subject-verb agreement (pattern (10)).

The result is that RCs formed from transitive verbs with normal subject-verb agreement are systematically ambiguous: they can be interpreted as SRCs or ORCs. This holds true whether the RC is prenominal or postnominal, as can be seen from (11).

(11) Some ambiguous RCs

a. Hu ågang atyu i [ha kadididak i biha] na påtgun.
AGR call that the AGR tickle.PROG the old.lady L child

'I called that child who was tickling the old woman.' (*subject gap*)

'I called that child who the old woman was tickling.' (*object gap*)

b. Hu ågang atyu na påtgun [i ha kadididak i biha].
AGR call that L child C AGR tickle.PROG the old.lady

'I called that child who was tickling the old woman.' (*subject gap*)

'I called that child who the old woman was tickling.' (*object gap*)

This systematic ambiguity is leveraged in the experiments reported on below.

3. Experiment 1: Relative Clause Order and the Subject Gap Preference

We conducted a picture-matching experiment to determine whether the gaps in ambiguous RCs would be preferentially interpreted as subject gaps, despite the flexible, verb-first word order of the language. We wanted to know, further, whether the syntactic position of the gap would be affected by head-RC order. We used a touch-tracking paradigm in this study to collect exploratory information about the dynamics of participants' responses.

3.1 Participants, Procedure, and Design

One hundred thirty-three native speakers of Chamorro in the CNMI participated in Experiment 1. Their ages ranged from 20 to 70 years (median age: 42; 58 male). 58 participated in the experiment on the island of Rota, 61 on the island of Saipan, and 12 on the island of Tinian. Demographic data were not collected for 2 speakers.

Participants performed a picture-matching task using a tablet computer. Each participant was instructed in Chamorro to move a small icon—the 'puck'—over to one of two pictures, which was potentially described by an RC contained in the instruction. The Chamorro instructions were recorded by Borja and presented auditorily.

The form of the RC was manipulated according to a 3 × 3 design that varied RC Type with Verb Type within the RC. The three levels of RC Type were *Postnominal, Prenominal,* and *Headless*. (A headless RC has a null head that can be translated 'one'.) The three levels of Verb Type were *Transitive, Passive,* and *Wh-Agreeing.* Each instruction was composed of the carrier frame shown in (12), followed by an RC.

(12) Chonnik i puti'un guatu gi ___
push the star there LOC
'Push the star over there to ...'

The nine conditions in one item set are illustrated in Table 1. Transitive verbs consisted of a verb stem preceded by subject-verb agreement (the third singular proclitic *ha*). Passive verbs consisted of a verb stem plus the passive infix *-in-*. Wh-Agreeing verbs showed wh-agreement instead of normal subject-verb agreement, and their form was counterbalanced across items: half of the items showed subject wh-agreement (realized with the infix *-um-*; pattern (9)), and the other half showed

object wh-agreement (realized with the infix -*in*- and suffixal subject-verb agreement; pattern (8a)). All verbs were in the progressive aspect. Transitive conditions were grammatically ambiguous, while Passive and Wh-Agreeing conditions were unambiguous.

3.2 Materials

Thirty-six item sets were constructed from 18 transitive verbs. The verbs were selected for their ability to host arguments equal in animacy. For example, the verb *dengkut* 'peck' can label the event of one animal pecking another; the verb *chiku* 'kiss' can label the event of one person kissing another. The Appendix lists the 18 verbs and the nouns that served as their arguments. For each verb, two matched item sets were generated with the same pair of nouns. In the first item set, a given noun was the head and the other noun appeared within the RC; in the second item set, the other noun was the head and the first noun appeared within the RC. Thus, the item set in Table 1, in which *låhi* 'man' is the head and *påtgun* 'child' appears within the RC, had a matched item set in which *påtgun* is the head and *låhi* appears within the RC. In this way, the serial position of nouns was totally counterbalanced across the experiment.

	Relative Clause Type		
	POSTNOMINAL	**HEADLESS**	**PRENOMINAL**
TRANS. VERB	atyu na **låhi** i ha chichiku i patgun *that L man C AGR kiss the child* 'that man who __ is kissing the child', or 'that man who the child is kissing __'	atyu i ha chichiku i patgun	atyu i ha chichiku i patgun na **låhi**
PASSIVE VERB	atyu na **låhi** i chinichiku ni patgun *that L man C AGR.PASS.kiss OBL child* 'that man who __ is being kissed by the child'	atyu i chinichiku ni patgun	atyu i chinichiku ni patgun na **låhi**
WH-AGR. VERB	atyu na **låhi** i chinikuku-ña i patgun *that L man C WH[OBJ].kiss the child* 'that man who the child is kissing __'	atyu i chinikuku-ña i patgun	atyu i chinikuku-ña i patgun na **låhi**

Table 1 **Example item set from Experiment 1: Verb Type × RC Type**

The RC is underlined, and the head is in bold. Word-by-word glosses and translations are given for postnominal RCs only. An underscore in the translation indicates the possible gap site. Translations are identical across RC Type; so are glosses, modulo word order. In headless RCs, the null head can be translated as 'one', e.g. 'that one who is kissing the child'.

3.3 Apparatus and Method

Experiment 1 combined picture-matching and touch-tracking. Touch-tracking is a variant of mouse-tracking (Freeman & Ambady, 2010) in which the finger-swipe trajectory is recorded while participants execute their response.

The trial sequence is illustrated in Figure 1. Each trial began with the puck flashing at the center of the bottom of the screen (Panel 1); this alerted participants to the onset of the trial. Then the two pictures were displayed simultaneously with the audio (Panel 2). Participants could move the puck as soon as they wished. We recorded the $\langle x,y,t \rangle$ coordinates of the puck (Panel 3). When the puck entered a rectangular region surrounding either target picture, the picture was highlighted (Panel 4). Participants could then either verify their selection or change it. Once the audio finished

playing, it could be repeated as many times as a participant wished. We added this feature to the experiment, because in piloting the study, we found that participants evinced considerable anxiety if they thought they could not repeat the stimuli. In both Experiment 1 and Experiment 2, the stimulus was repeated on 9% of trials. In an exploratory analysis separating repeated and unrepeated trials, we found no clear trends. We did not disaggregate the repeated trials from the picture choice data in estimating the subject gap preference, but we removed the repeated trials when we analyzed latency data.

The experiment was presented on Google Nexus 10 tablets running the Android operating system. Trial presentation and response collection were managed by custom software created on the OpenSesame platform (Mathôt, Schreij, & Theeuwes, 2012). Screen resolution was 1280 by 800, with an actual refresh rate of approximately 13-14 Hz.

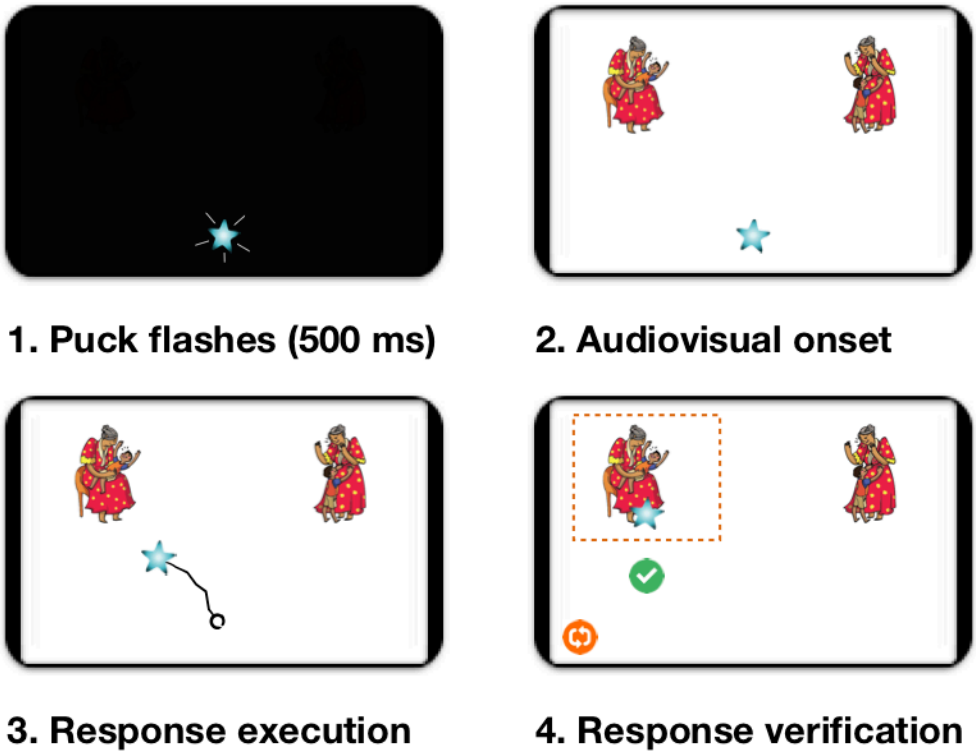


Figure 1 *Panel 1.* The puck appears centered at the bottom of a black screen, and flashes three times (300 ms on, 300 ms off). *Panel 2*. Audio begins to play 1800 ms from initial puck onset. Participant can move puck at any time after audio onset. *Panel 3.* The <*x,y*> position of the puck is polled each time the screen is redrawn. *Panel 4.* Once the puck enters a rectangular region surrounding an image (505 x 450 pixels in extent), the selected image is highlighted with a dashed line, and a green "check-mark" button appears below it. Participant can then either press the green button to verify this response, or move the puck to select the other image. Once the audio finishes playing, an orange button appears in the lower left corner of the screen. Pressing the button allows participant to replay the audio.

