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Four-year-old Cantonese-speaking children's online processing of relative clauses: A permutation analysis.

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Acknowledgements: This research was supported by 1-ZVB8 (PI: Chan), awarded by The Hong Kong Polytechnic University, and CE140100041 (CI: Kidd), awarded by the Australian Research Council. Angel Chan is a member of the The Hong Kong Polytechnic University-Peking University Research Centre on Chinese Linguistics and its support is gratefully acknowledged. Franklin Chang and Evan Kidd are members of the ESRC International Centre for Language and Communicative Development (LuCiD) and the support of the Economic and Social Research Council [ES/L008955/1] is gratefully acknowledged. Data and R code for our analyses can be found at http://sites.google.com/site/sentenceproductionmodel/permutationanalysis. We thank Elizabeth Wonnacott and two anonymous reviewers for helpful comments.

Abstract

We report on an eye-tracking study that investigated 4-year-old Cantonese-speaking children's on-line processing of subject and object relative clauses (RCs). Children's eye-movements were recorded as they listened to RC structures identifying a unique referent (e.g., *Can you pick up* *the horse that pushed the pig?*). Two RC types, classifier (CL) and *ge3* RCs, were tested in a between-participants design. The two RC types differ in their syntactic analyses and frequency of occurrence, providing an important point of comparison for theories of RC acquisition and processing. A permutation analysis showed that the two structures were processed differently: CL RCs showed a significant object-over-subject advantage, whereas *ge3* RCs showed the opposite effect. This study shows that children can have different preferences even for two very similar RC structures within the same language, suggesting syntactic processing preferences are shaped by the unique features of particular constructions both within and across different linguistic typologies.

Key words: Cantonese; Relative Clauses; On-line Processing, Permutation Analysis.

Cantonese-speaking 4-year-olds' online processing of relative clauses: A permutation analysis.

The acquisition and processing of relative clauses (RCs) has received an enormous amount of interest in the psycholinguistic literature (e.g., Kidd, 2011; Gibson, 1998; MacDonald, 2013). This focus has been driven by the fact that RC processing is assumed to largely reflect syntactic processes (as opposed to other processes like ambiguity resolution, though see Gennari & MacDonald, 2008; Hale, 2006; Yun, Chen, Hunter, Whitman, & Hale, 2015). Most research to date has been conducted on languages like English, German, and Hebrew, which are right-branching and have post-nominal (i.e., head initial) RCs. The general conclusion from this body of research is that, with some qualifications (e.g., Diessel & Tomasello, 2000; Kidd, Brandt, Lieven, & Tomasello, 2007), subject RCs like (1) are typically acquired earlier and are easier to process than object RCs like (2).

(1) The dog [that bit _ the bear].

(2) The dog [that the bear bit _].

Several explanations for this asymmetry exist. For instance, drawing upon formal grammatical theory, structurally-oriented theories attribute the difference to the fact that object RCs are hierarchically more complex than subject RCs (e.g., Frazier, 1987; Friedmann, Belletti, & Rizzi, 2009). Specifically, these models follow Chomskyan syntactic theory in assuming greater hierarchical distance between the head noun and the gap in object RCs in comparison to subject RCs. However, formal explanations fail to explain why object RCs are not more difficult than subject RCs in all instances (Kidd et al., 2007; Traxler, Morris, & Seely, 2002), why processing difficulty can be attenuated following increases in exposure through priming (Hutton & Kidd, 2011; Wells, Christiansen, Race, Acheson, & MacDonald, 2009), or why difficulties in on-line processing of object RCs are not exclusively syntactic (Bornkessel-Schlesewsky & Schlesewsky, 2009; Weckerly & Kutas, 1999).

Several alternative models do not assume that the parser builds hierarchical phrase structure trees from which meaning is read, instead assuming a linear left-to-right parsing system which, depending on the specific theory, attributes the difficulty associated with object RCs to different phenomena. These include (i) differences in the linear distance between filler and gap (greater for object RCs, Gibson, 1998), (ii) differences in frequency (object RCs often contain infrequent non-canonical word orders and rarely occur with two animate NPs, Ambridge, Kidd, Rowland, & Theakston, 2015; MacDonald & Christiansen, 2002), and (iii) cross-linguistic tendencies favouring relativisation on subject over direct object NPs (Keenan & Comrie, 1977). While explaining many of the effects that formal accounts fail to explain, no single explanation appears to cover the full range of empirical facts (for a good discussion see Kim & O'Grady, 2015).

Therefore, despite intense research over several decades, a comprehensive account of RC acquisition and processing has remained elusive. Recently researchers have begun to test these competing theories in typologically different languages that provide opportunities to tease apart predictions of theories in ways that investigating most European languages do not allow. For instance, studies of Basque have revealed a processing advantage in comprehension for object RCs in both children and adults (Carreiras, Duñabeitia, Vergara, de la Cruz-Pavía, Laka, 2010; Gutierrez-Mangado, 2011). Data from other highly inflected languages show no subject-object asymmetry (e.g., Finnish: Kirjavainen, Kidd, & Lieven, 2017; Kirjavainen & Lieven, 2011; Quechua: Courtney, 2006). However, most attention has been focused on East Asian languages such as Chinese (Mandarin and Cantonese), Japanese, and Korean, to which we now turn.

RC acquisition in East Asian Languages

RCs in East Asian languages are typologically very different from RCs in well-studied languages like English and German. Most notably, they are prenominal, such that the

RC is placed before the head noun, as in the Japanese object RC example in (3) (from Ozeki, 2011).

(3) [papa kara moratta] yatu

Dad from received one

'The one [I was given by Dad]'.

The languages for which we have the most data are Japanese and Mandarin. In both cases the acquisition data are mixed and do not point to a uniform pattern across languages. In Japanese the data suggest no subject advantage in acquisition. In a longitudinal study of children's spontaneous speech, Ozeki and Shirai (2007; see also, Ozeki, 2011) found that Japanese-speaking children produce subject, object and oblique RCs at approximately the same rate from the onset of production, and their functions are very different from what has been described in well-studied languages like English and German (Diessel & Tomasello, 2000; Brandt, Diessel, & Tomasello, 2008). In experimental work, Suzuki (2011) found a significant object advantage in 5-year-old children, but once children's knowledge of case marking was controlled the difference was not significant. One source of this variability is a preference for shifting heavy RCs early in Japanese (Hakuta, 1981; Yamashita & Chang, 2001; Hawkins, 1994), which could increase the frequency of object RCs compared to languages without this early shifting bias like English.

The data from Mandarin are more inconsistent still. In acquisition studies of both comprehension and production, both subject and object advantages have been found, in addition to null effects (for a review see Chan, Matthews, & Yip, 2011). One potential reason for the inconsistency was discussed by Chan et al. (2011): Chinese (both Mandarin and Cantonese) possesses the typologically rare combination of SVO main clause word order and pre-nominal RCs (Dryer, 2005). This combination creates competing processing demands based on surface/linear structure and canonical word order, which favour object RCs, and the general prominence of subjects, which favour subject RCs. Consider Mandarin sentences (4) and (5):

(4) [$_{RC}$ __ $_i$ qin1 gong1ji1] de lao2shu3$_i$

kiss chicken PRT mouse

V O S

'The mouse that kisses the chicken'

(5) [$_{RC}$ xiao3yang2 tui1 __ $_i$] de xiao3tu4 $_i$

sheep push PRT rabbit

S V O

'The rabbit that the sheep pushes'

Sentence (4) is a subject RC and sentence (5) is an object RC. Mandarin subject RCs have non-canonical VOS word order and, in (4), the verb and its object complement separate the head noun (mouse) and the gap. In contrast, object RCs follow canonical word order and the linear distance between head noun (rabbit) and gap is shorter. These features favour object RC processing and appear to significantly affect acquisition. Chen and Shirai (2015) report that object RCs are produced about 60% of the time by children and adults (compared to 20% subject RCs), suggesting that children learning Mandarin prefer object RCs and that they occur more frequently in the input. In contrast, the general prominence of subjects in nominative-accusative languages pull in the direction of subject over object RCs, a fact which is captured across numerous theoretical traditions in linguistics (e.g., Keenan & Comrie, 1977; O'Grady, 2011; Rizzi, 1990) and psycholinguistics (Bornkessel-Schlesewsky & Schlesewsky, 2009). Therefore, unlike in languages such as English, where *all* these cues favour subject RC processing, in Chinese the cues compete. This may explain the mixed acquisition results.