3.4 Analysis

Picture choice data were analyzed using logistic mixed-effects regression (see Borja, Chung, & Wagers, 2015 for preliminary analysis of some of the data). The RC Type conditions were coded by two coefficients using centered Helmert contrasts. The first coefficient, HEAD.FIRST, contrasted postnominal RCs with prenominal and headless RCs combined (postnominal coefficient: +2). The second coefficient, HEAD.NULL, contrasted headless RCs with prenominal RCs (headless

coefficient: +1). Unless otherwise stated, maximal random effects structure was included. Models were estimated using the *lme4* package in R (Bates, Maechler, Bolker, & Walker, 2014).

We examined latency data from the touch-tracking responses, in particular, response initiation times with respect to the offset of the auditory stimulus. For comparisons between groups, we estimated 95% confidence intervals on the difference of medians using a non-parametric bootstrap with subject clusters (10,000 replications; percentile method for estimating the interval). To compare the shape of initiation time distributions, we analyzed cumulative density functions by fitting them to a log-normal distribution and estimating its confidence interval using the *fitdistrplus* package (Delignette-Muller & Dutang, 2015; quantile-based C.I.s). For these analyses, we did exclude trials on which the participant repeated the stimulus. We also excluded initiation times less than 0 ms, namely, initiation times from responses that were initiated before the audio file finished playing. These constituted about 2.5% of the data; an equal fraction of the most extreme positive values were also trimmed, resulting in an approximate range of 0 to 8000 ms.

Errors. Data from 19 speakers were removed because of high error rates in the unambiguous conditions.[5] For each speaker, we calculated two measures to assess their ability to

[5] It is worth commenting on this exclusion rate. Chamorro cultural norms made it difficult for us to bar participants who represented themselves as speakers of Chamorro, even if it was clear that they were second-language learners. We therefore decided to use an objective exclusion criterion based on discrimination scores, as described in the text. It is probable that the excluded participants include non-native speakers as well as speakers who could not perform the task for other reasons (e.g., because they were hard of hearing). It is also possible that some highly proficient non-native speakers are included in the analyzed sample.

comprehend unambiguous RCs: *subject discrimination* assessed the ability to discriminate subjects from objects in constituent structure, and *agent discrimination*, the ability to discriminate agents from themes in argument structure. In either case, we estimated a d-prime score by scaling percent correct in one condition against the error rate in a matched condition, as defined in Table 2. Our policy was to remove participants if their grammatical subject d-prime or their thematic agent d-prime was 0 or less than 0. In other words, participants had to show *some* discrimination to be included in further analysis. This disjunctive policy identified 10 and 7 participants, respectively, for exclusion, plus 2 participants who did not meet the criterion in either category. Table 2 gives further details about this analysis.

We also removed trials with items containing the verbs *hongngang* 'startle' and *tattiyi* 'follow'. These verbs led to error rates above 30% on the unambiguous stimuli. In the case of *hongngang,* debriefings from multiple participants indicated confusion over how the event was depicted.

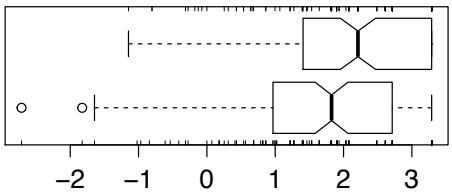
Discrimination type	Hits: p_H	False alarms: p_{FA}	
Subject	Wh.Agr[Subj]	Passive	
Agent	Passive	Wh.Agr[Obj]	
D-prime formula	$Z(p_H) - Z(p_{FA})$		

Table 2 **Discriminative error rates in unambiguous conditions**

The 'hits' column gives the conditions from which the *correct response* rate was taken for the hit rate. The 'false alarms' column gives the conditions from which the *error rate* was taken for the false alarm rate. To calculate the passive rates, only item sets were used which had a corresponding Wh-Agreement condition (object or subject, counterbalanced across items). Thus, a unique set of scores was used in each cell of the table. The function Z is the normal inverse cumulative distribution function. Perfect scores (0 or 1) were corrected with a 0.05 increment. Score distribution for each measure is indicated by the boxplots in the right column (maximum possible = 3.28).

3.5 Results

3.5.1 Ambiguous RCs

We found an overall subject gap preference (SGP) in the interpretation of ambiguous RCs: subject gap interpretations were selected on 68% of trials. However, the SGP was affected by the order of the RC with respect to the head and whether the head was overt or null. Crucially, prenominal RCs showed a modest preference for object gap interpretations, as subject gap interpretations were selected on just 43% of the trials. Table 3 gives the SGP rate for ambiguous RCs by RC Type. It also reports the results of the mixed-effects logistic regression, which incorporated two comparisons: HEAD.FIRST, the contrast between postnominal RCs and the two other RC types; and

HEAD.NULL, the contrast between headless and prenominal RCs. Both comparisons were statistically significant.

	Subject gap interpretations		*Logistic regression*				
			Coefficient		Estimate	*z*	P(>|*z*|)
Postnominal	94 (1)		HEAD	FIRST	1.19 (.25)	4.8	< .001
Headless	68 (3)			NULL	0.82 (.14)	6.0	< .001
Prenominal	43 (4)						
	68 (2)		INTERCEPT		1.65 (.30)	5.6	< .001

Table 3 **Subject gap interpretation rates for ambiguous transitive RCs**

The left-hand column gives the choice rate for pictures corresponding to subject gap interpretations, expressed as percentage. The standard error is reported in parentheses, calculated over items.

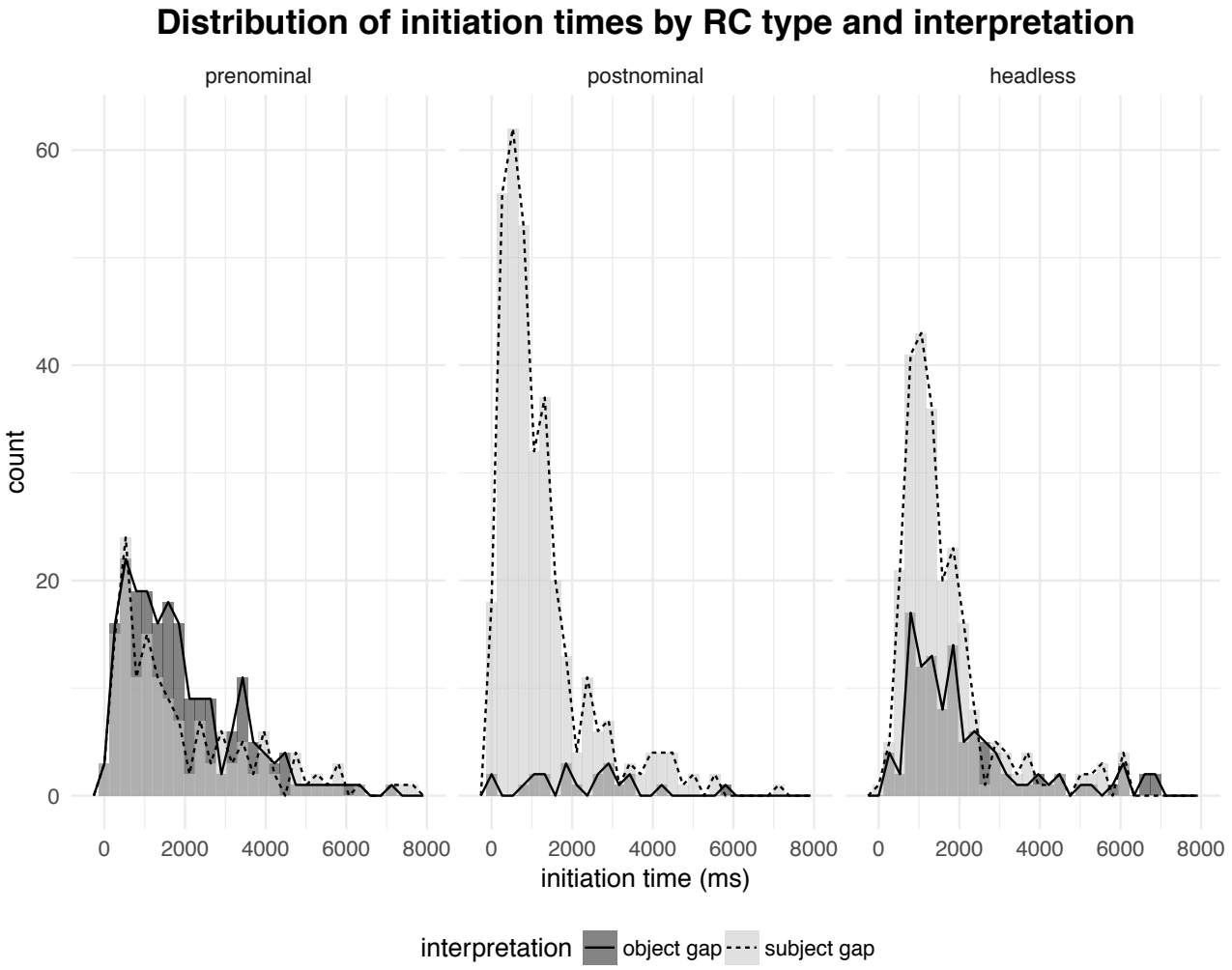
The right-hand column gives the results of the mixed-effects logistic regression: the fixed-effect coefficients, expressed in logits, with standard error in parentheses; the *z*-scores and corresponding *p*-value. The interpretation of coefficients is given in the analysis section.

We explored several aspects of participants' finger-swipe behavior, including (i) when a participant first initiated a response by touching or moving the puck, a measure we call the *initiation time*; and (ii) the probability of stalls or reversals in the trajectory of the finger-swipe once a response had been initiated. In this paper, we only report the analysis of (i), but we include a summary of (ii) in our supplemental materials.

In all three ambiguous RC types—prenominal, postnominal, and headless—we inspected the distribution of initation times by gap interpretation. This suggested that the earliest responses corresponded to subject gap interpretations. Figure 2 gives density plots of the initiation times for the three RC types according to the chosen interpretation, along with median initiation times. It is of particular interest that subject gap interpretations appeared to be among the earliest for prenominal

RCs, given that this RC type favored object gap interpretations in picture selection. We explored this initial impression in two ways. First, we estimated confidence intervals on the median differences between subject gap and object gap interpretations for each RC Type; second, we fit the empirical cumulative density function of the subject gap responses to prenominal RCs with a log-normal function, estimated its confidence interval, and compared it to the empirical CDF of the object gap responses. These analyses revealed qualified support for the idea that subject gap responses were earliest. In prenominal RCs, the median subject gap initiation time was 202 ms faster than the median object initiation time (95% confidence interval: [486, -142]). The CDF analysis is given in Figure 3. It shows that there was a greater fraction of subject gap responses than object gap responses for the earliest initiation times (approximately less than 2000 ms).

For postnominal and headless RCs, the initiation time data converge with the picture-matching data, in the following sense: the fastest responses to these types of ambiguous RCs also select the interpretation that is ultimately preferred—the subject gap interpretation. But the two measures appear to pull apart for ambiguous prenominal RCs. The fact that the fastest responses to prenominal RCs do not select the interpretation ultimately preferred for this RC type suggests that more than one parsing consideration is at play. We claim that there are two such considerations: (i) the drive to complete an open filler-gap dependency, which takes effect early and demands that the syntactic position of the gap be identified, and (ii) the drive to identify the subject of the clause. The interaction of these two considerations leads to an object gap preference in prenominal RCs but a subject gap preference otherwise. These ideas are made more precise in the Discussion.



Median initiation times (ms) and difference intervals

RC Type	Object	Subject	(O–S) 95% C.I.
prenominal	1510	1308	[486, –142]
postnominal	2038	816	[2181, 589]
headless	1635	1266	[650, 79]

Figure 2 Experiment 1. Histograms and frequency polygons for initiation times to ambiguous sentences, for each RC Type and interpretation. *X*-axis: initiation time (ms) with respect to audio offset. The solid line and darkest fill represents the distribution of responses to the object gap interpretations, while the dashed line and lighter fill represents the subject gap interpretations. Table inset below the chart gives median initiation times for each condition and a difference score between object and subject median initiation times with 95% confidence interval.

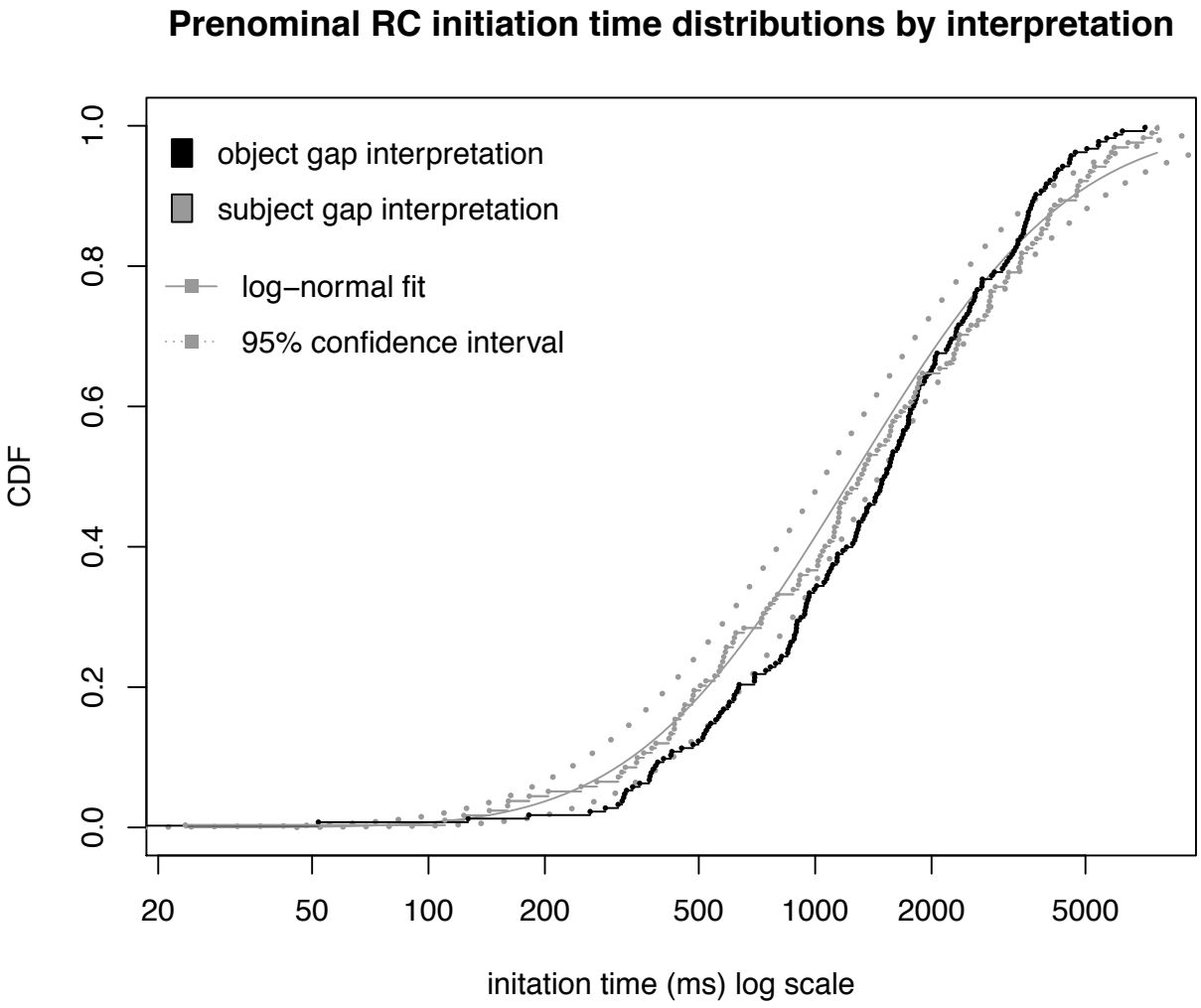


Figure 3 Experiment 1. The empirical cumulative density functions of initiation times for subject and object gap interpretations are compared for prenominal RC conditions. For early initiation times, there is a larger fraction of responses for subject gap interpretations, but this shifts over the response interval. Solid, black symbols: CDF for object gap responses. Solid, gray symbols: CDF for subject gap responses. Log-normal fit to the subject gap responses is plotted with a solid gray line and its 95% confidence interval indicated by a dotted gray line. Data plotted on log ms scale.

3.5.2 Unambiguous RCs

Error rates in unambiguous RCs were generally low and uniform. However, they were sensitive to some of the same general factors observed in the ambiguous RCs. Table 4 reports these error rates.

		Verb Type		
RC Type		WhAgr:Subj	Passive	WhAgr:Obj
Postnominal		2 (1)	6 (1)	22 (4)
Headless		3 (1)	11 (2)	6 (3)
Prenominal		12 (3)	32 (3)	13 (3)

Table 4 **Error rates for unambiguous RCs**

Each cell gives the error rate for conditions with unambiguous verbs, expressed as percentage. The standard error is reported in parentheses, calculated over items. For WhAgr:Subj and Passive verbs, the correct answer requires a subject gap analysis. For WhAgr:Obj verb, the correct answer requires an object gap analysis.

The highest error rates were observed when the interpretation signaled by the unambiguous morphology was opposite the interpretation preferred for ambiguous stimuli in the same RC Type. Thus, the error rate for object wh-agreement was highest in postnominal RCs—exactly the environment that encouraged the most subject gap interpretations in the ambiguous stimuli. The error rate for subject wh-agreement was highest in prenominal RCs—the environment that encouraged the fewest subject gap interpretations in the ambiguous stimuli. Finally, prenominal RCs led to the highest error rates on average, although this was largely due to a high error rate on passives.

The initiation times for correct trials reinforce the generalization that the parsing of unambiguous RCs is susceptible to the same general factors that operate in ambiguous RCs. Figure 4 plots the median initiation times for correct trials with 95% confidence intervals. Most notably, in postnominal RCs, subject wh-agreement gave rise to the very earliest initiation times, and object wh-agreement gave rise to the very latest ones. These patterns echo the strong preference for subject gaps in this type of RC. There was relatively little variation in the initiation times for prenominal and headless RCs.