Cantonese RC acquisition

The situation is mirrored in Cantonese, with some language-specific differences in RC formation that make it a particularly interesting language to study (Matthews & Yip, 2001). Cantonese has two common relativisation strategies, as shown in (6) and (7).

(6) [$_{RC}$ keoi5 gaan2 __$_i$] go2 lap1 tong2 $_i$

3SG choose that CL candy.

'The candy she chooses'.

(7) [$_{RC}$ keoi5 gaan2 __ $_i$] ge3 tong2 $_i$

3SG choose PRT candy.

'The candy(ies) she chooses'.

Sentence (6) is a *classifier* RC (henceforth CL RC), so-called because it contains the demonstrative *go2* and an appropriate classifier before the head noun. CL RCs are commonly used in spoken Cantonese, and are relatively informal in register. A more formal relativisation strategy that is similar to the structure in Mandarin Chinese is to mark the RC with the particle *ge3,* as in (7). Although the two can be used interchangeably in many cases, there is a semantic contrast between them: the CL RC entails specific reference, while the *ge3* RC does not and can be construed as quantifying over a set of candies. The *ge3* RC, therefore, is also not specified for number: both singular head and plural head readings are possible. For CL RCs with a plural head, for instance *the candies she chooses*, the classifier *di1* for plural objects and kinds is obligatory.

The two Cantonese RC types also differ in another interesting way that is relevant to acquisition. There is an isomorphism between object classifier RCs and simple main clauses, such that the object classifier RC in (6) is identical in surface form to a SVO main clause as in (8).

(8) keoi5 gaan2 go2 lap1 tong2

3SG choose that CL candy

'She chooses that candy'.

This structural overlap raises the possibility that children bootstrap into the syntax of RCs from their knowledge of simple transitives, predicting an early acquisition advantage for object RCs because children may use their early developed knowledge of canonical sentence patterns to acquire more complex syntactic patterns (Diessel, 2007). Chan et al. (2011) argue that during this process Cantonese-speaking children may analyse object classifier object RCs as internally headed RCs. Thus (6) can be analysed as (9):

(9) [$_{NP/S}$ keoi5 gaan2 go2 lap1 tong2]

3SG choose that CL candy.

'The candy she chooses'.

Under the internally headed RC analysis, sentence (9) has the internal structure of a SVO clause, but behaves as a NP in terms of its external syntax. The internally headed RC analysis is represented by the notation NP/S in (9) above, indicating a constituent having externally the syntax of a NP but internally that of a clause (S). The internal structure is a SVO main clause, with the object, which is also the head noun, *in situ*. Hence the head 'candy' is *internal* to the RC. This internally headed analysis is only possible for Cantonese object classifier RCs since it is only in this case where there is complete surface identity with simple clauses and therefore ambiguity of analysis. In contrast, while object *ge3* relatives have structural similarity (also SVO) they lack the surface identity relation because of the presence of the relative marker *ge3*.

Examples like (6) are attested in young children's naturalistic speech (Yip & Matthews, 2007). These utterances are structurally ambiguous as they can be analysed as head-final RCs (6) or internally headed RCs (9). Further suggestive evidence for the internally headed RC analysis comes from ill-formed child utterances in naturalistic speech (10) and experimental tasks (11) (examples from Chan et al., 2011; Yip & Matthews, 2007).

(10) ngo5 sik6 joek6 aa3 [$_{NP/S}$ ngo5 sik6 joek6] haai6 lei1zek3 (Alicia 2;08.10)

I eat medicine SFP I eat medicine is this CL

'I'm taking medicine. The medicine I take is this one.'

(11) Experimenter (in an elicited imitation task):

[$_{RC}$ baan1maa5 daai6lik6 tek3 gan2 __*i*] [$_{head\ noun}$ go2 zek3 coeng4geng2luk2*i*] hai2 lei1dou6

zebra big-force kick PROG that CL giraffe is here

'The giraffe that the zebra's kicking hard is here.'

Child (pointing to the particular giraffe that the zebra was kicking):

[$_{NP/S}$ baan1maa5 daai6 lik6 tek3 gan2 coeng4geng2luk2] hai2 lei1dou6

zebra big-force kick PROG giraffe is here

'The giraffe that the zebra's kicking hard is here.'

The second clause *'ngo5 sik6 joek6'* in (10) and the first clause from the child *'baan1maa5 daai6 lik6 tek3 gan2 coeng4geng2luk2'* in (11) are functionally noun-referring expressions, but structurally ill-formed because the demonstrative *go2* plus classifier or the particle *ge3* would be required in order to be grammatical. They are, however, consistent with the analysis whereby the children were using SVO clauses [$_S$ 'I take medicine'] and [$_S$

'zebra's kicking giraffe forcefully'] as internally headed RCs [$_{NP}$ 'I take medicine'] and [$_{NP}$ 'zebra's kicking giraffe forcefully'] to mean 'the medicine I take' and 'the giraffe that the zebra's kicking hard'.

To summarise, Cantonese has two relativisation strategies, one that is commonly used in spoken discourse (classifier RCs) and the other which is more formal (*ge3* RCs). For both RC types there is surface order overlap between object RCs and simple transitive sentences, both containing SVO word order. However, in object CL RCs there is complete surface identity between simple SVO sentences and object RCs, allowing for an internally-headed object RC analysis. These specific features of Cantonese lead to some interesting predictions regarding RC acquisition and processing. If, following Chan et al. (2011), simple transitives serve as a pathbreaking construction that allow children to bootstrap into the syntax of RCs (à la Abbot-Smith & Behrens, 2006), then we may observe a general object preference across the acquisition of all RC types. Furthermore, this advantage may be more pronounced for classifier RCs because: (i) they are generally more frequent in spoken Cantonese, and (ii) there is complete isomorphism with simple transitives, allowing them to be analysed as internally headed RCs, which do not involve gaps or extraction, are structurally simpler, and hence may be easier to process, than externally headed RCs.[1] Since *ge3* RCs are structurally similar to Mandarin *de* RCs, their performance in Cantonese can help us to understand how the formal structure of these RCs work under different input conditions.

To date there has been very little published research on Cantonese RC acquisition. In a naturalistic study of three bilingual children, Yip and Matthews (2007) reported that all children produced object classifier RCs before or simultaneously with subject RCs. Chan et al. (2011) discussed two unpublished studies investigating comprehension and production of

[1] In Korean, for instance, which has both head-final RCs and head-internal RCs attested, both children and adult L2 learners have been shown to acquire head-internal RCs earlier than head-final RCs (Jeon & Kim, 2007).

CL RCs only. The comprehension experiment used the picture selection methodology and revealed a significant object advantage. In contrast, the production experiment, which used the sentence imitation method, revealed a numerical but non-significant object advantage. In contrast, Lau (2016) reported on 3 – 5-year-old Cantonese-speaking children's comprehension of CL RCs using picture selection and reported a significant subject advantage. The difference between the Chan et al. and Lau studies was that, whereas Chan et al presented test RC structures in a supportive discourse context (thereby fulfilling the felicity conditions governing RC use, see Corrêa, 1995), the study reported in Lau did not. Lau also presented data from an elicited production experiment, which showed no overwhelming preference for either subject or object RCs.

In the only study that has simultaneously tested both classifier and *ge3* RCs, Kidd, Chan, and Chiu (2015) tested monolingual (mean age = 6;3) and Cantonese-English bilingual children (mean age = 8;11, groups matched on Cantonese verbal ability) using picture selection. They reported a non-significant object advantage in the monolingual group for both RC types, and a significant subject advantage for the bilingual group, which was more pronounced for CL RCs (an effect attributed to cross-linguistic influence from English). Therefore, across the small set of naturalistic and experimental studies that have tested monolingual children, the data point to a general although weak object advantage for CL RCs, at least when test structures are presented in a felicitous discourse context, whereas the data for *ge3* RCs are too preliminary to draw any firm conclusions.