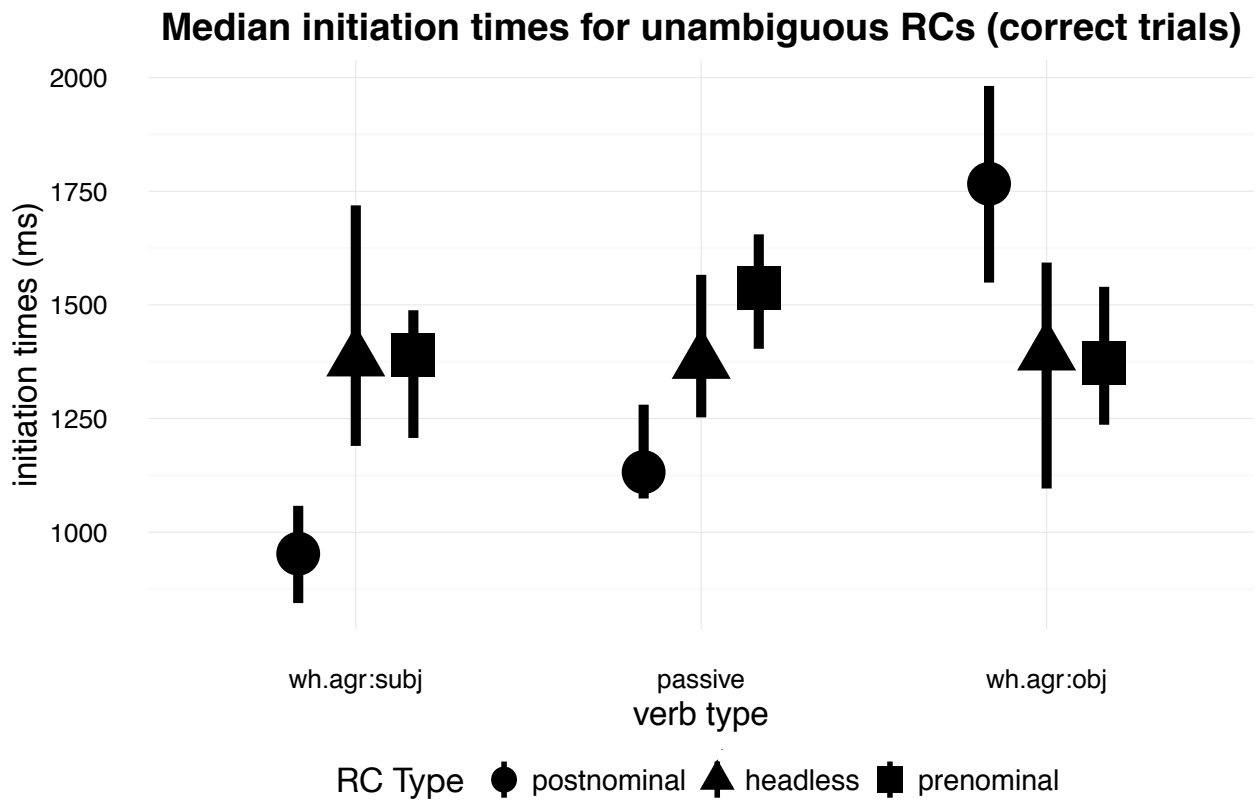


Figure 4 Experiment 1. Median initiation times (ms) for unambiguous conditions, separated by verb type (WhAgr:Subj, Passive, WhAgr:Obj) and RC Type. Error bars represent 95% confidence intervals.

3.6 Discussion

There were two important findings in Experiment 1. First, the extent of the SGP in ambiguous RCs depended on the RC's order with respect to the head. Participants overwhelmingly preferred subject gap interpretations when the RC was postnominal, and they slightly preferred object gap interpretations when the RC was prenominal. Second, participants gave subject gap responses more quickly across the board—even for prenominal RCs, which elicited more object gap interpretations overall.

The preference data from Experiment 1 clearly support the view that comprehenders are sensitive to head-RC order. Ambiguous RCs elicited more object gap interpretations when the RC

was prenominal. But the distribution of errors for *un*ambiguous RCs was also sensitive to head-RC order. When an unambiguous RC required a subject gap, e.g., when the verb was passive or showed subject wh-agreement, there were fewer errors when the RC was postnominal. However, when an unambiguous RC required an object gap, i.e., when the verb showed object wh-agreement, there were fewer errors when the RC was prenominal.

Two findings from the ambiguous RCs suggest that there is a subject gap advantage nonetheless. First, the preference for object gaps in prenominal RCs was not as extreme as the preference for subject gaps in postnominal RCs. Second, subject gap responses were always initiated earliest—although this finding was less strongly supported in the prenominal RCs. This suggests a temporal priority for the positing of subject gaps, even if the odds are ultimately against them.

4. Experiment 2: Resolution of Morphological Ambiguity

In Experiment 2, we wanted to examine more closely how head-RC order affects the identification of the gap. We wanted to see whether we could replicate two surprising results from Experiment 1: first, ambiguous postnominal RCs gave rise to more subject gap interpretations than ambiguous prenominal RCs, and second, subject gap responses were initiated earlier. We further wanted to test the strength of the SGP by pitting it against a Chamorro-specific constraint that would only allow object gap interpretations. We call this constraint the person-animacy hierarchy (PAH).

4.1 Background: The Person-Animacy Hierarchy

As observed in 2.1, Chamorro allows pronouns to be null (unpronounced). Subject pronouns are almost always null when subject-verb agreement signals their person features; see, e.g., the main

clause in (7a) and the RC in (7b). Object pronouns can be null if their antecedent is clear from the discourse context; compare the overt object pronoun in (13a) with the null object pronoun in (13b).

(13) Overt and null object pronouns

a. Hu na'hallum i patgun na para bai hu hongngang gui'.
AGR make.assume the child C FUT AGR startle him
'I made the boy think that I was going to scare him.' (entry for *na'hallum* in the unedited Chamorro-English Dictionary database)

b. Kumuekuentus put guåhu ya hu sapblåsus.
AGR.speak.PROG about me and AGR smack
'He was talking about me so I smacked him.' (entry for *sapblåsus* in the unedited Chamorro-English Dictionary database)

Pronouns in Chamorro are regulated by the PAH, a Chamorro restriction that prohibits transitive clauses from having certain combinations of subject and object. The restriction is sensitive to morphology—it does not hold when the verb shows wh-agreement or any other exceptional form of subject-verb agreement (Chung, 1998)—but otherwise it is similar to restrictions found in Algonquian languages (Aissen, 1997; Christianson & Cho, 2009). Speakers occasionally allow the PAH to be violated by isolated sentences in fieldwork sessions. However, a corpus study of connected discourse (Clothier-Goldschmidt, 2015) reveals that it is invariably respected in production. Among other things, the PAH disallows transitive clauses in which the object is a third person animate pronoun (e.g., 'her', 'him', 'them') but the subject is not a pronoun. The prohibition holds whether the object pronoun is overt or null, as (14) shows.

(14) No clauses in which the object is a pronoun but the subject is not

a. *Ha lalåtdi gui' si Maria.

AGR scold him Maria

('Maria scolded him.')

b. *Ha tattiyi si Juan para i kareta.

AGR follow Juan to the car

('Juan followed him to the car.')

Importantly, the PAH does not treat the gap in an RC as a pronoun. If it did, the object gap interpretation of the RCs in (11) should be prohibited, but that interpretation is grammatical and well-attested in discourse. The observation leads to a prediction. An RC that contains a transitive verb plus a null pronoun can be interpreted as having an object gap and a null subject pronoun; but it should not be interpreted as having a subject gap and a null (third person animate) object pronoun, because that would violate the PAH.

Experiment 2 explores this prediction by investigating the processing of RCs that contain a transitive verb plus a null pronoun, as opposed to a transitive verb followed by an overt NP. Our goal was to determine whether and to what extent the PAH affected the interpretation of the gap. Generally, RCs in which the transitive verb has normal subject-verb agreement are ambiguous (see section 2), but when the RC contains a null pronoun as opposed to an overt NP, the PAH should force an object gap interpretation. We entertained two opposing conjectures. If the PAH is a dominant pressure in comprehension, there should be a very low SGP in RCs of this type. Alternatively, if the SGP is the dominant pressure, violations of the PAH should occur. Experiment 2 was another picture-matching task with touch-tracking which included some of the same conditions from Experiment 1, but also added conditions in which the RC contained a null pronoun.

4.2 Participants, Procedure, and Design

Ninety-eight native speakers of Chamorro participated in Experiment 2. Their ages ranged from 19 to 66 years (median age: 44.5; 49 males). Most of the participants had lived primarily on Rota (43) or Saipan (50) during childhood; a few had lived primarily on other islands, i.e. Tinian (1), Pågan (1), or Guam (3).

Participants performed the same task as in Experiment 1, but this time the form of the RC was manipulated according to a design that crossed RC Type (2) × NP Type (2). The two levels of RC Type were *Postnominal* and *Prenominal*, and the two levels of NP Type were *Overt NP* and *Null Pronoun*. A full item set is illustrated in Table 5.

	RC Type	
NP TYPE	**PRENOMINAL**	**POSTNOMINAL**
Overt NP	atyu i ha chichiku i patgun na **tåta** *that the AGR kiss.PROG the child L dad* 'that dad who __ is kissing the child' 'that dad who the child is kissing __'	atyu na **tåta** i ha chichiku i patgun
Null Pronoun	atyu i ha chichiku na **tåta** *that the AGR kiss.PROG L dad* 'that dad who he is kissing __' ✓ PAH ('that dad who __ is kissing him') * PAH	atyu na **tåta** i ha chichiku

Table 5 Example item set from Experiment 2: Verb Type × RC Type

The RC is underlined, and the head is in bold. Word-by-word glosses and translation are given for prenominal RCs only. An underscore in the translation indicates the possible gap site. Translations are identical across RC Type, and so are glosses, modulo word order. Translations of the Null Pro condition are annotated to indicate compliance with (✓) or violation of (*) the PAH.

4.3 Materials

Thirty-two item sets were constructed. The item sets were composed as 16 matched sets, each of which used the same two nouns but counterbalanced them for position. We used mostly the same

verbs (and pictures) as in Experiment 1, but we changed 2 verbs and omitted another based on error rates in Experiment 1 and participant debriefing (see the Appendix). Eight lists of 32 items were formed, with the constraint that, for each pair of matched sets, we could not use the same condition from both sets. Finally, 24 unambiguous RCs were used as fillers: 8 formed from intransitive verbs and 16 formed from passive or antipassive forms of transitive verbs. The experiment consisted of 40 trials in total.

Each stimulus was composed of the carrier frame from Experiment 1 (repeated below), followed by an RC.

(12) Chonnik i puti'un guatu gi ___

push the star there LOC

'Push the star over there to ...'

In addition, the carrier frame was preceded by a context-setting instruction which served to make the null pronoun felicitous when it was present. The instruction consisted of the imperative *atan* 'look at' followed by an NP that introduced what we call the (discourse) topic. (15) gives the three context-setting instructions used for the item set in Table 5, which were counterbalanced across presentations.[6]

[6] For Null Pronoun conditions, the topic was always the same as the RC head. For the other conditions, the topic was sometimes the same as the head (15a), other times the same as the RC-internal NP (15b), and still other times the general NP *i litråtu siha* 'the pictures' (15c). There was an equal split between topics that were linked to the NP within the RC and those that were not. For the experimental sentences, the ratio of types of topic was 2 (*Topic≠Head)* : 1 (*Topic=Head*) : 1

(15) a. Atan i tata. *Topic ≠ RC Head*
look.at the father
'Look at the dad.'

b. Atan i patgun. *Topic = RC Head*
look.at the child
'Look at the child.'

c. Atan i litråtu siha. *Topic = General*
look.at the picture PL
"Look at the pictures."

4.4 Analysis

Picture choice data were analyzed using logistic mixed-effects regression. For the regression analysis, the RC Type conditions were coded by two coefficients using sum contrasts. The first coefficient, RC.TYPE, contrasted postnominal RCs with prenominal RCs (postnominal coefficient: +1/2). The second coefficient, NP.TYPE, contrasted RCs containing an Overt NP with those containing a Null Pronoun (Overt NP coefficient: +1/2). Maximal random effects structure was included, nesting the two fixed effects under both subjects and items. Models were estimated using the *lme4* package in R.

(*Topic=General)*. For the filler sentences, topics were equally balanced between *Topic=Head* and *Topic=General.*

We examined latency data with the same methods as Experiment 1. As before, we excluded trials on which the participant repeated the stimulus. Initiation times less than 0 ms were excluded, which was about 1.5% of the data; an equal fraction of the most extreme positive values were also trimmed, resulting in an approximate range of 0 to 9200 ms.

Data from 4 speakers were removed for having too many errors on the filler sentences.

4.5 Results

Overall, subject gap interpretations were selected on 75% of trials when the RC contained an Overt NP, but only on 13% of trials when the RC contained a Null Pronoun. NP Type thus affected the interpretation of the gap, consistent with the PAH. When the RC contained a Null Pronoun, the subject gap interpretation was highly disfavored. This is because an RC with a subject gap and null pronoun object would violate the PAH (see 4.1). Consequently, object gap interpretations prevailed. Table 6 gives the SGP for transitive RCs by RC Type and NP Type.

Above and beyond this, for the two Overt NP conditions, which matched conditions from Experiment 1, we observed a replication of the effect of head-RC order on the SGP. There were more subject gap responses for postnominal RCs (97%) compared to prenominal RCs (54%). Interestingly, this asymmetry was also present in the Null Pronoun conditions, even though the overall SGP was depressed. While prenominal RCs with a null pronoun gave rise to almost no subject gap interpretations (4%), postnominal RCs gave rise to a more considerable SGP (21%). This supports the claim that head-RC order affects the preferred position of the gap. It further shows that the PAH is a strong pressure in comprehension but it is not inviolable.

	Subject gap interpretations			*Logistic regression*			
				Coefficient	Estimate	*z*	P(>|*z*|)
	Overt NP	Null Pronoun		RC TYPE	3.50 (.61)	5.7	<.001
Postnominal	97 (1)	21 (2)		NP TYPE	5.79 (.66)	8.8	<.001
Prenominal	54 (3)	4 (1)		RC×NP	1.36 (.81)	1.7	<.10
	75 (3)	13 (2)		INTERCEPT	-0.60 (.23)	-2.5	<.05

Table 6 **Experiment 2: Subject gap interpretation rates by NP and RC Type**

The left-hand column gives the choice rate for pictures corresponding to subject gap interpretations, expressed as percentage. The standard error, calculated over item means, is reported in parentheses.

The right-hand column gives the results of the mixed-effects logistic regression: the fixed-effect coefficients, expressed in logits, with standard error in parentheses; the *z*-scores and corresponding *p*-value. The interpretation of coefficients is given in the analysis section. The maximal random effects structure that led to a convergent model included by-subjects and by-items intercepts and slopes for RC TYPE and NP TYPE, but not for their interaction.

In Experiment 1, we observed that the subject gap responses were earlier in prenominal RCs. We wanted to know whether the same thing held true in Experiment 2, so we first asked whether the median initiation time was earlier for subject gap responses compared to object gap responses for the 2 Overt NP (== ambiguous) conditions. In ambiguous prenominal RCs, the median initiation time for subject gap responses was 1705 ms, compared to 1982 ms for object gap responses. The 95% confidence interval on the object-subject difference was [724 ms, -173 ms] (8.9% of bootstrap differences < 0). We also directly examined the CDFs of subject versus object gap responses, which are given in Figure 5. It shows that there was a greater fraction of subject gap responses than object gap responses for the earliest initiation times (as in Experiment 1, approximately less than 2000 ms).