Current research

In the current paper we report on a study that investigated 4-year-old monolingual Cantonese-speaking children's online processing of subject and object CL and *ge3* RCs. Children's eye-movements to toy referents were recorded while they heard test sentences containing a RC. There are several advantages to studying children's online processing. Most broadly, on-line data reveal complexity effects ‘in the moment’, giving a clearer indication of sentence difficulty than might be observed with off-line tasks, where such effects can be obscured by post-interpretative processes. This is important in the context of East Asian RCs, where results comparing subject and object RCs have been very inconsistent. With respect to Cantonese in particular, on-line data may reveal differences between the processing of classifier and *ge3* RCs that are not evident in offline data (e.g., Kidd et al., 2015).

There are a broad range of theoretical models that make predictions about RC acquisition and processing, and we do not have space here to do all of them justice. We instead contrast theoretical approaches that are relevant to the specific case of Cantonese. Firstly, several models from a variety of traditions predict a universal subject preference across all languages (e.g., Bornkessel-Schlesewsky & Schlesewsky, 2009; Friedmann et al., 2009; Keenan & Comrie, 1977; Vasishth, Chen, Li, & Guo, 2013; Yun et al., 2015), and so predict a general subject preference for CL and *ge3* RCs. In contrast, several different models predict either a no preference or an object preference. For instance, O’Grady (2011) attributed the aforementioned mixed results for Chinese RCs to a conflict between a general preference to relativise on subjects and differences in filler-gap distances between subject and object RCs, which are shorter in the case of object RCs. The implication is that these two influences on RC interpretation pull in opposite directions, and may therefore neutralise any potential asymmetry.[2] Usage-based approaches predict earlier acquisition of object RCs in Cantonese because of their similarity to simple transitive sentences (Diessel, 2007). For example, Fitz, Chang, and Christiansen (2011) found that substructure similarity between different RC constructions influenced the ease of learning the constructions over development. This predicts a difference between the CL RCs and the *ge3* RCs, since simple transitives do not include the *ge3* marker.

[2] Note this is our interpretation of O’Grady (2011), who does not explicitly make this prediction.

Method

Participants

Seventy (N = 70) typically-developing monolingual 4-year-old Cantonese-speaking children were recruited from preschools in Hong Kong. Sentence type was tested between-participants (i.e., CL versus *ge3*). Since we were interested in children's online processing of sentences when they correctly interpreted the RC, we excluded children whose accuracy was too low to provide an accurate record of their eye-movements. We set the inclusion criterion to 50% overall comprehension accuracy. For CL RCs this meant that 18 out of 37 children were excluded, and 15 of 33 children excluded for *ge3* RCs (final N = 37). The final sample for the CL condition therefore consisted of 19 children aged between 4;3 and 4;9 (Mean =4;7, SD =0;2), and for the *ge3* condition consisted of 18 children aged between 4;3 and 4;9 (Mean = 4;7, SD = 0;2). No child possessed any known language and/or cognitive impairment.

Part of the large drop-out rate is no doubt due to the age of the children we tested. On-line studies of syntactic processing in children aged younger than 5 years are still vanishingly rare, but are important because they better capture the intersection between the acquisition of knowledge and the implementation of parsing routines. Therefore, if we are to capture the emergence of structural parsing routines we will inevitably face problems like participant attrition. Our attrition rate (47%) suggests that we are capturing RC processing at an age where there is significant variation amongst Cantonese-speaking children. Therefore, although our results only represent those 4-year-old children who have fairly good competence with transitive RC structures, they are likely to reflect online processing of RCs as relatively newly mastered forms.

Materials

Eight CL and eight *ge3* relative clause constructions served as target sentences: 4 subject-extracted and 4 object-extracted (see Appendix). Each sentence contained common nouns and verbs familiar to the children so as not to confound syntactic processing with lexical processing or gaps in vocabulary. The nouns denoted farm or zoo animals (bear, cow, dog, elephant, giraffe, horse, lion, monkey, panda, pig, tiger, zebra). These mapped onto a set of toy animals which served as referents for the NPs in the target trials. Eight transitive action verbs were used (bite, bump, chase, feed, kick, lick, push, tickle, wipe). A digital camera was used to record children's eye-movements, which recorded an image every 33ms.

Procedure

Referent selection task

We used a modified version of Brandt et al.'s (2009) referent selection task (see also Rahmany, Marefat, & Kidd, 2014). In the task, children are introduced to four animals that are placed on a table in four locations equidistant from a central video-camera that protrudes from a hole cut in the table (see Figure1). There were two experimenters. One monitored the camera to ensure that it recorded the child's face and also played each pre-recorded item from a laptop. The other experimenter was responsible for placing the toy referents in pre-specified locations on the table. As each animal was placed on the table, the experimenter elicited the name of each toy from the child to both ensure that the child knew the toy's label and to maintain the child's interest in the task. Typically, children correctly named the toy, but on the rare occasion they provided a label that was different to what was used in the audio the experimenter corrected the child.

[insert Figure 1 about here]

An example trial is shown in (12).

(12a) tai2 haa5! nei1 zek3 hung4jan2 teoi1-gan2 nei1 zek3 daai6zoeng6 wo3 look PRT this CL bear push-PROG this CL elephant SFP

'Look! This bear is pushing the elephant.'

(12b) ji2! ling6ngoi6 jat1 zek3 hung4jan2 zau6 tek3-gan2 nei1 zek3 daai6zoeng6

EXCL another one CL bear then kick-PROG this CL elephant

'The other bear is kicking the elephant.'

ji4gaa1, tai2haa5 go3 haa1haa1siu3 gung1zai2 aa3

now look.at CL smiley figure SFP

'Now look at the smiley face.'

(12c) nei5 ho2-m4-ho2ji5 ling1hei2

you can-not-can pick.up

tau4 sin1 sek3 daai6zoeng6 go2 zek3 hung4jan2 aa3

just.now kiss elephant that CL bear SFP

'Can you pick up # the bear that just kissed the elephant?'

(#: pause)

A target trial began with two background scenes (12a and 12b), the function of which was to create a felicitous discourse context in which the RC in the critical sentence (12c) uniquely identified one referent from a set (Corrêa, 1995; Hamburger & Crain, 1982). Therefore, both background scenes described activities in which two tokens of the same type, which in (12) is a bear, were participants in transitive actions with another animal on the table. As the background scenes were played, one experimenter acted out the scenes and returned the animals back to their locations before the next sentence played (target trials were played as one continuous audio file). After the two background scenes the children heard the attention getter *ji4gaa1, tai2haa5 go3 haa1haa1siu3 gung1zai2 aa3 (now look at the smiley face)*, which served to divert their attention away from the toy referents to a smiley face sticker in the centre of the table just below the camera. This was important because it meant that children's subsequent looks to the toy referents while they heard the test sentence (12c) would reflect processing of that sentence rather than perseverative looking attributable to background scenes. The order of mention of the target referent in the background scenes was counterbalanced across trials, with half in the first background scene and half in the second. The location of the toys was pseudorandomised across trials, with one restriction: the two tokens of the head referent were never placed along the same vertical plane (from the child's perspective). That is, while there were trials in which the two tokens of the head occurred on the same horizontal plane (either in front of or behind the camera), or diagonally across the line of the camera, they were never placed such that one was directly behind the other. This was because the eye-movements were coded offline (à la Snedeker & Trueswell, 2004), and organising the toys in this manner ensured more accurate eye-movement coding because looks to the target versus distractor toy required children to make saccades or head movements.

The children's choice of toy referent provided offline indications of their final interpretations of the sentence. The entire experiment lasted approximately 20 minutes per child.