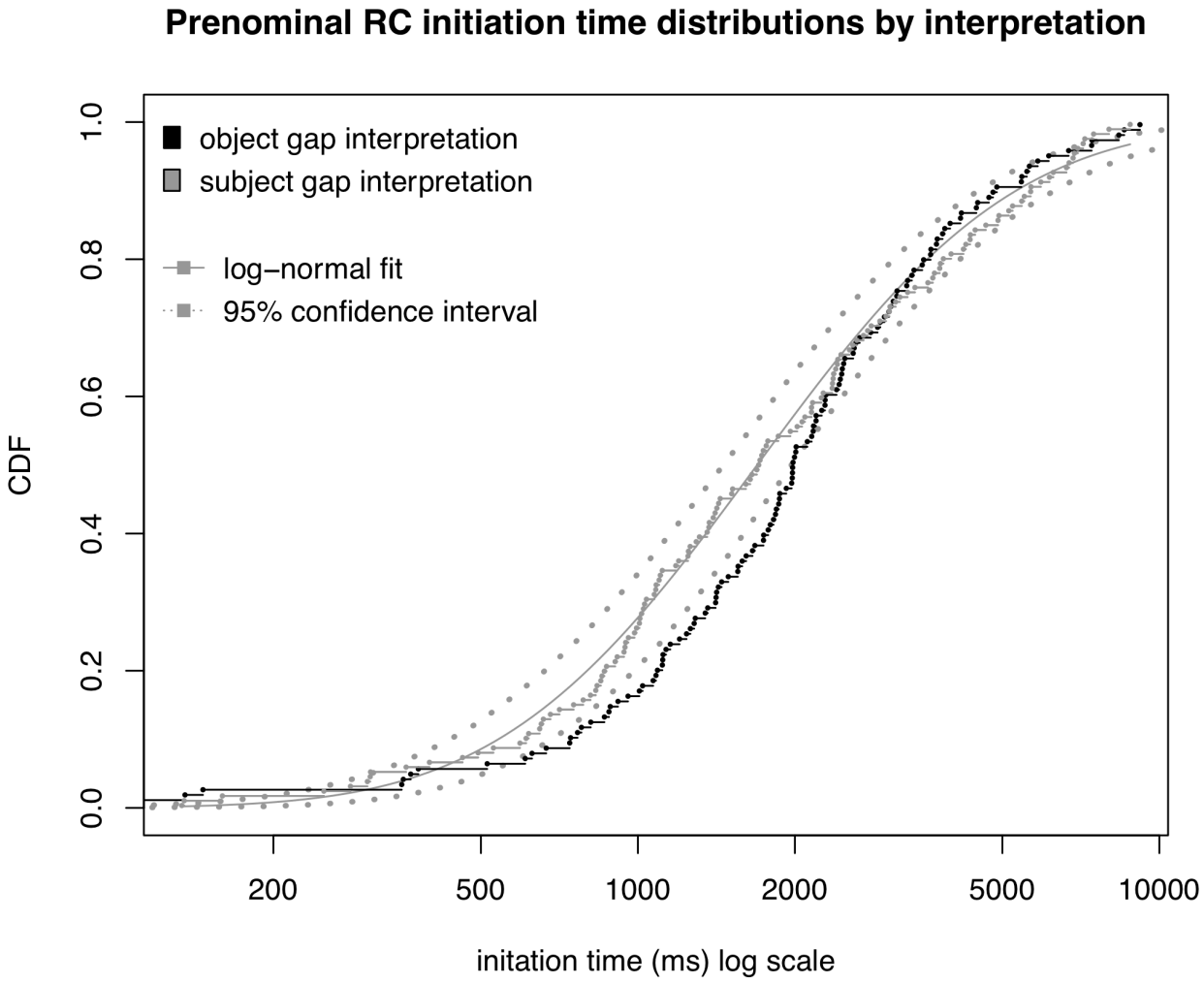


Figure 5 Experiment 2. The empirical cumulative density functions of initiation times for subject and object gap interpretations are compared for prenominal RC conditions. For early initiation times, there is a larger fraction of responses for subject gap interpretations, but this shifts over the response interval. Solid, black symbols: CDF for object gap responses. Solid, gray symbols: CDF for subject gap responses. Log-normal fit to the subject gap responses is plotted with a solid gray line and its 95% confidence interval indicated by a dotted gray line. Data plotted on log ms scale.

If we turn to the Null Pronoun conditions, for which the subject gap response is incompatible with the PAH, we found that there were only 13 PAH-violating subject gap responses in prenominal RCs. However, there were nearly five times as many in postnominal RCs. So we then asked how the initiation times of these PAH-incompatible subject gap responses compared to the

PAH-compatible object gap responses. Despite being the minority response, and incompatible with the PAH, we found that the median initiation time was once again faster for subject gap responses: 932 ms, compared to 2777 ms for object gap responses. The 95% confidence interval on the object-subject difference was [1446, 153] (<1% of bootstrap differences less than 0).

5. General Discussion

5.1 Overlapping Pressures in Incremental Relative Clause Processing

In Experiment 1 and Experiment 2 we identified three generalizations about how Chamorro relative clauses are interpreted. We refer to them as *head-RC order, subject gap earliness*, and *morphological informativity.*

Head-RC order. Prenominal RCs and postnominal RCs differed in how amenable they were to subject gaps. This was reflected in two ways. In both experiments, the preference for subject gaps was much stronger in postnominal RCs than in prenominal RCs. In prenominal RCs, object gaps were even slightly preferred in Experiment 1. This finding was echoed in Experiment 1 by the pattern of error rates for unambiguous RCs—RCs in which the verb showed wh-agreement. When wh-agreement indicated a subject gap, error rates were lowest in postnominal RCs and highest in prenominal RCs. When wh-agreement indicated an object gap, error rates were lowest in prenominal RCs and highest in postnominal RCs.

Subject gap earliness. We found that subject gap responses were initiated sooner than object gap responses, even when the environment ultimately promoted an object gap response. Participants took longer, on average, to respond to prenominal RCs, and when they did respond, they were more likely to give subject gap responses at first. The same pattern was observed in headless RCs. This

finding is more qualified than the head-RC order generalization, in a way which depended on the two ways we analyzed the initiation time distributions.

Morphological informativity. In Experiment 1, wh-agreement provided a cue to disambiguation. In Experiment 2, the null pronoun within the RC depressed the preference for subject gaps, because a subject gap interpretation would have violated the PAH. These aspects of the morphosyntax emerged as pressures in comprehension but were nonetheless subordinate to the mechanisms that give rise to head-RC order and subject gap earliness. In Experiment 1, the error rates for wh-agreement were affected by RC order, as discussed above. In Experiment 2, despite the fact that the PAH ought to force an object gap interpretation for these RCs, we found a sizeable minority of subject gap responses (21%) for postnominal RCs containing a null pronoun. These were initiated faster than the PAH-compliant object gap responses.

Do any of the existing frameworks for analyzing incremental RC processing provide a way to understand these generalizations? First, let us consider the contribution of memory.

The finding that prenominal RCs encourage more object gap responses may be related to analogous claims for prenominal RCs in Mandarin (Hsiao & Gibson, 2003; Gibson & Wu, 2013). Although the preponderance of recent research suggests that there probably is no object gap advantage in Mandarin (Vasishth et al., 2013), we think that prenominal RCs in Chamorro clearly do promote an object gap interpretation. In both experiments we found relatively more object gap interpretations in prenominal RCs than in postnominal RCs; moreover, in Experiment 1 we found absolutely more object gap interpretations than subject gap interpretations in the ambiguous prenominal RCs. The constructions we investigated were unambiguously RCs from the beginning; they could not be mistaken for main clauses. But there were no morphosyntactic cues within the RC that indicated whether the gap was a subject or an object. In these ways, Chamorro main clauses

and RCs are different enough from Mandarin that we do not think we can straightforwardly port to Chamorro an account in terms of memory-based explanations (Gibson, 2000; Gordon, Hendrick, & Johnson, 2001; Vasishth & Lewis, 2005). Consider the schematic representations of Chamorro prenominal RCs in (16), in which potential other material, whether pronounced or unpronounced, is represented by dots.

(16) Dependency between Head and Embedded Verb in Prenominal RC

i [$_{RC}$ V ... NP ...] na **NP**

|------x------------|

Because Chamorro is a verb-first language, the verb in a prenominal RC is always separated from the head (in bold) by the RC-internal NP, which introduces a distinct discourse referent. Consequently, the distance between the embedded verb and the head is constant: the dependency that integrates the two must cross the RC-internal NP whether the RC is a SRC or an ORC. One might suggest instead that the dependency whose 'distance' must be minimized holds not between the head and the embedded verb, but rather between the head and the *position* of the gap.[7] Such a hypothesis would have to assume that the parser locates each type of gap in its own designated linear order in the input string. Specifically, subject gaps in Chamorro would always have to precede the direct object, and object gaps would always have to follow the subject. Granting this, the distance between the head and an object gap would indeed be shorter than the distance between the head and a subject gap in a prenominal RC, as shown in (17).

[7] We thank Shravan Vasishth for this suggestion.

(17) Dependency between Head and Gap in Prenominal RCs

a. *Subject Gap* i [$_{RC}$ V _ NP] na **NP**

|--x---------|

b. *Object* Gap i [$_{RC}$ V NP _] na **NP**

|--------|

In a theory embedded in the ACT-R framework (Lewis & Vasishth, 2005), a gap that was closer to the head noun, as is the object gap in the hypothetical representation (17b), could be retrieved more quickly and with fewer errors than a gap that was farther away. However, it is not clear to us what theoretical or empirical considerations would justify the assumptions underlying the representations in (17). The requirement that subject gaps and object gaps have fixed linear positions seems inconsistent with the evidence of Chamorro clauses with overt subjects and objects, which can have the word orders VSO or VOS, although VSO is the default (section 2). Just as important, an account in terms of head-gap distance would have nothing to say about subject gap earliness in prenominal RCs.

Next, let us consider the contribution of linguistic experience. Unfortunately, there is not enough Chamorro corpus data for us to be able to estimate the frequency of particular RC orders, the probability of subject gaps versus object gaps conditioned by RC type, and so on. Based on Chung's fieldwork and Borja's knowledge of the language, it seems safe to assume that prenominal RCs are less common than postnominal RCs. If it were true that comprehenders had more experience with postnominal RCs, then it would be reasonable for them to have sharper estimates of what is probable inside postnominal RCs than inside prenominal RCs. That could help make sense of the fact that the SGP is highly biased in postnominal RCs, and less biased in prenominal RCs.

But once again, such an account does not offer any purchase on why the dispreferred subject gap interpretations in prenominal RCs are among the earliest responses.

Another way to consider the role of linguistic experience is to ask how closely the word order inside RCs approximates the word order in main clauses. Clauses in Chamorro are verb-first, so it is conceivable that the RCs that are most similar to main clauses are prenominal (though recall that the determiner at the left edge of a prenominal RC clearly indicates its RC status). If prenominal RCs have a word order more analogous to that of main clauses, then perhaps the string *V NP na NP* would be preferentially analyzed as VSO, consistent with an object gap interpretation. There are several difficulties with this reasoning, some of which have been mentioned earlier: (i) Clauses can be VSO or VOS, although VSO is the default. (ii) VO order is very common because the subject is often a null argument. Finally, (iii) the word order VO is common because subjects frequently occur at the right edge of the clause (Chung, 1998). None of these observations invalidates an attempt to build a theory of RC parsing based on canonical word order. However, as with an account in terms of head-gap distance, they raise the issue of what the 'grain-size' is of the word order pattern that most strongly determines the RC parse.