Eye-movement coding

Children's faces were recorded, which enabled coding of their eye-movements to different locations on the table. The children's individual recordings were digitised to avi files and were coded using the visual editing program Sound Forge©. The program shows the visual display (i.e., recording of child's face) and a separate audio track as a wav file. The wav file enables the location of critical points in the target sentences, and the video allows frame-by-frame coding of eye-movements to the four locations on the table. Each frame was 33ms. Coding began at the beginning of the RC. Since RCs in Cantonese are pre-nominal, this meant that we coded the entire RC. Although it is possible to identify the target before hearing the head noun because it can be predicted from the preceding verb and NP argument, we report looking behaviour until 2400ms post RC-onset because this is, to our knowledge, the first eye-tracking study of RC processing in any Chinese language, and as such we do not have specific hypotheses regarding the location of any statistical effects in the eye-movement record. The data of three children in each sentence condition (15.8% of final sample for CL condition and 16.67% of final sample for *ge3* condition) were re-coded by a second trained coder for inter-coder reliability, which was high (CL: $r_s = .923$, $p < .001$; $\kappa = .937$, $p < .001$; *ge3*: $r_s = .945$, $p < .001$; $\kappa = .944$, $p < .001$).

Results

Offline responses

Children's offline responses give an initial indication of the relative difficulty of each sentence type, which is likely to be reflected in the on-line looking patterns. Figure 2 shows children's offline comprehension accuracy for CL and *ge3* subject and object RCs.

[insert Figure 2 about here]

Figure 2 shows that the children performed similarly on CL subject and object RCs. For *ge3* RCs, children performed much better on subject than on object RCs. Response (correct = 1) was predicted using Generalized Linear Mixed Models (GLMM) (Jaeger, 2008) using the *lme4* package for Linear Mixed Effects (Bates & Maechler, 2010) in *R* (version 3.2.2, R Core Development Team, 2014). Sentence type (CL versus ge3), extraction (subject versus object) and their interaction were entered as fixed effects. Random effects for participants and items were included and there was a random slope for RC type (Barr, Levy, Scheepers, & Tilly, 2013).

The results from mixed model revealed no reliable main effects of either sentence type or RC extraction, and no interaction. This is due to the large variability across children in their ability to correctly respond in each condition, as can be seen by the large standard error bars that overlap with the means of the other conditions. There was, however, a significant intercept ($\beta = 0.826$, $z = 6.26$, $p < 0.001$), which shows that accuracy at selecting the correct referent was significantly above chance overall.

On-line data

Standard approaches for analysing eye-tracking data involve dividing the data into separate windows (e.g., 200ms) and looking for interactions of time window and experimental conditions. These approaches are most effective when dealing with a population where previous research has shown that differences tend to occur within the windows used in the analysis. These conditions are often met with eye-tracking studies of adult speakers of well-studied languages like English, but they are less likely to be appropriate when dealing with developmental data in less-studied languages like Cantonese. When it is not known where effects will appear, post-hoc test with adjustments for multiple comparisons are needed and these will be less sensitive than when appropriate windows are known beforehand. Recently, non-parametric permutation tests have been found to be appropriate for analysis of data where analysis regions were not known *a priori* (for detailed overviews see Groppe, Urbach, & Kutas, 2011; Maris & Oostenveld, 2007; Maris, 2012). Eklund, Nichols, and Knutsson (2016) showed that these techniques yield target familywise error rates of 5% over 3 million random task group analyses of fMRI resting state data, showing that this approach is robust over noisy data. It has also been applied successfully to study noisy data in studies of infant word processing (e.g., Dautriche, Swingley, & Christophe, 2015; Von Holzen & Mani, 2012).

Although different theories make distinct predictions regarding the relative complexity of Cantonese subject and object RCs, they do not make predictions regarding the precise temporal location of processing difficulty in the eye-tracking record. While adults can be consistent in the amount of time that they take to process a particular structure, children will vary in the exact location of this difficulty depending on their point in development. Since Cantonese RCs are head final, and since RC-internal word order differs across subject and object RCs, we wanted to cast a wide net and analyse eye-movements throughout the entire RC and beyond, rather than simply at the disambiguation point (i.e., the head noun). This enabled us to not only identify any differences in processing across different structures, but also identify how word order differences between structures within the RC affects the identification of the head referent.

Before describing our permutation analysis in detail, we first describe the rationale for the analysis. To avoid any assumptions about windows, we use the time bins at the rate provided by the eye-movement coding (i.e., every 33ms) and we apply a test statistic comparing subject and object RC for each time bin (any test statistic can be used and here we use the *t*-test from a regression model). This provides a list of the observed bins with significant subject/object differences ($p < 0.05$, unadjusted for multiple comparisons). We then cluster adjacent bins with significant test statistics together. This captures the fact that adjacent time windows are not independent, but rather are likely to reflect a single processing event. For example, if we have a difference at 1000ms and later at 1066ms between subject and object RCs, it is likely that this difference is due to same underlying process. In contrast, mixed models analyses make the incorrect assumption that all data points are independent.

The next step is to create a sample of 1000 experiments. For each experiment, we take the data for each time bin, permute the subject/object labels without replacement, and apply the test statistic to predict the actual looking data using the permuted labels. By permuting the labels, we remove any link between the labels and the eye-tracking data, and hence these 1000 tests give us a distribution under the null hypothesis. The left-most panel in Figure 3 shows the 95% confidence interval for the observed data in the *ge3* condition at time bin 1914 ms, where there is a strong subject preference (error bars do not overlap). When the labels are permuted as in the last three panels, then the difference can become weaker (Exp. 1), disappear (Exp. 2), or go in the opposite direction (Exp. 3).

[insert Figure 3 about here]

Since each experiment independently permutes each time bin, we need to sum together the results for each experiment for each cluster (we call this the sum *t*-distribution). Smaller clusters have smaller sum *t*-values that can increase values in the centre of the distribution, so it is more conservative to use only the largest sum *t*-value for each experiment in our *maximal* sum-*t* distribution. Finally, we can compute *p*-values by computing the proportion of the maximal sum *t*-values in the distribution that are greater than the sum *t*-values for each of the clusters in the observed data. If this proportion is less than 0.025, then we can conclude that it is significant by a two-tailed test.

Children were tested on all items in the structure type condition to which they were assigned (i.e., either CL or *ge3* RCs). However, children are notoriously variable participants and can be affected by individual preferences for stimuli (in our case, toy referents). Therefore, overall looking to the target will vary depending on the participant, the particular sentence being heard, and the sample of toys in the display. This variation works against our goal, which is to understand how the structures that are heard influenced looking behaviour to the target. Hence, we computed the mean proportions of looks to the target referent at the start of each trial (i.e., beginning of RC) and subtracted this from the looks to the target referent in that trial (we will use *target proportion* to refer to this measure). Figure 4 shows the mean target proportion averaged across participants and item, with CL RCs shown in the top panel and *ge* RCs shown in the bottom panel. Looks were coded from the onset of the RC (0ms) for 2400ms. The onset and offset of different linguistic units are shown at the top of each figure with solid lines for object RC and dashed lines for subject RCs. The offset of the head noun marks the absolute uniqueness point of each sentence, where the head noun can be unambiguously identified. Note, however, that anticipatory predictive looks are possible because the head-final nature of Cantonese RCs means that the RC comes before the head.

[insert Figure 4 about here]

As the first step in the permutation analysis, we applied regressions to each time window to predict target proportion with subject/object condition (effect coded) and the difference between these *p*-values and 0.05 are shown in Figure 4 as bars around -0.1. If the bar extends below -0.1 and is grey, the *p*-value is greater than 0.05, otherwise, if it is black and above -0.1, it is significant. Adjacent bins were clustered together if they were significant. There was one cluster in the CL study (1716-1815ms) and four clusters in the *ge3* study (1551-1584ms, 1617-1650ms, 1683-2244ms, and 2310-2442ms).

In the next step, 1000 experiments were run by permuting condition labels in each significant time bin and applying regression to predict the observed target proportion. Next we produced the sum *t* distribution by summing the *t*-values produced for each time bin within each cluster (*all sum t* histograms for CL and *ge3* experiments in top of Figure 5). The dashed lines in Figure 5 show the borders of the band that contains 95% of the sum *t*-values. Since the *ge3* condition has one large cluster and 3 smaller clusters, there are more data points in the centre of the distribution due to the small effects in the smaller clusters. To remove this bias, we select the largest absolute sum *t*-value for each simulation and place that into the maximal sum *t*-distribution (bottom two panels in Figure 5). The *ge3* maximal sum *t*-distribution is bimodal, because when we randomly permute and test four clusters, one of the tests will tend to yield a non-zero sum *t*-value by chance and this value will be the maximal value. The 95% band for the *ge3* all sum *t* distribution represents the likelihood of getting a significant effect when four clusters are tested, but we are interested in whether our participants distinguish subject and object RCs, so this one test is better matched by the *ge3* maximal sum *t* distribution, which is an exact distribution based on the biggest effect that could occur by chance for our four comparisons.

[insert Figure 5 about here]

The maximal sum *t* distribution for *ge3* has a bigger band than the distribution for CL because it includes a large cluster of 561ms, while CL only has one cluster of 99ms. Since we are interested in whether there is an effect of any length, we will test the observed CL cluster sum *t*-values against the CL distribution, and the observed *ge3* effect against the *ge3* distribution. For each of the clusters, *p*-values were the percentage of values in the corresponding distribution that were less than observed sum *t*-values. Unlike traditional linear model approaches (e.g., ANOVA), where theoretical distributions (e.g., normal, *t*) are matched to data by the use of parameters like degrees of freedom, the permutation test is a non-parametric test, because we have computed an exact distribution that takes into account the number of clusters that we are testing as well as the size and variability of our data.

The permutation analysis revealed one significant cluster for each structure type. For CL RCs the children look significantly more at the head referent of object RCs between 1716ms and 1815ms post RC onset (total window time = 99ms, sum $t = 6$, $p < .003$), suggesting a significant object advantage. For *ge3* RCs the children looked significantly more at the head referent of subject RCs between 1683ms and 2244ms post RC onset (total window time = 561ms, sum $t = 43$, $p < .001$), suggesting a significant subject advantage. These significant clusters are denoted in Figure 4 by the long grey shading.

Comparison with linear mixed effects analysis over pre-specified time windows.

Since permutation analyses have not been used extensively for studying child language data, it is worthwhile to compare our permutation analysis with a traditional mixed model analysis. To do this, we averaged the target proportion for each 200 millisecond window for each subject in each condition (CL and *ge3*) for each RC extraction type (subject/object). We then applied a mixed model to the proportion target looks with window, condition (CL and *ge3*), and RC type (all centred). Subject and items were random effects and the maximal model had random slopes for window and extraction type for both subjects and items. In this analysis, there was a main effect of window, $\beta = 0.052$, $SE = 0.0024$, $\chi^2(1) = 432.3$, $p < 0.001$, an interaction of window with RC type, $\beta = -0.01$, $SE = 0.0048$, $\chi^2(1)=3.97$, $p = 0.046$, and a three-way interaction of window, RC type, and extraction, $\beta = 0.036$, $SE = 0.0097$, $\chi^2(1) = 13.92$, $p < 0.001$. To explore this three-way interaction, posthoc comparisons were performed comparing subject and object conditions in each window in both RC types (*p*-values were adjusted for the 24 multiple comparisons, Bretz, Hothorn, & Westfall, 2011). The only significant differences between subject and object was in the 1800-2000 window in the GE study, $\beta = 0.33$, $SE = 0.14$, $t(54)=2.3$, $p = 0.025$.

The significant region in the mixed model analysis is shown as a curved line in Figure 4. Although the mixed model identifies a fairly strong three-way interaction, only one *ge3* region is identified in the posthoc analysis. The fact that this region is smaller than the region identified by the permutation analysis is due in part to the fact that the cluster is divided across multiple windows and these windows are treated as independent events. However, this assumption does not hold: there is a correlation of 0.94 between the target preferences in the 1800-2000 and the 2000-2200 *ge3* windows. The posthoc analysis does not identify the significant CL cluster that was found in the permutation analysis and this is because the window is larger than the cluster and hence it potentially includes more noise than the cluster used by the permutation analysis. Furthermore, the posthoc analysis uses a *p*-value threshold that is adjusted for multiple comparisons and that could help to explain why fewer regions are significant. Thus, the mixed model is a weaker analysis than the permutation test, because it assumes that independent processing components take place in 200ms windows and multiple comparisons with higher thresholds for significance are needed to find the window where the effect of RC extraction can be found.

Discussion

In the current study we investigated 4-year-old monolingual Cantonese-speaking children's online processing of two types of RC. Chinese RCs are important in the context of current competing theories of syntactic processing and development because they separate two cues to interpretation that are confounded in more well-studied languages like English. Namely, because Chinese RCs have the typologically rare combination of SVO canonical word order and head-final RCs (Dryer, 2005), object RCs follow the canonical SVO word order whereas subject RC have non-canonical VOS word order. This therefore pits one cue to interpretation – word order (MacDonald & Christiansen, 2002; Diessel, 2007) – against another cue – subject prominence (e.g., Bornkessel-Schlesewsky & Schlesewsky, 2009; Friedmann et al., 2009; Vasishth et al., 2013; Yun et al., 2015), and allows an explicit investigation of how children may weigh these cues. Our results intriguingly suggest that RC processing in Cantonese depends significantly on the type of RC used and their relationship to other structures in the language. Specifically, for CL RCs we observed no difference in offline accuracy across subject and object RCs, and a brief but significant time window which suggested an online processing advantage in favour of object RCs. In contrast, for *ge3* RCs we see the more familiar subject advantage, although this was only statistically reliable in the on-line looking behaviour. We discuss each result in turn.

The significant object advantage for CL RCs is consistent with past comprehension research with 4-year-old monolingual children (Chan, et al., 2011; cf. Lau, 2016), extending the result to on-line data. The result is consistent with the suggestion that children gain added-value from the isomorphism between simple SVO transitives and classifier object RCs (Chan et al., 2011; Diessel, 2007). Note that this is not to say that the children were processing the sentences as simple canonical sentences. Had they have done this they would have selected the RC subject rather than the head noun. Instead, the children were processing both sentence types as noun modifiers, as evidenced by their above chance accuracy in off-line responding. As such, we suggest that two properties of Cantonese CL object RCs may have contributed to the object advantage. Firstly, object RCs follow canonical word order which may facilitate thematic role assignment (Chen & Shirai, 2015; Diessel, 2007). Secondly, the possibility that classifier object RCs can be analysed as internally headed RCs may facilitate processing further (Chan et al., 2011).

Further evidence in favour of the internally-headed analysis and against a purely word order based explanation comes from the results of the *ge3* RCs. Although CL and *ge3* RCs share word order similarities, with object RCs following canonical word order, the children showed a distinct subject advantage when processing *ge3* RCs. This result is consistent with developmental studies that have reported offline experimental comprehension data in Mandarin (Hu, Gavarró, Vernice, & Guasti, 2015), and with adult studies that report a consistent subject preference (e.g., Vasishth et al., 2013; Jäger, Chen, Li, Lin, & Vasishth, 2015). The data from the *ge3* RCs therefore support theoretical approaches predicting a subject preference for Chinese RCs (e.g., Bornkessel-Schlesewsky & Schlesewsky, 2009; Friedmann et al., 2009; Vasishth et al., 2013; Yun et al., 2015).

An important question to address from these results is why two largely similar sets of sentences, which can be used for the same function of noun modification, yield different results? One possible explanation for the difference derives from linguistic analyses of the two. Cantonese classifier RCs and *ge3* RCs have been argued to have different syntactic structures, reflected by their distinct patterns of syntactic behaviours such as ellipsis and topicalization. Specifically, Cheung and Li (2015) argue that *ge3* RCs involve a complementation relationship between RC and the head noun, while classifier RCs involve an adjunction relationship between RC and the head noun (c.f. Cheng & Sybesma 2009). Therefore, one could crucially derive from Cheung and Li's analysis that extraction or filler-gap dependency is possible for complementation structures only (i.e. *ge3* RCs), but not for adjunction structures with classifier RCs. If Cantonese CL vs *ge3* RCs differ in whether filler-gap syntactic dependency is involved, the subject advantage observed for *ge3* RCs may reflect similar structural constraints in the processing of filler-gap dependency structures hypothesised to contribute to processing complexity in European languages (such as structural distance, favouring subject RCs, Friedmann et al., 2009). However, it must be acknowledged that there is considerable debate amongst linguists regarding the analysis of Chinese RCs. The 'non-uniform' approach argues that not all types of Cantonese/Mandarin RCs involve filler-gap dependencies (e.g., Cheung & Li, 2015; Chang & Sybesma, 2009); whereas the 'uniform' approach, based largely on Mandarin RCs, argues that all Chinese RCs involve filler-gap dependencies (Aoun & Li, 2003; Simpson, 2002).