Finally, we consider universalist accounts that claim that subject gaps are the easiest to posit by virtue of the syntactic prominence of the subject. There are a variety of such theories, for example the Accessibility Hierarchy (Keenan & Comrie, 1977) and the Minimal Chain Principle (De Vincenzi, 1991). Such theories comport well with subject gap earliness. But they do not offer any understanding of the head-RC order generalization—namely, that subject gaps were *dispreferred* in prenominal RCs. Incidentally, it doesn't really matter what kind of universalist account is proposed—it might be phrased in terms of grammatical features such as case or semantic role. Those accounts too would have to explain why the RC order matters, all else equal.

Because none of these frameworks on its own explains the full range of findings, we offer a hybrid hypothesis for Chamorro that incorporates insights from all of them.

5.2 Maximize Incremental Well-Formedness

At the core of our theory is the idea that comprehenders attempt to incrementally satisfy as many grammatical licensing requirements as they can. Their ability to do so is subject to two factors: **timing**—when evidence for a licensing requirement becomes available; and **quality**—how strong or informative the evidence is that would enable the requirement to be satisfied. We believe this idea is widely shared in some form or other (Pritchett, 1992; MacDonald, Pearlmutter, & Seidenberg, 1994; Stevenson & Merlo, 1997; Aoshima, Weinberg, & Phillips, 2004; Smolensky & Legendre, 2006).

Licensing requirements can be language-general or language-particular. We propose that the comprehension of RCs in Chamorro is guided by two language-general requirements: (i) the drive to complete an open filler-gap dependency, which incorporates a preference for subject gaps (as in the Accessibility Hierarchy or the Minimal Chain Principle) and (ii) the drive to identify the subject, which holds for all types of clauses. In Chamorro, as an RC unfolds, evidence for an open filler-gap dependency is encountered first. This leads to the early but defeasible commitment that the gap is the subject of the RC, and derives the generalization of subject-earliness. The timing and strength of the evidence for the identity of the RC's head and the RC's subject depend on the type of RC being parsed. When the head precedes the RC, the drive to complete the filler-gap dependency and to identify the RC's subject can be satisfied simultaneously by linking the head noun to the subject gap. When the head follows the RC, the drive to identify the RC's subject can be satisfied by the RC-internal NP at a point before the head is encountered. This, we claim, derives

the generalization of head-RC order. Over and above this, the influence of morphological informativity can be traced to two Chamorro-specific requirements, namely, (iii) wh-agreement and (iv) the PAH.

We illustrate our theory with the three types of ambiguous RCs investigated earlier: postnominal, prenominal, and headless. Consider first the postnominal RC in (18). The RC (underlined) contains a transitive verb with normal subject-verb agreement. Three approximate time points are indicated by circled numerals, corresponding to the introduction of crucial morphemes. At each time point, comprehenders will try to interpret the string so that as many open dependencies as possible are satisfied.

(18) ① ② ③

atyu na låhi i ha chichiku i patgun

that L man C AGR *kiss.PROG the child*

'that man who the child is kissing __' or 'that man who __ is kissing the child'

At time point ①, the comprehender encounters the RC complementizer *i*. This provides evidence for an open filler-gap dependency in which the filler is the head *låhi* 'man', which is already known. Although there is no evidence yet about the gap's syntactic position within the RC, the parser makes the defeasible assumption that it is the subject.

At time point ②, the comprehender encounters the verb of the RC, which activates various open dependencies. The verb's argument structure signals that it must be integrated with two NPs, the subject and the object, and its agreement signals that the subject is third person singular. This information is compatible with the parser's early commitment from ① that the gap, which forms a dependency with *låhi*, is the subject of the RC. Although nothing prevents the gap from being

linked instead to the object, doing so would require an unforced reanalysis and would leave the verb-subject dependency unresolved.[8]

At time point ③, the comprehender encounters the RC-internal NP *i patgun* 'the child'. The only licensing requirement that remains open is the verb-object dependency. Integrating *i patgun* as the object satisfies this requirement and requires no changes in previously made commitments. Although it would be possible for *i patgun* to be integrated as the subject of the RC, nothing motivates this reanalysis, so the default is for commitments made earlier to persist.

The subject gap analysis emerges as the strong favorite in the parsing of postnominal RCs from a combination of the timing of the initiation of open dependencies and the strength of the evidence used to resolve them. Because the head precedes the RC, an open filler-gap dependency is initiated first. The parser's early commitment to link the gap to the subject is consistent with the requirements that the verb imposes on the subject, so both dependencies are resolved simultaneously.

Next, consider a prenominal RC like (19). Here the timing of open dependencies and the quality of the evidence used to resolve them pull apart.

(19) ① ② ③

atyu i ___ ha chichiku i patgun na låhi

that C AGR *kiss.PROG* *the child* *L* *man*

'that man who the child is kissing __' or 'that man who __ is kissing the child'

[8] In RCs in which the verb shows object wh-agreement, such as (8a), this reanalysis would be motivated.

At time point ①, the comprehender encounters the RC complementizer, which provides evidence for an open filler-gap dependency. Here the quality of the evidence for both gap and filler is low, given that there is no information yet about the gap's syntactic position within the RC and the head of the RC has not yet been encountered. At this point, the parser makes the defeasible assumption that the gap is the subject.

At time point ②, the comprehender encounters the verb of the RC, which activates the open dependencies described earlier. These open dependencies are consistent with the parser's early commitment from ①, but the commitment remains weak in the absence of better evidence about the RC head.

Finally, at time point ③, the comprehender encounters the NP *i patgun* 'the child'. This NP presents the opportunity to resolve the open verb-subject dependency by integrating the verb with an overt constituent with descriptive content (as opposed to a hypothesized null element whose meaning would have to be recovered from context). We hypothesize that the strength of this evidence for resolving the verb-subject dependency outcompetes the parser's earlier commitment to link the gap to the subject, so the parser analyzes *i patgun* as the subject of the RC and reanalyzes the gap as the object.

Consistent with this, we found that most comprehenders preferred the object gap analysis for prenominal RCs, but the trials in which they selected the subject gap analysis were faster. In those trials, the subject gap analysis was never defeated and so the comprehender's initial commitment (at time point ①) persisted.

Finally, consider the headless RC in (21). Parsing at time points ① and ② proceeds in the same way as for the prenominal RC in (19).

(20) ① ② ③

atyu i ha chichiku i patgun

that C AGR.*kiss.PROG* *the child*

'that one who the child is kissing __' or 'that one who __ is kissing the child'

As in the prenominal RC, the overt NP encountered at time point ③ provides high-quality evidence for resolving the open verb-subject dependency. This should favor the object gap analysis. However, we found a much higher SGP for headless RCs compared to prenominal RCs (69% v. 43%). We hypothesize that, at time point ③, the comprehender also encounters prosodic evidence which indirectly identifies the RC head as null. This evidence is indirect and therefore weak: the acoustics of the signal at time point ③ could indicate that the RC-internal NP is utterance-final and therefore that there is no overt head. However, it is consistent with the parser's initial commitment to the subject gap analysis at time point ①. These two weak sources of evidence for the subject gap analysis are cumulatively enough to withstand one strong source of evidence for the object gap analysis on a substantial number of trials.

5.3 The Preference for Subject Gaps

In the theory we sketched above, is there any need for the claim that fillers are preferentially linked to subject gaps? Or could an apparent subject gap preference stem from the coincidental satisfaction of other licensing requirements, such as the need to complete the filler-gap dependency and the need to identify the subject? The error rates from Experiment 1 provide one source of evidence bearing on this issue. In Experiment 1, there were three unambiguous verb types with distinctive morphology: passive verbs, subject wh-agreement verbs, and object wh-agreement verbs. For these verb types, the most surprising result was the high error rate for object wh-agreement in

postnominal RCs. We interpret this as evidence that postnominal RCs strongly favor a subject gap analysis, independent of the verb's morphology. Consistent with this, verbs with subject wh-agreement in the same environment gave rise to the lowest error rate. In prenominal RCs, on the other hand, the error rates for subject wh-agreement and object wh-agreement were comparable (though the object wh-agreement error rate is somewhat lower than the subject wh-agreement error rate).

These patterns suggest that when comprehenders initially posit an open filler-gap dependency, they preferentially link the gap to the subject, even before encountering the verb of the RC. As Keenan and Comrie (1977, p. 94) put it: "If an NP plays a role in another clause, interpret it as a subject unless there are indications to the contrary." Object wh-agreement provides an indication to the contrary—but notably this morphological evidence does not entirely overcome the comprehender's initial commitment to a subject gap interpretation. Postnominal and prenominal RCs differ nonetheless in that the initial subject gap analysis is strengthened in postnominal RCs, because the identity of the head is already known.

The same reasoning applies to the unambiguous RCs in Experiment 2. When there is a null pronoun inside the RC, the gap should be the object, because identifying it as the subject would violate the PAH. As with object wh-agreement in Experiment 1, there was a sizeable minority of subject gap interpretations in the postnominal RCs (21%), but fewer in the corresponding prenominal RCs (4%). This pattern is expected if comprehenders make an initial commitment to subject gaps before even encountering the verb and its licensing requirements – a relatively strong commitment in the case of postnominal RCs, and a weaker, more defeasible commitment in the case of prenominal RCs.

Although the patterns in the unexpected subject gap interpretations are the same, we note that the cues are impressionistically different: wh-agreement involves distinctive verb morphology, whereas the PAH requires a comparison of the verb's two arguments.