While syntactic analyses may provide an independent and linguistically-motivated explanation for the difference across CL and *ge3* RCs, there are likely to be other sources of information that contribute to or perhaps even explain the effect. One possibility is that structural frequency in the input significantly influences the processing of these structures (Ambridge, Kidd, Rowland, & Theakston, 2015; MacDonald, 2013). To examine this possibility, we extracted all of the mor-ed Cantonese utterances from CHILDES and searched for utterances using *go2* CL or *ge3* (25,635 utterances from the HKU Fletcher, Leung, Stokes, and Weizman, 2000, corpus; 196,931 utterances from the Lee, Wong, Leung, Man, Chung, Szeto, and Wong, 1994 corpus). No utterances containing *ge3* RCs were found, attesting to its low frequency in adult child-directed speech. We extracted 589 utterances containing a verb followed by the demonstrative *go2* followed by a classifier (each element separated by any number of words). Since our goal was to understand the biases for subject and object RCs, we further restricted this set to those items with either a noun/pronoun/proper noun before or after the verb preceding *go2* (186 potential RCs in adult child-directed speech). Out of this set, only 44 utterances contained CL RCs, with 27 object RCs (i.e, 61.4%) and 17 subject RCs (38.6%). There were an additional 54 simple SVO transitives that were similar in form to the object CL RCs. Overall, we found that CL RCs are more often object- than subject-extracted, and that simple transitives, which share surface identity with object CL RCs, are even more frequent. Consequently, the naturalistic data are consistent with the suggestion that structural frequency affects online processing.

Although we did not find *ge3* RCs, there are several studies which report input frequencies for the comparable Mandarin *de* structures, which we compare to our results. Using the 5 million word Sinica corpus[3], Vasishth et al. (2013) found that sentences following a subject RC pattern (V-N-*de*-N) are more frequent than structures following an object RC pattern (N-V-*de*-N) by a ratio of 5.5:1. The pattern holds when specifically looking at subject and object RCs with two animate nouns (4.3:1). Similarly, Yun et al. (2015) found that subject RCs are more frequent than object RCs in the Chinese Treebank 7 (Xue et al. 2005). In contrast to Cantonese CL RCs, these corpus data suggest a subject preference, which is consistent with the subject preference we observed for *ge3* RCs. It must be acknowledged, however, that analyses of child language corpora have yielded different results. Chen and Shirai (2015) found that object RCs were 3 times more likely than the subject RCs in the input to children (see also Liu, 2015). Importantly, Chen and Shirai did not control for animacy in their analysis, which is likely to have played a significant role in

[3] http://app.sinica.edu.tw/kiwi/mkiwi/modern_e_help.html

object RC use. For instance, work across several languages has shown that children have less difficulty processing object RCs that have inanimate heads (e.g., Kidd et al., 2007; Kirjavainen et al., 2017), which are more frequent in the input.

Predictions based on linguistic analyses and/or input-based accounts mainly predict that one structure will be better than another overall, rather than making strong predictions about the time course of processing. In our data, both CL conditions and the *ge3* subject RC condition rise to target proportion of 0.6, which suggests that by 2.5 seconds the children converge on the correct target to a similar degree relative to the start of the trial. However, the *ge3* object condition only reaches target proportion of 0.4, which suggests that children experienced considerable difficulty processing the structures, even after head noun offset. One explanation of this difference can be found in expectation-based accounts of parsing (Hale, 2006; Levy, 2008). Yun et al. (2015) found a subject RC bias in entropy reduction in a minimalist model trained on Mandarin Chinese input (where there was a subject RC bias in the input). Critically, the largest proportional change in entropy was at the head noun, with entropy reduction was twice the magnitude in object RC condition compared to the subject RC condition. The effect of extraction for *ge3* RCs begins to emerge during the head noun, suggesting that it may in fact begin at *ge3*. One possibility is that in the object *ge3* condition children anticipate a simple transitive interpretation following the N-V segment, but must renanalyse the parse at the end of the RC. Reanalysis is costly, especially for children (Kidd, Stewart, & Serratrice, 2011; Trueswell, Sekerine, Hill, & Logrip, 1999), and may be especially so for *ge3* object RCs because of their rarity in the input. The subject *ge3* RCs are also a low frequency structure, but since their configuration is clearly not canonical SVO transitive from the beginning of the sentence children may parse them as a RC at an earlier point in processing.

On the other hand, the object bias in CL RCs only appears for a short period (99ms) and then the subject RC target proportion catches up and by the end of the trial, both are near 0.6. One interpretation of this result, which is consistent with the *ge3* results and our corpus analysis, is that children are parsing the object RC as a transitive and, given the high frequency of the structural pattern (which is not the case for *ge3* object RCs), they show a benefit over the subject RC, which is not similar to canonical SVO transitives. However, once the sentence is experienced and the participant must select the appropriate toy, they must reanalyse this transitive into a structure which helps them to identify the appropriate referent. This post-structural processing is more difficult for the object RC than the subject RC, because the subject RC is constructed as a RC from the beginning. The short bias for the object CL RCs is then due to the ease of structural analysis and the difficulty of referential processing, while subject CL RCs are the opposite. This referential account depends on having a discourse context where there is an expectation for noun modification, as in our test materials. When this expectation is not set up, as in Lau (2016), children are often garden-pathed and do interpret the sentences as SVO transitives (see also Kidd et al., 2015, who showed this occurs in Cantonese-English bilinguals).

Our results therefore provide a novel insight into the specificity with which word order regularities exert an effect on syntactic processing. MacDonald and Christiansen (2002, see also Wells, Christiansen, Race, Acheson, & MacDonald, 2009) suggested that differences in word orders frequencies (i.e., in English, NVN for subject RCs and NNV for object RCs) explains the subject-object asymmetry in English because subject RCs, although not particularly frequent, follow the frequent canonical word order (the *frequency X regularity* interaction). Our data do not support the most general interpretation of this claim – that the effect derives from the frequency of abstract word orders, which in the case of Cantonese predicts an object advantage for *both* CL and *ge3* RCs because both are NVN. Instead, the data, along with our corpus analyses, suggest that structural frequencies within the language can both help (for CL RCs) and hinder (for *ge3* RCs) processing, highlighting the tight link between on-line processing and the input-based learning of structures in typologically-different languages (e.g., Chang, 2009; Fitz et al., 2011).

Conclusion.

Relative clauses in East Asian languages like Cantonese are important in debates concerning syntactic acquisition and processing, since the typological features of East Asian languages potentially allow for long standing debates, such as the source of the subject-object asymmetry in RCs, to be addressed in languages with fewer confounds than are found in European languages. Consistent with acquisition work on typologically diverse languages such as Finnish (Kirjavainen et al., 2017) and Quechua (Courtney, 2011), the results from the present study highlight the significance of language-specific influences on syntactic processing. We have, for the first time, identified an asymmetry in the online processing of different RC types within the one language, and have argued that this is likely to derive from differences in structural frequencies that either support or do not support correct syntactic predictions to be made at crucial points in the sentence. The results are important because data from new languages widen the evidential base upon which theories can be tested and developed (Kelly, Kidd, & Wigglesworth, 2015). They also highlight the value of online studies in acquisition, which have the potential to reveal differences in processing that may not be obvious in offline data.

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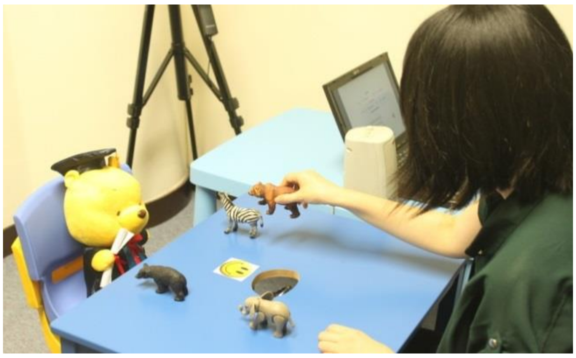

The layout of the toy props and the hidden digital camera to capture eye movements of the participant in the visual world eye tracking task	Experimenter acting out the background sentences and played the recorded test sentence. E.g.: 'This bear is kicking the zebra. The other bear is kissing the zebra. Can you pick up the bear that just kicked the zebra?'

Figure 1. Experimental set-up.

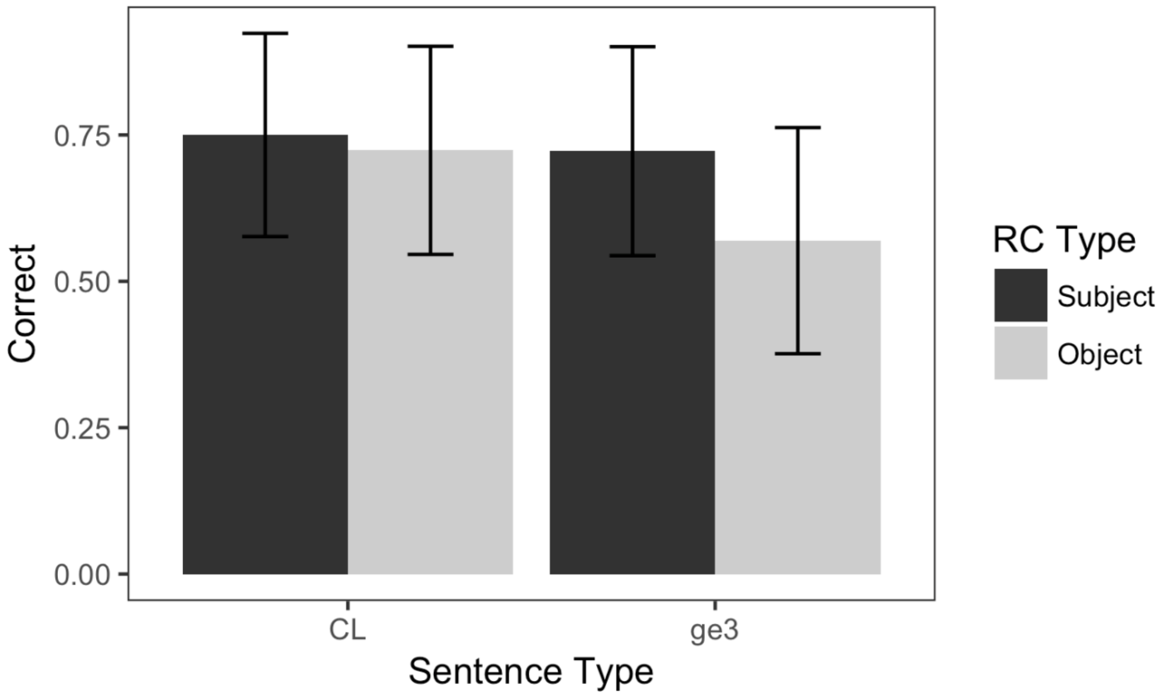

Figure 2. Offline comprehension accuracy for subject and object CL and *ge3* RCs (standard error bars for data with random effects removed).

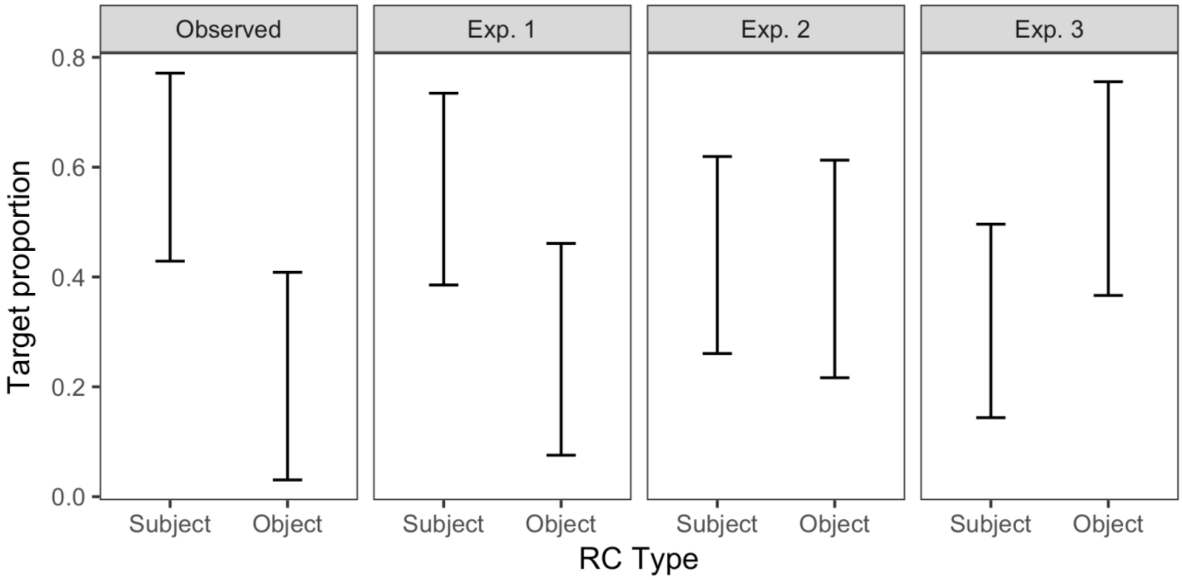

Figure 3. Permutation of observed labels yields three different effects.