5.4 Variation Across the Lifespan

Because our participants spanned a wide age range—from 19 to 70 years—we could also ask whether younger and older speakers perceive ambiguous RCs in the same way. Older speakers of Chamorro often express the view that younger speakers have an incomplete command of Chamorro word forms, or favor constructions that are superficially similar to English. However, our data suggest that younger speakers do not differ significantly from older speakers in how they comprehend ambiguous RCs. The youngest participants in our experiments did perform more errorfully on unambiguous RCs that contained complex word forms, such as wh-agreement. However, this was only true for RCs containing an overt head, whether they were prenominal or postnominal. Younger speakers performed comparably to older speakers on headless RCs, which are superficially not very English-like at all. We tentatively conclude that younger speakers have no trouble interpreting complex Chamorro words—specifically, verbs inflected with wh-agreement. We suggest instead that they might be more resource-sensitive than older speakers, who are likely to use Chamorro more frequently.

We performed an age-based analysis on the data from Experiment 1, which included prenominal, postnominal, and headless RCs. We split our participants into quintiles by age, resulting in the following five age-bands: (20, 32], (32, 39], (39, 44], (44, 54], and (54, 70]. For each age band, we calculated the SGP for ambiguous RCs as well as the error rates for each unambiguous RC. Figure 6 reports these averages.

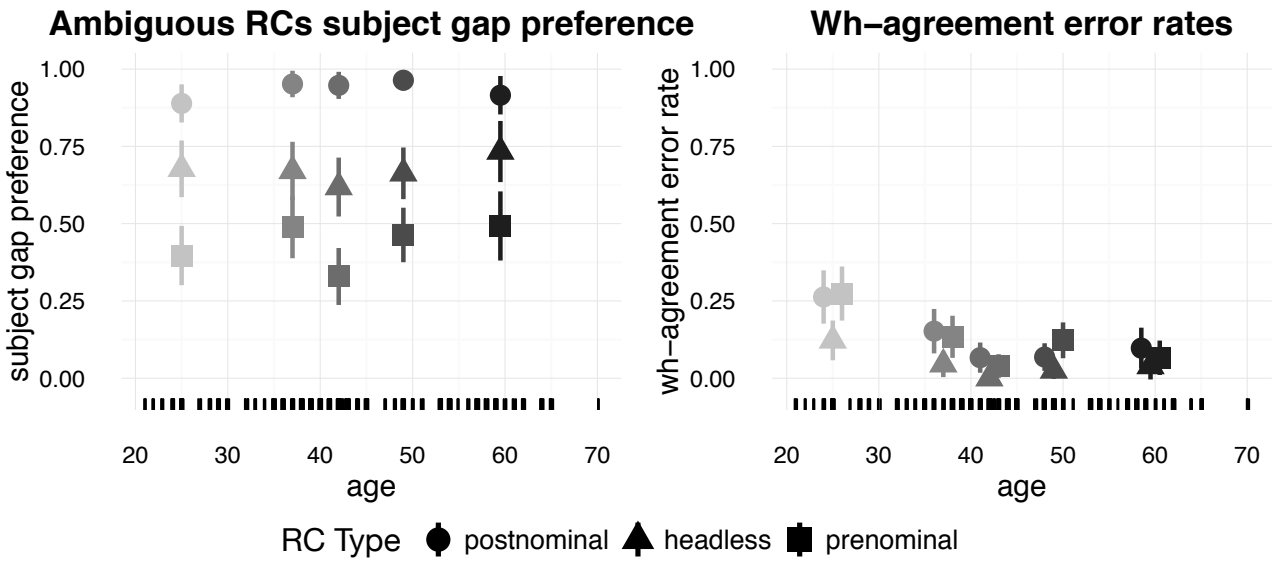


Figure 6 *Left panel.* Age-related differences in subject gap preference rates for ambiguous RCs from Experiment 1. *Right panel.* Age-related differences in error rates for unambiguous RCs from Experiment 1. Participants were grouped into 5 age quintiles (details in text), here represented by the median age in each group (and light to dark shading). Symbol shapes correspond to RC Type.

There was limited age-related variation in how the ambiguous RCs were interpreted. In all five age-bands, speakers interpreted postnominal RCs as predominantly containing subject gaps (range: 89-96% SGP), headless relative clauses as mostly containing subject gaps (62-68% SGP), and prenominal RCs as containing object gaps (33-49% SGP). The range of variation was greatest for prenominal RCs.

The unambiguous RCs in Experiment 1 contained verbs that were passive or inflected for wh-agreement. Here we only include verbs with wh-agreement. Error rates were highest on RCs with object wh-agreement, reaching 47% for postnominal RCs, compared to a minimum error rate of 11% achieved by speakers in the (39, 54] age bands. However, when the same age bands are compared for headless RCs, there was no great disparity: error rates ranged from a minimum of 0% for speakers aged (39, 44] up to 8% for both the very youngest and very oldest speakers. We take

this to demonstrate that the youngest speakers can interpret the information provided by object wh-agreement. We conjecture that younger speakers are more heavily impacted by the demands imposed by the twin tasks of comprehending a complex noun phrase containing an RC: namely, restricting the head with its relative clause modifier and linking the verb of the RC to its arguments. At least the first of these tasks is simplified when the head is null. An alternative explanation could be that younger speakers perform best in a Chamorro language processing task on stimuli that are most like 'garden-variety' Chamorro and least similar to English. In this connection, note that most sentences formed from transitive verbs in Chamorro narrative discourse contain just one full NP rather than two (Cooreman, 1987).

5.5 Conclusion

Evidence from two experiments reveals that in Chamorro, a verb-first language, the comprehension of RCs is sensitive to the order of the RC with respect to the head. This claim has previously been advanced for other languages, but so far the supporting evidence has been comparative: data from languages with exclusively postnominal RCs, such as English, has been compared to data from languages with exclusively prenominal RCs, such as Mandarin or Basque. What is novel about our study is that Chamorro allows both types of RCs, so that all factors besides the relative order of RC and head can be held constant. Our findings clearly indicate that RC comprehension is affected by head-RC order as well as other language-specific factors, such as wh-agreement and the PAH. However, we also found new support for a language-general factor: regardless of the relative order of RC and head, a subject gap advantage emerged in early response measures. This advantage was reinforced in postnominal RCs, but often outcompeted in prenominal RCs by other pressures, such as the drive to identify the subject, which we assume is language-general, or the PAH, which is

clearly language-particular. We framed this competition in terms of a model in which licensing requirements play a key role in comprehension. Constituents which are directly encountered are more successful at satisfying a licensing requirement than those whose presence is merely inferred. The fact that the head of the prenominal RC remains 'unseen' for much of the parsing process allows other open dependencies to exert greater influence. Consequently we expect more variable results in the recognition and interpretation of prenominal RCs: a fact we observe in Chamorro, and one which we expect to observe more generally in languages with similar syntactic characteristics.

Our account does not posit any parsing pressures that are RC-specific: all theories of language comprehension must incorporate mechanisms for resolving filler-gap dependencies and identifying the subject of the clause. The only feature of our analysis that is not universally shared by other theories of parsing is the assumption that, all else being equal, subject gaps are favored. The Chamorro results reported here constitute novel evidence for the view that this subject gap preference is language general.

6. Supplementary Material

Data, experimental materials and analysis scripts may be found at the following URL: https://osf.io/b8zwq/ (DOI: 10.17605/OSF.IO/B8ZWQ).

Appendix. Chamorro Verbs and Noun Pairs used in Experiments 1 and 2

Verb	*Notes*		**Noun Pairs**			
dengkut		*peck*	sihik	*kingfisher*	gåyu	*rooster*
tugung		*charge at*	katu	*cat*	ga'lågu	*dog*
kadidak		*tickle*	påtgun	*child*	biha	*old lady*
lasa		*massage*	låhi	*man*	palåo'an	*woman*
galoppi	◦	*jump over*	kairu'	*frog*	guali'ik	*gecko*
dispidi	1	*bid farewell*	biha	*old lady*	låhi	*man*
dingu	2	*depart (tr.)*				
tattiyi	1,*	*follow*	chiba	*goat*	kabåyu	*horse*
dalalaki	2					
de'un		*pinch*	palåo'an	*woman*	påtgun	*child*
dulalak		*chase*	gåyu	*rooster*	ga'lågu	*dog*
chiku		*kiss*	påtgun	*child*	låhi[1]/tåta[2]	*man/dad*
paini		*comb*	biha	*old lady*	palåo'an	*woman*
gatcha'		*step on*	babui	*pig*	chiba	*goat*
påtik		*kick*	kabåyu	*horse*	babui	*pig*
oflak		*lick*	kairu'	*frog*	katu	*cat*
hongngang	1,*	*startle*	guali'ik	*gecko*	sihik	*kingfisher*
patcha		*touch*	doktu	*doctor*	påtgun	*child*
patmåda		*slap*	palåo'an	*woman*	doktu	*doctor*
ngingi'	◦	*kiss hand*	doktu	*doctor*	biha	*old lady*

Notes

[1] Used only in Experiment 1

[2] Used only in Experiment 2

***** Removed from analysis in Experiment 1

° The *ngingi'* is a traditional gesture of respect in which one sniffs or kisses the back of an elder's right hand.

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