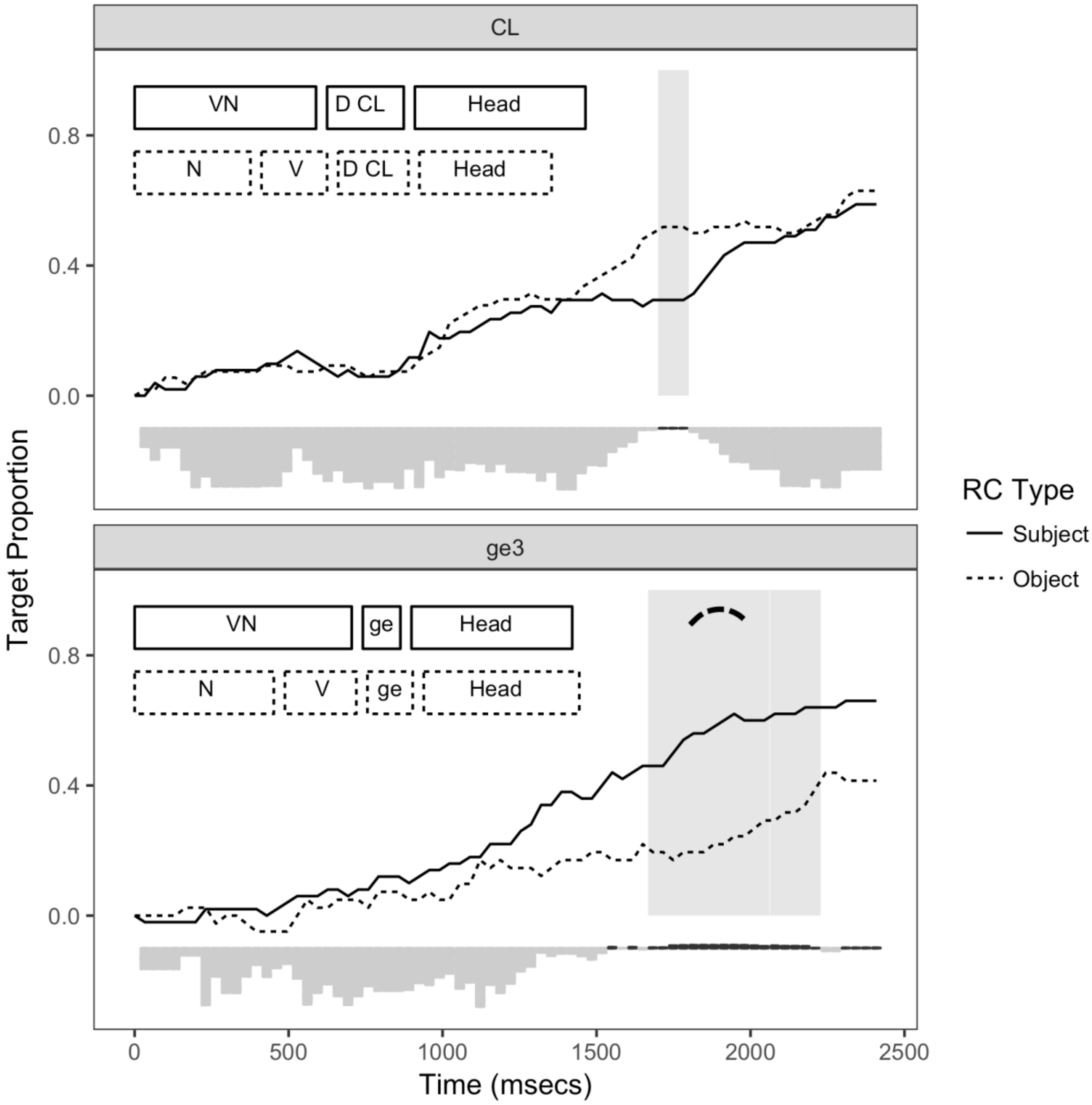

Figure 4. Average target proportions for CL (top panel) and *ge3* (bottom panel) RCs are shown by solid/dashed lines. Onset/offsets for different units are shown by the size of the rectangles at the top left (solid for subject, dashed for object). Small grey/black bars near -0.1 are *p*-values for individual time bins. The large grey bars represent the time windows identified by the permutation analysis as significant. Curved lines represent 200ms windows identified as significant by mixed model post hoc analysis.

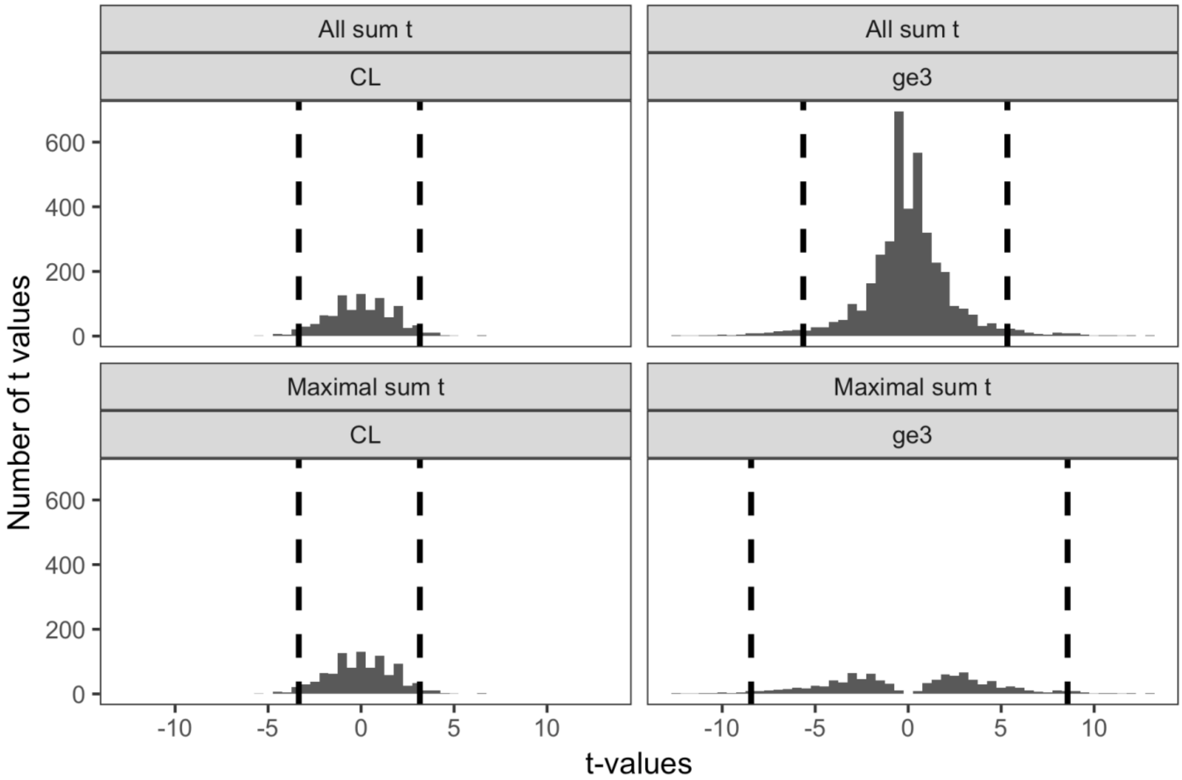

Figure 5. Distributions created by permutation distribution for CL and *ge3* studies with either all sum *t* values or only maximal sum *t* values. Dashed lines represent range for 95% of the *t*-values.

Appendix

Can you pick up [relative clause] head noun? DEM: demonstrative; CL: classifier

Subject-extracted CL relative clause

1. 追 獅子 嗰 隻 狗仔
   zeoi1 si1zi2 go2 zek3 gau2zai2
   chase lion DEM CL dog
   the dog that chased the lion

2. 踢 斑馬 嗰 隻 熊人
   tek3 baan1maa5 go2 zek3 hung4jan2
   kick zebra DEM CL bear
   the bear that kicked the zebra

3. 抹 豬仔 嗰 隻 馬騮
   maat3 zyu1zai2 go2 zek3 maa5lau1
   wipe pig DEM CL monkey
   the monkey that wiped the pig

4. zit1 馬騮 嗰 隻 牛牛
   zit1 maa5lau1 go2 zek3 ngau4ngau2
   tickle monkey DEM CL cow
   the cow that tickled the monkey

Object-extracted CL relative clause

1. 馬仔 推 嗰 隻 狗仔
   maa5zai2 teoi1 go2 zek3 gau2zai2
   horse push DEM CL dog
   the dog that the horse pushed

2. 老虎 咬 嗰 隻 熊人
   lou5fu2 ngaau5 go2 zek3 hung4jan2
   tiger bite DEM CL bear
   the bear that the tiger bit

3. 羊仔 摸 嗰 隻 馬騮
   joeng4zai2 mo2 go2 zek3 maa5lau1
   sheep touch DEM CL monkey
   the monkey that the sheep touched

4. 老虎 餵 嗰 隻 牛牛
   lou5fu2 wai3 go2 zek3 ngau4ngau2
   tiger feed DEM CL cow
   the cow that the tiger fed

Appendix B
Can you pick up [relative clause] head noun?

Subject-extracted *ge3* relative clause

1. 舐 斑馬 嘅 獅子
   laai2 baan1maa5 ge3 si1zi2
   lick zebra ge3 lion
   the lion that licked the zebra

2. 撞 熊人 嘅 老虎
   zong6 hung4jan2 ge3 lou5fu2
   bump bear ge3 tiger
   the tiger that bumped the bear

3. 咬 牛牛 嘅 大象
   ngaau5 ngau4ngau2 ge3 daai6zoeng6
   bite cow ge3 elephant
   the elephant that bit the cow

4. 推 長頸鹿 嘅 老虎
   teoi1 coeng4geng2luk5 ge3 lou5fu2
   push giraffe ge3 tiger
   the tiger that push the giraffe

Object-extracted *ge3* relative clause

1. 熊貓 舐 嘅 獅子
   hung4maau1 laai2 ge3 si1zi2
   panda lick ge3 lion
   the lion that the panda licked

2. 大象 追 嘅 老虎
   daai6zoeng6 zeoi1 ge3 lou5fu2
   elephant chase ge3 tiger
   the tiger that the elephant chased

3. 豬仔 踢 嘅 牛仔
   zyu1zai2 tek3 ge3 ngau4zai2
   pig kick ge3 cow
   the cow that the pig kicked

4. 大象 撞 嘅 長頸鹿
daai6zoeng6 zong6 ge3 coeng4geng2luk5
elephant bump ge3 giraffe
the giraffe that the elephant bumped